# FTA RESEARCH

FEDERAL TRANSIT ADMINISTRATION

# Rail Capacity Improvement Study for Commuter Operations

NOVEMBER 2012

FTA Report No. 0037
Federal Transit Administration

**PREPARED BY**

William Moore Ede
Joseph Brosseau
Duane Otter
Joshua Matthews

Transportation Technology Center, Inc.
A subsidiary of the Association of American Railroads

. i
l Tran i i i i

## COVER PHOTO

*Courtesy of Edwin Adilson Rodriguez, Federal Transit Administration*

# Rail Capacity Improvement Study for Commuter Operations

NOVEMBER 2012

FTA Report No. 0037

**PREPARED BY**

William Moore Ede
Joseph Brosseau
Duane Otter

Transportation Technology Center, Inc.
A subsidiary of the Association of American Railroads
Pueblo, Colorado USA

**SPONSORED BY**

Federal Transit Administration
Office of Research, Demonstration and Innovation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

**AVAILABLE ONLINE**

*http://www.fta.dot.gov/research*

# Metric Conversion Table

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| | | **LENGTH** | | |
| **in** | inches | 25.4 | millimeters | mm |
| **ft** | feet | 0.305 | meters | m |
| **yd** | yards | 0.914 | meters | m |
| **mi** | miles | 1.61 | kilometers | km |
| | | **VOLUME** | | |
| **fl oz** | fluid ounces | 29.57 | milliliters | mL |
| **gal** | gallons | 3.785 | liters | L |
| **$ft^3$** | cubic feet | 0.028 | cubic meters | $m^3$ |
| **$yd^3$** | cubic yards | 0.765 | cubic meters | $m^3$ |
| | | NOTE: volumes greater than 1000 L shall be shown in $m^3$ | | |
| | | **MASS** | | |
| **oz** | ounces | 28.35 | grams | g |
| **lb** | pounds | 0.454 | kilograms | kg |
| **T** | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| | | **TEMPERATURE (exact degrees)** | | |
| **$^oF$** | Fahrenheit | 5 (F-32)/9 or (F-32)/1.8 | Celsius | $^oC$ |

| REPORT DOCUMENTATION PAGE | | | *Form Approved*<br>*OMB No. 0704-0188* |
|---|---|---|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503. | | | |
| 1. AGENCY USE ONLY | 2. REPORT DATE<br>November 2012 | | 3. REPORT TYPE AND DATES COVERED<br>August 2009–January 2013 |
| 4. TITLE AND SUBTITLE<br>Rail Capacity Improvement Study for Commuter Rail Operations | | | 5. FUNDING NUMBERS<br>CO-26-7011 |
| 6. AUTHOR(S)<br>William Moore Ede, Joseph Brosseau, Duane Otter, Josh Matthews | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSE(ES)<br>Transportation Technology Center, Inc.<br>A subsidiary of the Association of American Railroads<br>Pueblo, Colorado USA | | | 8. PERFORMING ORGANIZATION REPORT NUMBER<br>FTA Report No. 0037 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>U.S. Department of Transportation<br>Federal Transit Administration<br>Office of Research, Demonstration and Innovation<br>East Building<br>1200 New Jersey Avenue, SE<br>Washington, DC 20590 | | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER<br>FTA Report No. 0037 |
| 11. SUPPLEMENTARY NOTES [http://www.fta.dot.gov/research] | | | |
| 12A. DISTRIBUTION/AVAILABILITY STATEMENT<br>Available from: National Technical Information Service (NTIS), Springfield, VA 22161. Phone 703.605.6000, Fax 703.605.6900, email [orders@ntis.gov] | | | 12B. DISTRIBUTION CODE<br>TRI-20 |
| 13. ABSTRACT<br>The Federal Transit Administration (FTA) notes that over the last decade, commuter rail systems have experienced increased ridership that closely matches the increases in gasoline prices. FTA also identified highway congestion and environmental concerns as other factors that have helped to boost ridership. As a result of these and other factors, some major commuter rail systems have reached or are approaching capacity. FTA has expressed concerns that commuter rail systems would not be capable of fully handling the resulting increase in ridership demand. This study offers a combination of considerations and evaluation tools pertaining to relevant means of capacity improvements (technology, operations, route, and vehicle upgrades), both conventional and emerging. Guidance regarding the economics is offered to help balance the mix to minimize cost of achieving the level of capacity improvement required. The report describes principles and concepts related to capacity for commuter rail operations. Topics include track and station configuration, rolling stock, train operations, and signal issues. Transportation Technology Center, Inc. (TTCI) identifies promising potential improvements and additions to infrastructure to increase capacity (emphasizing cost-effective technology solutions). Discussion is provided on investment planning to increase commuter rail system capacity by making the various improvements noted. The study also discusses the benefits, effectiveness, and life cycle costs of the various solutions. To illustrate these principles, TTCI has evaluated various aspects of the present capacity limitations versus ridership for a large commuter rail system in the United States to determine capacity constraints and to identify areas where improved capacity might be needed. Two sections present an overview and selected case studies of the Metrolink system operating in the Los Angeles regional area with analysis of various capacity issues. In each case study, different aspects of commuter rail capacity are examined. In some cases, suggestions are offered where improvements could be made that would increase system reliability. | | | |
| 14. SUBJECT TERMS<br>Light rail transit, rail capacity improvements, Rail Traffic Controller model | | | 15. NUMBER OF PAGES<br>78 |
| 16. PRICE CODE | | | |
| 17. SECURITY CLASSIFICATION OF REPORT<br>Unclassified | 18. SECURITY CLASSIFICATION OF THIS PAGE<br>Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT<br>Unclassified | 20. LIMITATION OF ABSTRACT |

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## ACKNOWLEDGMENTS

The authors acknowledge the Federal Transit Administration for funding this study, and particularly the support of Terrell Williams. The authors also acknowledge the assistance of Eric Wilson of Berkeley Simulations for his assistance in the use of the Rail Traffic Controller model.

## ABSTRACT

The Federal Transit Administration (FTA) notes that over the last decade, commuter rail systems have experienced increased ridership that closely matches the increases in gasoline prices. FTA also identified highway congestion and environmental concerns as other factors that have helped to boost ridership. As a result of these and other factors, some major commuter rail systems have reached or are approaching capacity. FTA has expressed concerns that commuter rail systems will not be capable of fully handling the resulting increase in ridership demand.

This study offers a combination of considerations and evaluation tools pertaining to relevant means of capacity improvements (technology, operations, route, and vehicle upgrades), both conventional and emerging. Guidance regarding the economics is offered to help balance the mix to minimize cost of achieving the level of capacity improvement required.

The report describes principles and concepts related to capacity for commuter rail operations. Topics include track and station configuration, rolling stock, train operations, and signal issues. Transportation Technology Center, Inc. (TTCI) identifies promising potential improvements and additions to infrastructure to increase capacity (emphasizing cost-effective technology solutions). Discussion is provided on investment planning to increase commuter rail system capacity by making the various improvements noted. The study also discusses the benefits, effectiveness, and life cycle costs of the various solutions.

To illustrate these principles, TTCI has evaluated various aspects of the present capacity limitations versus ridership for a large commuter rail system in the United States to determine capacity constraints and to identify areas where improved capacity might be needed. Two sections present an overview and selected case studies of the Metrolink system operating in the Los Angeles regional area with analysis of various capacity issues.

In each case study, different aspects of commuter rail capacity are examined. In some cases, suggestions are offered where improvements could be made that would increase system reliability.

# EXECUTIVE SUMMARY

The Federal Transit Administration (FTA) notes that over the last decade, commuter rail systems have experienced increased ridership that closely matches the increases in gasoline prices. FTA also identified highway congestion and environmental concerns as other factors that have helped to boost ridership. As a result of these and other factors, some major commuter rail systems have reached or are approaching capacity. FTA has expressed concerns that commuter rail systems will not be capable of fully handling the resulting increase in ridership demand.

This study offers a combination of considerations and evaluation tools pertaining to relevant means of capacity improvements (technology, operations, route, and vehicle upgrades), both conventional and emerging. Guidance regarding the economics is offered to help balance the mix to minimize cost of achieving the level of capacity improvement required.

The report describes principles and concepts related to capacity for commuter rail operations. Topics include track and station configuration, rolling stock, train operations, and signal issues. Transportation Technology Center, Inc. (TTCI) identifies promising potential improvements and additions to infrastructure to increase capacity (emphasizing cost-effective technology solutions). Discussion is provided on investment planning to increase commuter rail system capacity by making the various improvements noted. The study also discusses the benefits, effectiveness, and life cycle costs of the various solutions.

To illustrate these principles, TTCI has evaluated various aspects of the present capacity limitations versus ridership for a large commuter rail system in the United States to determine capacity constraints and to identify areas where improved capacity might be needed. Two sections present an overview and selected case studies of the Metrolink system operating in the Los Angeles regional area with analysis of various capacity issues.

In each case study, different aspects of commuter rail capacity are examined. In some cases, suggestions are offered where improvements could be made that would increase system reliability.

The following specific conclusions are noted:

1. Capacity issues for commuter rail lines can be very different depending on the type of operation, that is, single or multiple track, single or bidirectional operation.
2. Key factors affecting commuter rail capacity include time between trains, operating speeds between stations, acceleration and deceleration capabilities of trains, station dwell time, signal system, and rolling stock, both cars and locomotives.

3. Key factors affecting commuter rail trip time include length of route, number and distance between stations, and passenger perception of trip length and delay.
4. In commuter rail operations on corridors shared with freight operations, the freight operators must be kept whole in terms of their ability to provide service to their freight customers.
5. Scheduling for commuter rail operations needs to take into consideration the long braking distances and relatively long time between trains needed to operate safely.
6. In developing schedules for commuter rail operations, consideration should be given to allow operating windows for various freight and long-distance passenger operations, as well as track maintenance, temporary speed restrictions, equipment problems, and schedule recovery time.

SECTION 1

# Introduction

## Background

The Federal Transit Administration (FTA) notes that over the last decade, commuter rail systems have experienced increased ridership that closely matches the increases in gasoline prices. FTA also identified highway congestion and environmental concerns as other factors that have helped to boost ridership. As a result of these factors, many major commuter rail systems have reached, or are approaching capacity. FTA notes that many older commuter rail systems are “behind the curve” on infrastructure rehabilitation and replacement projects and on capital investments required to increase capacity typically take years from inception to completion. FTA has expressed concerns that all of these factors may come together in a “perfect storm” driven by events beyond the control of the United States, such as the price of oil, such that commuter rail systems would not be capable of fully handling the resulting increase in ridership demand.

## Objective

The objective of this study is to offer a combination of considerations and evaluation tools pertaining to relevant means of capacity improvements (technology, operations, route, and vehicle upgrades), conventional and emerging. Guidance regarding the economics is offered to help balance the mix to minimize the cost of achieving the level of capacity improvement required.

To meet this objective, Transportation Technology Center, Inc. (TTCI) has evaluated various aspects of the present capacity limitations versus ridership for a large commuter rail system in the United States to determine capacity constraints and to identify areas where improved capacity might be needed. TTCI identifies promising potential improvements and additions to infrastructure to increase capacity (emphasizing cost-effective technology solutions). The study also discusses the benefits, effectiveness, and life cycle costs of the various solutions. A sequence for implementation of the various recommended changes is suggested.

## Scope

In this report, TTCI provides a generic study of commuter rail system capacity issues and a case study that illustrates the current capacity limitations and ridership for a large commuter rail system. TTCI identified various infrastructure investments to increase capacity, their level of effectiveness, noted life cycle cost considerations, and how long it would take to put them into place. TTCI conducted the following tasks as identified in the FTA contract:

1. Determined how close the selected system is to capacity and identified points that are restricting capacity based on operating data.
2. Developed an inventory of potential infrastructure investments that would increase the core capacity of commuter rail systems, emphasizing cost-effective technology solutions over expensive track additions.
3. Discussed the capacity benefits and relative cost of implementing each investment under applicable scenarios from the selected systems or on a parametric basis.
4. Suggested an implementation sequence and migration path for various investments for the applicable scenarios or on a parametric basis.
5. Summarized and recommended the top infrastructure investments transit agencies could make that would provide the biggest impact on capacity improvements.

The Los Angeles area commuter rail system, Metrolink, was used for the case study. This system was selected, in part, because it offered a wide variety of operations—some on freight-owned track, some on agency-owned track, both single- and multiple-track corridors, and significant Amtrak traffic on one corridor. Furthermore, TTCI already possessed a Rail Traffic Controller (RTC) simulation model for the system.

# Limitations

This study focuses primarily on train operations and not on the ability to move people on and off platforms, station design, pedestrian flow, ticketing functions, security issues, and the like. Maximum train length and loading, and minimum time between trains need to be considered in design for these other issues to accommodate the appropriate passenger flows.

Metrolink personnel were fully engaged in contracting and implementing Positive Train Control under a very short timeframe and did not have the personnel available to work with the study team. Consequently, the study team did not have the benefit of the expertise of the Metrolink operators, which might otherwise have altered the direction or findings of this study.

# Organization of the Report

Section 2 describes principles and concepts related to capacity for commuter operations. Topics include track and station configuration, rolling stock, train operations, and signal and train control issues. Section 3 discusses investment planning to increase commuter rail system capacity by making improvements in the various issues noted in Section 2. Section 4 presents a case study of selected corridors on the Metrolink commuter rail system to illustrate possible application of capacity improvements.

SECTION

2

# Commuter Capacity Concepts

## Basic Capacity Principles for Commuter Operations

Typical commuter rail operations consist of either locomotive-hauled trains or electric multiple-unit (EMU) or diesel multiple-unit (DMU) trains of 4 to 12 cars, running on single or multiple track lines with stations typically spaced about 1 to 5 miles apart. Total length of run ranges from 20 to 60 miles. Trains are typically spaced with schedule headways (times from one train departure to the next) of 20 to 30 minutes during peak hours. Typical maximum speeds range from 60 to 90 mph. Typical average speeds range from 20 to 45 mph, depending on length of routes, number of stations, and types of service. In many cases, commuter rail operations use track owned and dispatched by freight railroads for at least a portion of their routes. In such cases, freight railroads need to be kept whole in terms of their ability to run trains as needed to serve their customers. In many cases, freight railroads will be unwilling to operate commuter trains unless they are able to retain their flexibility to operate their own trains at any time of the day.

Some commuter rail routes operate only during rush periods, inbound to the urban center in the morning, and outbound in the afternoon. Peak period headways are typically about 20 to 30 minutes. Other routes operate day-long service, including operation in both directions throughout day, with additional trains serving rush hour passengers. Off-peak headways might be 60 to 120 minutes.

Capacity is defined in terms of the number of passengers delivered per hour. For the design of new systems, capacity should include projected future demand. Typically, the incremental cost of building additional capacity into a system at the start is more economical than adding capacity to an existing system.

For commuter rail operations, there is no simple formula for analyzing and increasing capacity. The nature of commuter rail systems varies considerably, depending on factors such as type and amount of traffic (including freight and long-distance passenger trains), length of run, station spacing, train equipment, track configuration, and train control system. A typical commuter rail system might have several routes, each with its own set of characteristics that govern capacity.

Note that there is a difference between physical capacity and practical capacity. Physical capacity is capacity that is theoretically possible. On double track lines, and on single track lines where the track is operated in one direction during peak periods, the physical capacity is determined primarily by how closely trains can follow each other. For a single track line with bidirectional traffic, the physical capacity is determined primarily by the round-trip (grid) time between adjacent sidings when there is traffic in both directions.

Practical capacity is somewhat less and includes allowances for service disruptions and the capability to recover from disruptions. Often, it must also include windows for operation of freight trains and/or long-distance passenger trains.

There are some fundamental design issues that constrain various aspects of capacity. Station platform length dictates train length, which limits the number of cars per train. This, in turn, limits the number of passengers per train. This study assumes that during peak periods a system will be running at nominal capacity in terms of operating full-length trains. Therefore, the focus is on optimizing the train operations for the remainder of this report.

For the design of new systems, schedules, or routes, several items should be considered for commuter rail. Some items deal primarily with trip time. Others deal primarily with capacity.

## Commuter Rail Items Affecting Trip Time

- **Length of route** – Longer routes will lead to longer trip times, all other factors being equal. For most metropolitan areas, commuter operation systems operate shorter routes closer to the city center, whereas commuter rail systems serve outlying areas. For commuters 35 to 60 miles out, there may be a need to cut traveling time. Further details and illustrations are provided later in the report.
- **Distance between stations** – If stations are spaced too far apart, passengers may have to spend considerable time traveling to or from a station and might opt to drive for their entire commute. On the other hand, if stations are spaced too closely, trains will spend more of their time starting and stopping rather than running at top speed, and the average train speed will be low. Connecting bus services often serve commuter rail stations to provide an effective extension of the service area for a commuter rail system and allow for greater station spacing. Further details and illustrations are provided later in the report.
- **Number of stations** – The number of stations on a route is related to the distance between stations and the length of the route. Each station requires dwell time for boarding and detraining of passengers, as well as deceleration and acceleration times, so total trip time for trains is increased with the number of stations. However, an insufficient number of stations can

mean greater walking or driving distances for passengers, increasing overall passenger travel time. Further details and illustrations are provided later in the report.

- **Passenger perception/acceptance of delay** – The way passengers perceive delay can affect their overall trip experience. Regardless of actual trip time, a trip during which a train runs at full speed but stops for several delays might be perceived as taking longer than one during which a train runs at reduced speeds but avoids coming to a complete stop for delays.

Trip time for the commuter is door-to-door (home-to-workplace), not just station-to-station. If the distance to a station is too far, the commuter might opt to drive the entire distance between home and work. This perception of trip time needs to be taken into consideration when determining the number of stations and the distance between stations.

## Commuter Rail Items Affecting Capacity

- **Time between trains** – Running more trains during a given period of time is an obvious way to increase capacity, assuming the equipment is available to do so, and it can be done without increasing trip times to unacceptable levels. At some point, the signal and train control systems will limit the spacing of trains. For systems already operating near the capacity of their signal and train control systems, an investment in those systems might be needed to further improve capacity.
- **Operating speeds between stations** – The faster that trains are able to operate between stations, the shorter the trip time for passengers. Just as critical to trip time, and maybe more so, is the time spent at stop or operating at slow speed. Operating speed is a function of track topology and condition that determines permitted maximum operating speed and of the equipment performance (acceleration and braking capabilities, power-to-weight ratio, and top achievable speed) as well as the signal and train control system on the line. Frequently, the best way to maximize average speed is to minimize the time spent at slow speed or at stop. Further details and illustrations are provided later in this report.
- **Allowance for temporary speed restrictions (frequency and duration)** – Temporary speed restrictions, also known as slow orders, are often necessary during periods of track maintenance or if defects are found and need to be repaired. Major tasks such as rail or tie renewals may require work blocks, during which a track may need to be taken out of service for a block of time. Allowance should be planned for to allow train operations to recover even when a reasonable number of temporary speed restrictions are in place. Scheduling of maintenance during off-peak hours is common practice to minimize the effects on system capacity during peak periods.

- **Acceleration/deceleration rates for trains** – The faster that trains can accelerate departing a station and brake to a stop approaching a station, the shorter the transit time that trains can be scheduled. For areas with closely-spaced stations, the acceleration and deceleration rates of the trains can be a major factor in determining the achievable average operating speed between stations. Further details and illustrations are provided later in this report.
- **Station dwell times** – Station dwell time is the amount of time a train is stopped in a station for boarding and detraining of passengers. Station dwell times include time required to stop the train at its designated place at a station, as well as time required to open and close doors.
- **Time for passenger entry/exit** – Time for passengers to board and detrain is often the largest part of station dwell time. Platform level and number of steps and stairs that passengers must negotiate in boarding or detraining are key factors to consider.
- **Train length and station platform length** – Train length and station platform length are important factors in system capacity. Longer trains can carry more passengers. But train length is limited by station platform length. However, longer trains may need additional locomotive power to maintain the same trip time.
- **Vehicle design and door configurations** – Vehicle design and door configurations are important considerations for capacity in several ways. Internal seating arrangements and number of doors per car affect time for passenger entry and exit, thus affecting dwell time and headways possible. Car design also affects the number of passengers that a car can hold.

## Typical Types of Commuter Rail Operations

There are several different types of commuter rail operations. Each tends to have its own capacity issues:

- Single track – all moves in rush hour directions
- Single track – limited moves in opposing direction
- Double track with current of traffic operation
- Two or more tracks with bidirectional operation

There are different capacity issues and constraints for each type of operation, as will be discussed below. Track configurations such as number of tracks, siding spacing, and crossover spacing are important for track maintenance purposes as well as overtake purposes. There are also differences between operations that are primarily single direction or current of traffic, and those that are bidirectional. Even if the rush hour operation is in a single direction, there may be freight moves in the opposing direction.

In single track territories, an opposing move means there must be a meet between opposing trains, resulting in delay. On double track, typically there will only be a meet delay when one train overtakes another train by running against the current of traffic. Use of pocket tracks (a third track long enough to hold a commuter train) at stations can avoid some overtake delays.

It is useful to estimate what the delays will be for various operations. The following section discusses principles that apply. These can be used to estimate delays to trains in planning stages for various levels of traffic and schedules.

There is a fixed component and a variable component when there is a delay during a train meet or overtake. The sizes of these component delays depend on train characteristics and plant and signalling system characteristics. Fixed delay relates to the minimum amount of delay for meets between opposing trains on single track, as well as overtaking trains on multiple tracks. Fixed delay is the difference between the running time for a straight through routing, and a route through a siding or crossovers. Fixed delay is a function of:

- allowable train speed through diverging routes of turnouts
- train length
- siding length
- whether or not the siding is signal equipped
- train acceleration and deceleration capability
- time for an opposing train to travel from the approach (distant) signal until it clears the siding turnout

Variable delay is related to travel time between sidings. The average amount of variable delay is half the running time between two consecutive sidings. Variable delay is a function of:

- siding spacing
- speeds of trains

These concepts are useful to provide estimates of potential running times or changes in running time for preliminary investigations into new or changed services.

In general, it is more effective to increase commuter rail system capacity by reducing delays instead of increasing the top speed of trains. Realize that not all delays can be eliminated, particularly for a single track operation with bidirectional traffic. It is good practice to distribute delays evenly throughout a route and throughout the system, for reasons that will be illustrated below.

Key factors affecting commuter rail line trip time are power-to-weight ratio, station spacing, station dwell time, and top speed. The influences of these various factors are illustrated in the following series of four graphs.

Figure 2-1 illustrates the effects of several key factors on average train speed over a commuter rail route. First, as station dwell time increases, the average train speed decreases. An increase in station dwell time from 30 seconds to 2 minutes causes a loss of around 7 to 9 mph in average speed over a typical range of operating conditions.

Second, note that as the power-to-weight ratio increases, average train speed increases. The effect is more noticeable when station stops are farther apart. The benefits of increased power-to-weight ratio are quite small when stations are spaced 1 mile apart. Also note the effect of diminishing returns—as additional power is added, the benefit is smaller. For example, adding a second locomotive to a train might increase *average* speed by 5 mph, but adding a third locomotive might provide only 2 mph of additional increase.

Third, note that station spacing has a significant effect on average train speed. With stops every mile, it is hard to achieve an average speed of 25 mph even under the best of conditions. With station stops every 5 miles, average speeds approaching 50 mph are achievable. For long routes, station spacing is a key factor in keeping the total trip travel time acceptable. Another operating strategy for long routes is the use of local service (making all stops) in outlying areas in conjunction with express service (skipping most or all stops) until reaching the central business district or terminal. Skip stop service is another option to effectively decrease the number of station stops, thereby effectively increasing the average distance between stops. A few common stops are typically needed to facilitate transfers.

## Figure 2-1

*Effects of Power-to-Weight Ratio, Station Dwell Time, and Station Spacing on Average Train Speed*

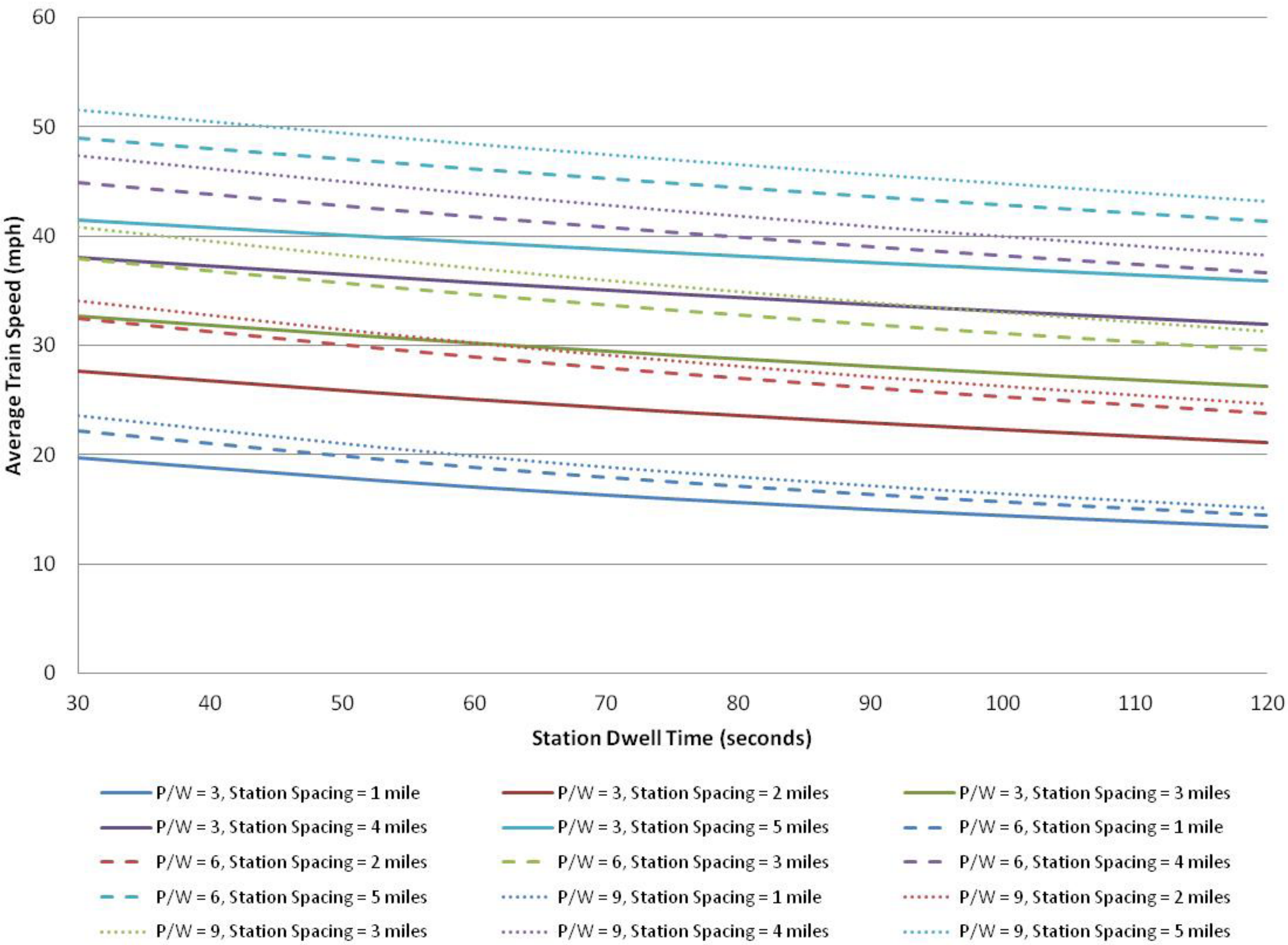



Figure 2-2 illustrates the effects of the same key factors on total train running time over a commuter rail route of 20 miles. First, note that increases in station dwell time increase the total running time. The effect is more pronounced on routes with close station stops (1 mile) as compared to those with longer distances between station stops (5 miles), as is to be expected, because essentially 5 times more dwell time is being added in the former case.

Second, note that an increase in power-to-weight ratio (adding a second locomotive) reduces total train running times in all typical cases as would be expected. The benefit of adding a second locomotive is most noticeable on routes with closely spaced stations. In all cases, there is a smaller benefit of adding a third locomotive. For routes with stations spaced 5 miles apart, the benefit of a third locomotive is barely noticeable in terms of reduced total trip time.

Third, note that station spacing has a significant effect on total train running time. Trip time on a route with stations stops every 1 mile takes almost three times longer than on a route of the same distance with stops every 5 miles. Simply increasing the station spacing from one per mile to one per 2 miles provides around a 30-percent reduction in total train running time.

## Figure 2-2

*Effects of Power-tp-Weight Ratio, Station Dwell Time, and Station Spacing on Total Train Running Time for a 20-Mile Route*

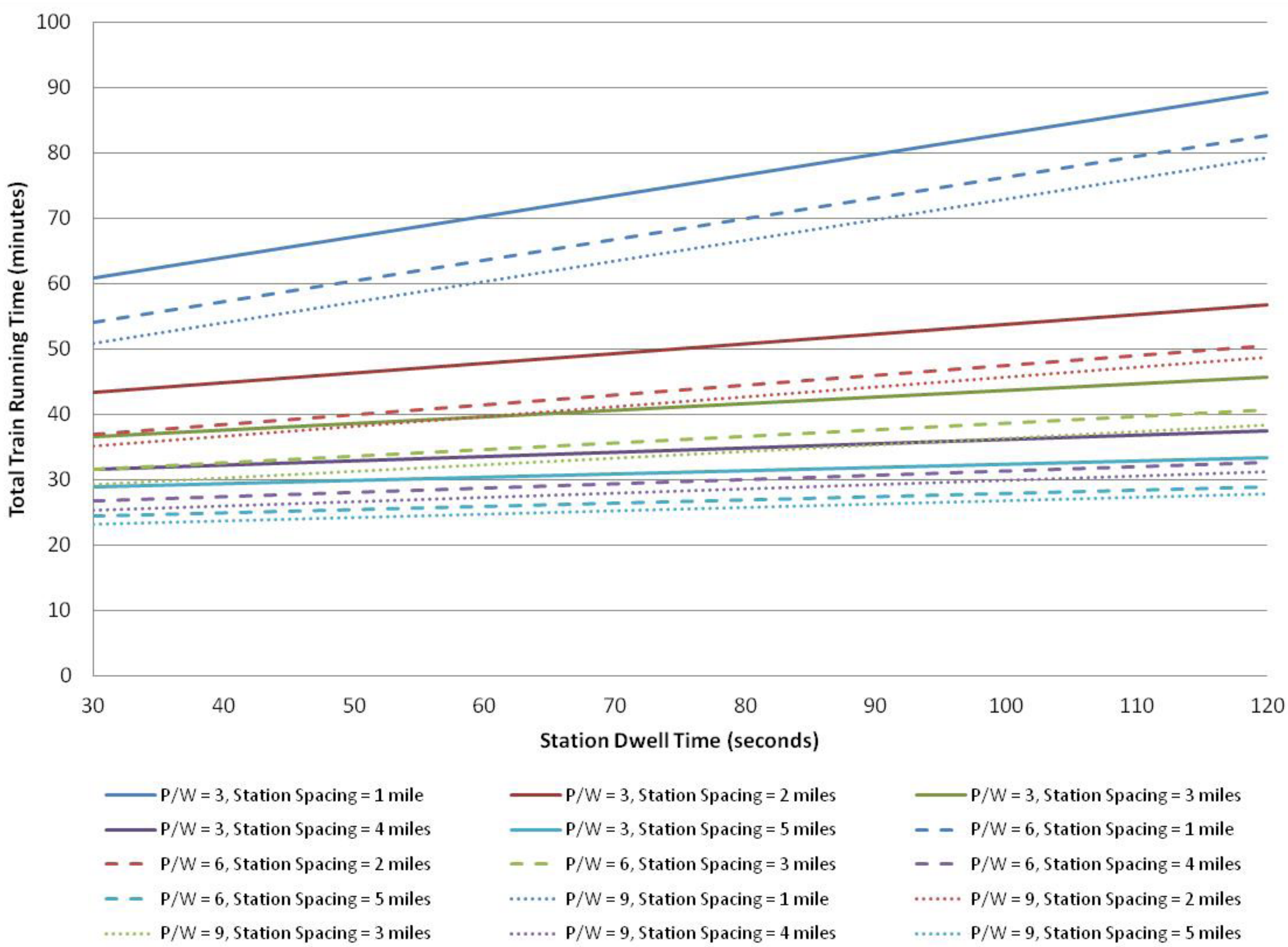



Figure 2-3 illustrates the effects of maximum permitted train speed on average train speed over an entire route. This example is for a route with stations spaced at 2-mile intervals. Note first that increasing maximum train speed above 60 mph has little to no effect. With the 2-mile station spacing used in this example, trains spend almost all of their time between stations either accelerating or braking. There is little, if any, time spent running at maximum train speed for trains capable of running faster than 60 mph.

Second, note once again that adding a second locomotive (increasing the power-to-weight ratio) provides a noticeable improvement in overall train speed for the cases shown. Adding a third locomotive provides only a small improvement. The benefits of adding a second locomotive are somewhat greater for shorter station dwell times.

Third, note again that for 2-mile station spacing, station dwell times are a major factor in determining average train velocity over the route. This trend points out the importance of keeping dwell times low, as well as reducing other delays. To increase capacity on a typical commuter operation, it is more effective to reduce delays and to reduce the time operating at a slow speed than it is to increase top train speed.

## Figure 2-3

*Effects of Maximum Permitted Train Speed on Average Train Speed for an Entire Route with 2-Mile Station Spacing*

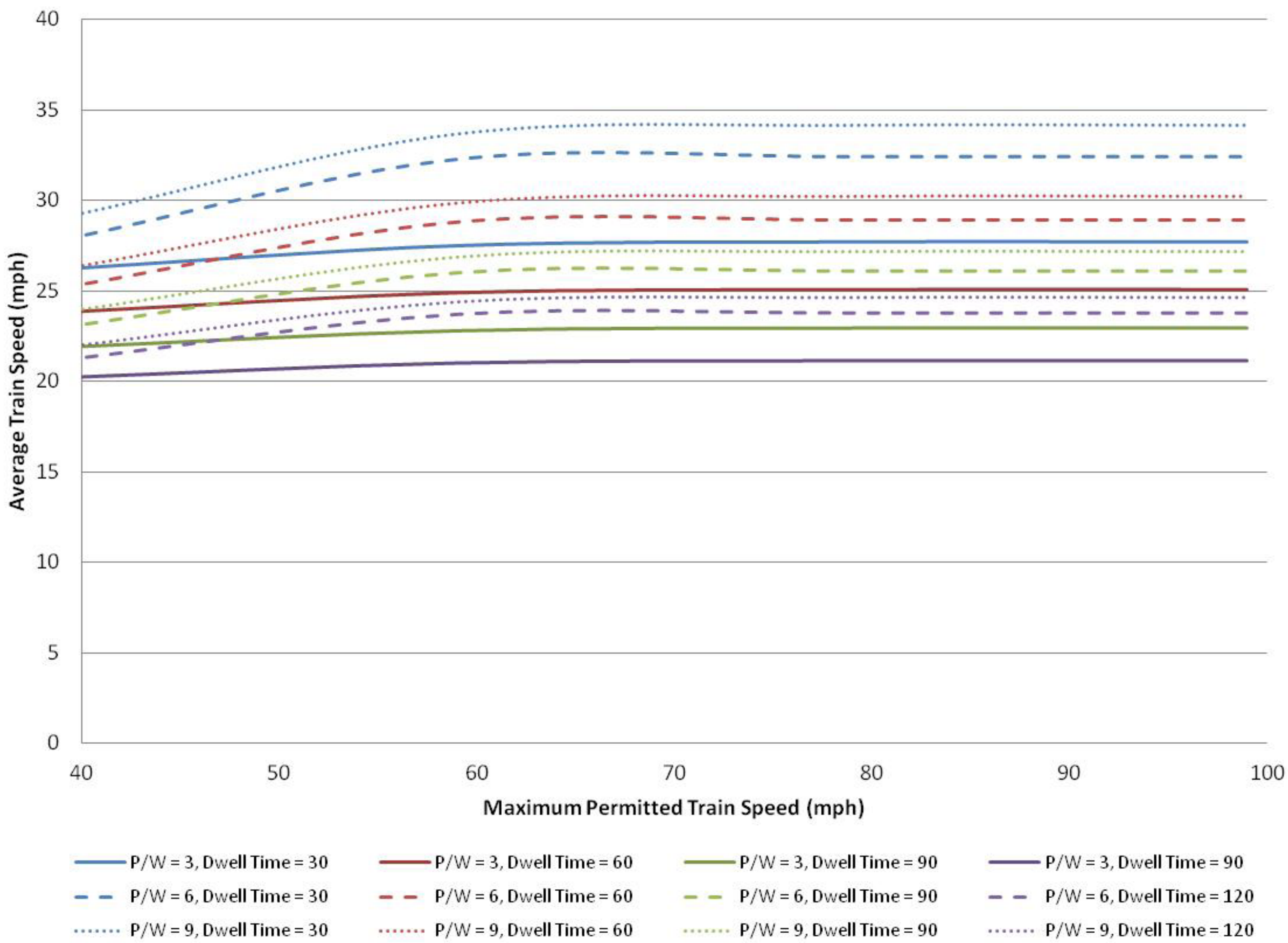


Figure 2-4 illustrates the effect of maximum permitted train speed on the total train running time. Again, this example is for a 20-mile route with stations spaced every 2 miles.

First, note again that trains with a maximum permitted speed greater than 60 mph provide little or no operating benefit with stations spaced 2 miles apart. They spend most of their time either accelerating or braking, and thus little or no time is spent operating at maximum permitted speed.

Second, note the effects of adding second and third locomotives to trains. The addition of a second locomotive typically decreases total run time by about 6 minutes on this route. Adding a third locomotive only decreases run time by an additional 1 to 2 minutes.

Third, note again the effect of dwell times on total running time. Reducing dwell time from 120 seconds to 30 seconds per station provides a reduction in total run time of about 13 minutes.

## Figure 2-4

*Effects of Maximum Permitted Train Speed on Total Train Running Time for an Entire Route with 2-Mile Station Spacing*

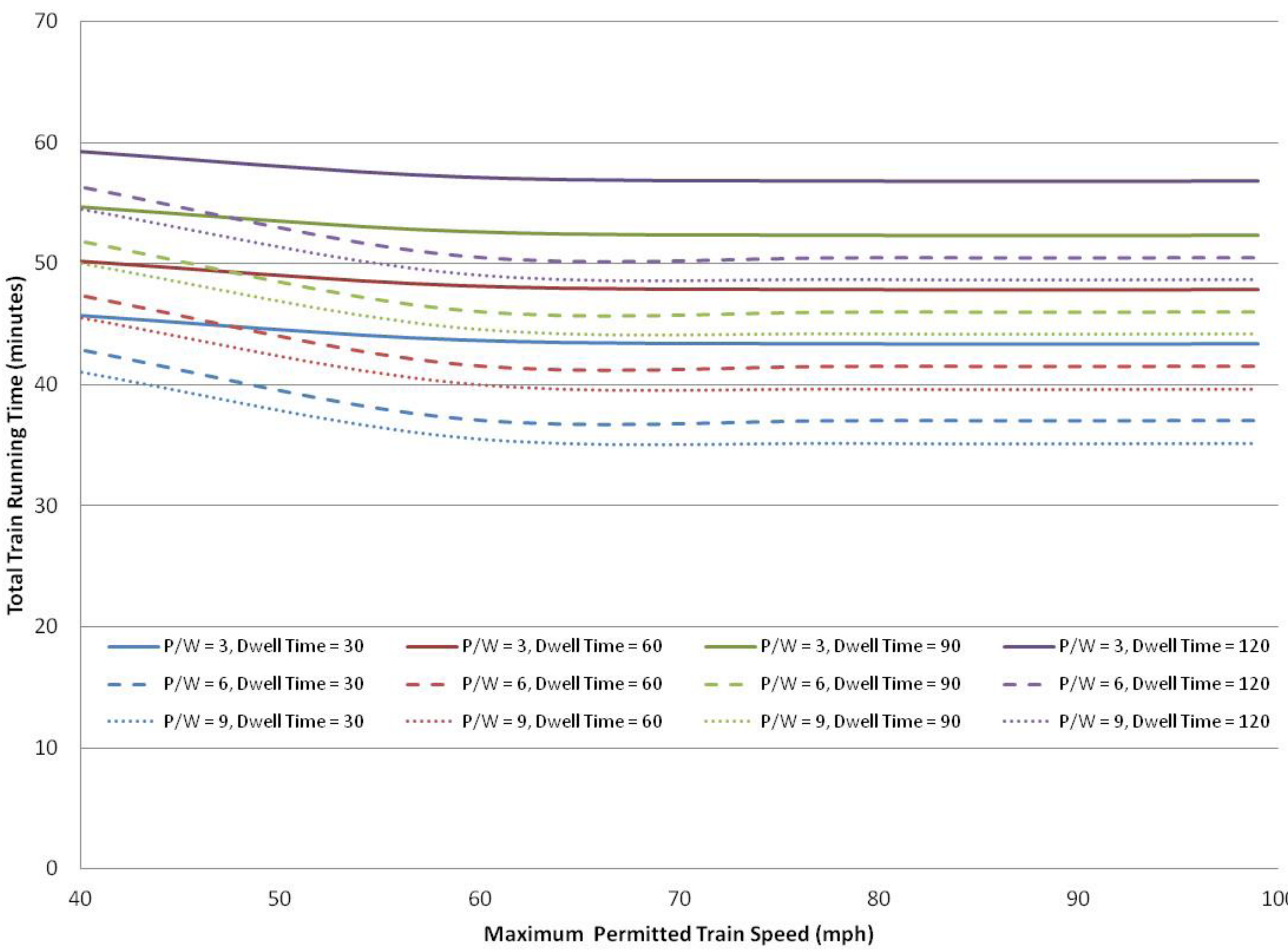


Table 2-1 lists the effects of power-to-weight ratio on trip time, as well as distance and time to accelerate a train to 80 mph. For the lower power-to-weight ratios, a commuter train typically would not reach 80 mph between station stops, because the distance to accelerate to 80 mph is greater than typical station spacing.

**Table 2-1**

*Effects of Power-to-Weight Ratio on Trip Time and Train Acceleration to 80 mph*

| Power to Weight Ratio (horsepower per ton) | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|
| Distance to Accelerate (Miles) | 23.0 | 7.3 | 3.6 | 2.5 | 1.9 |
| Acceleration Time (minutes) | 23.7 | 7.7 | 4.3 | 3.0 | 2.3 |
| Time Lost (minutes) | 3.7 | 2.3 | 1.6 | 1.2 | 1.0 |

**Figure 2-5**

*Train Speed (Green Lines) for Power-to-Weight = 2.9 horsepower per ton with Station Stops 5 Miles Apart*

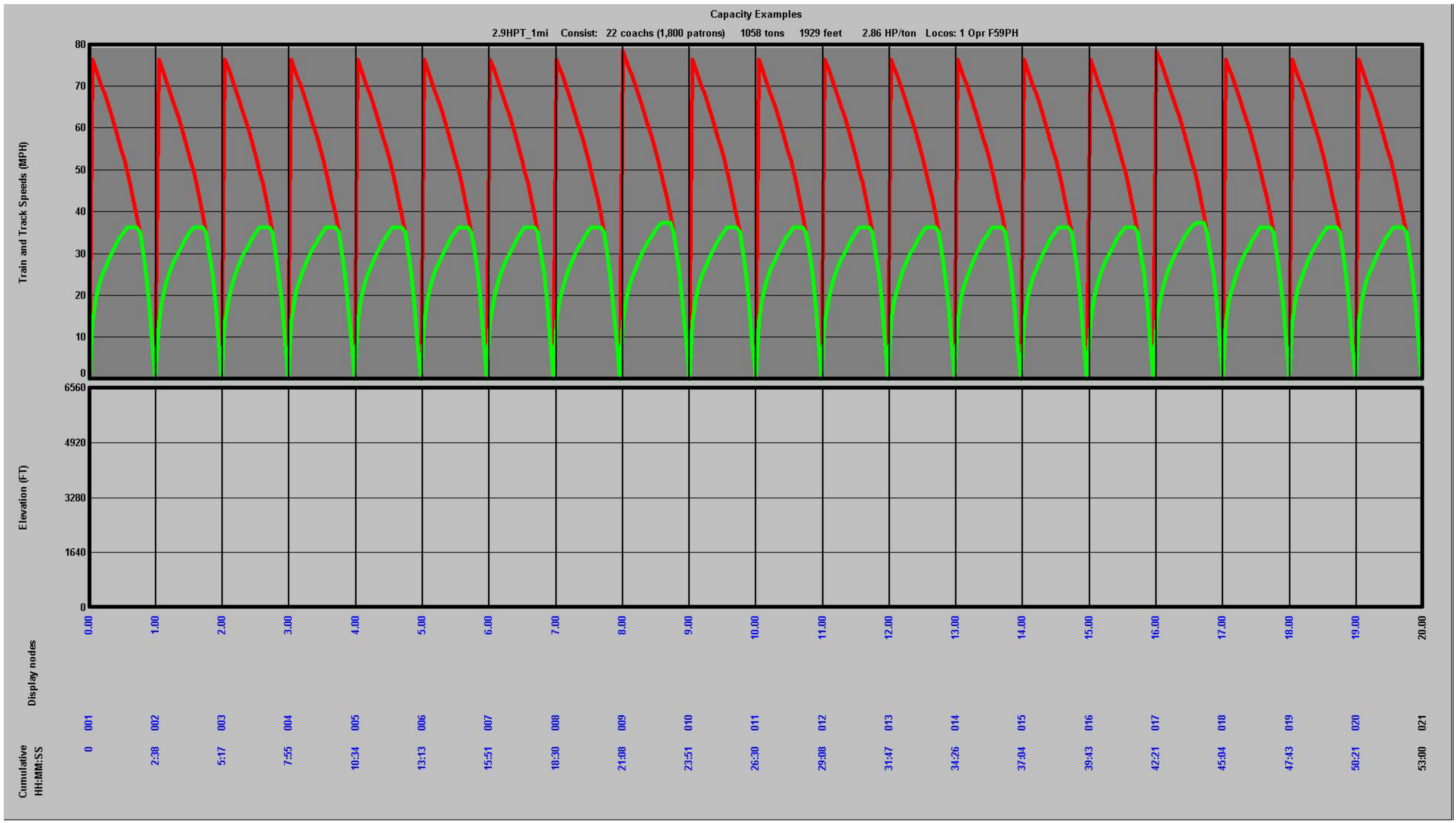
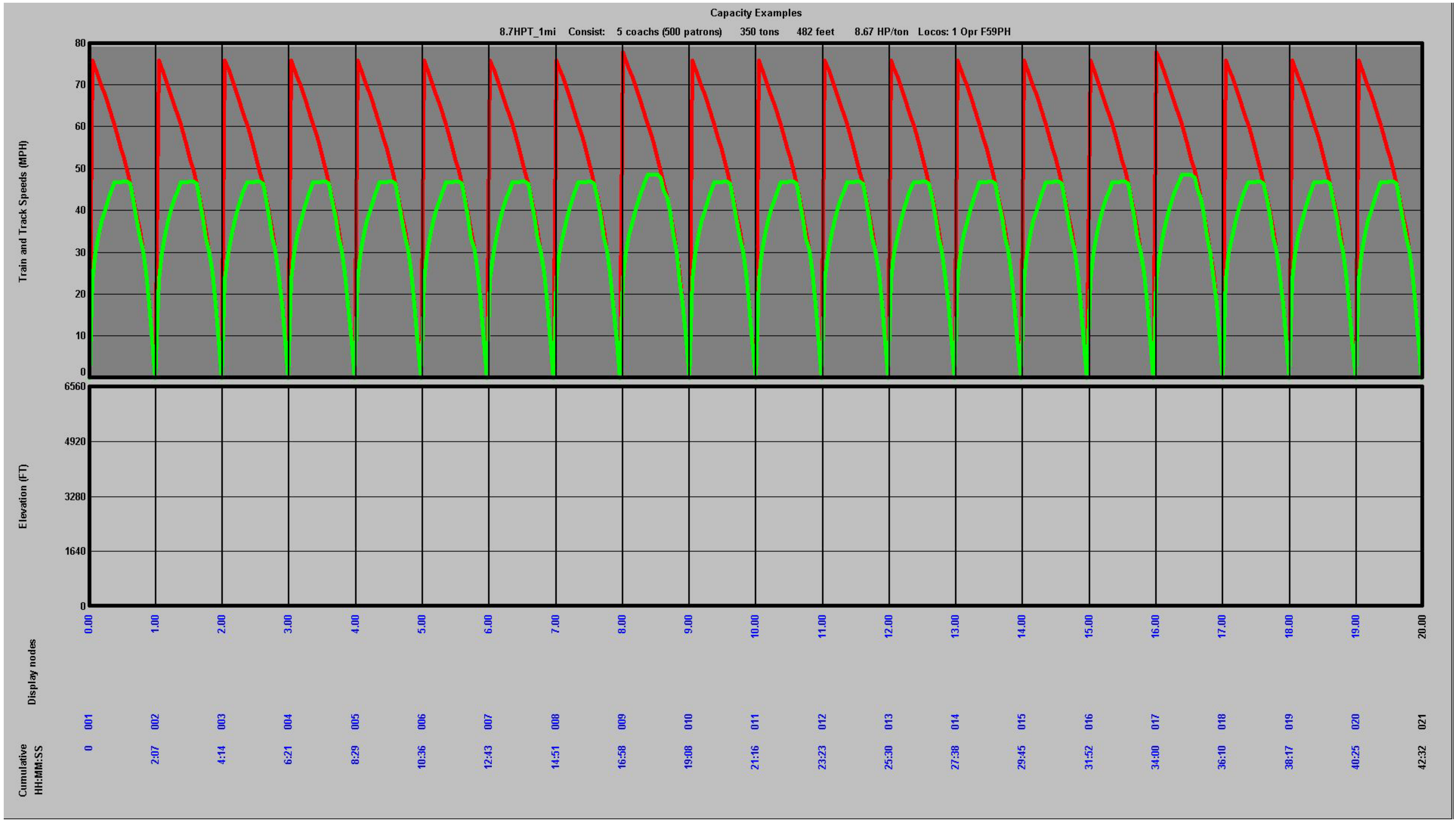


Figure 2-6 shows that by increasing the power-to-weight ratio to 8.7 horsepower per ton, a top speed of about 49 mph can be achieved on the same route. Total running time (not including station dwell times) is reduced from 53 minutes to 42.5 minutes, savings more than 10 minutes on this 20-mile route.

**Figure 2-6**

*Train Speed (Green Lines) for Power-to-Weight = 8.7 horsepower per ton with Station Stops 1 Mile Apart*



When the station spacing is changed from 1 mile to 2 miles, higher speeds and additional reduction in total trip time are possible, as shown in Figure 2-7. Top speed increases to about 64 mph, and total running time (not including station dwell times) is reduced to just over 30 minutes.

**Figure 2-7**

*Train Speed (Green Lines) for Power-to-Weight = 8.7 horsepower per ton with Station Stops 2 Miles Apart*

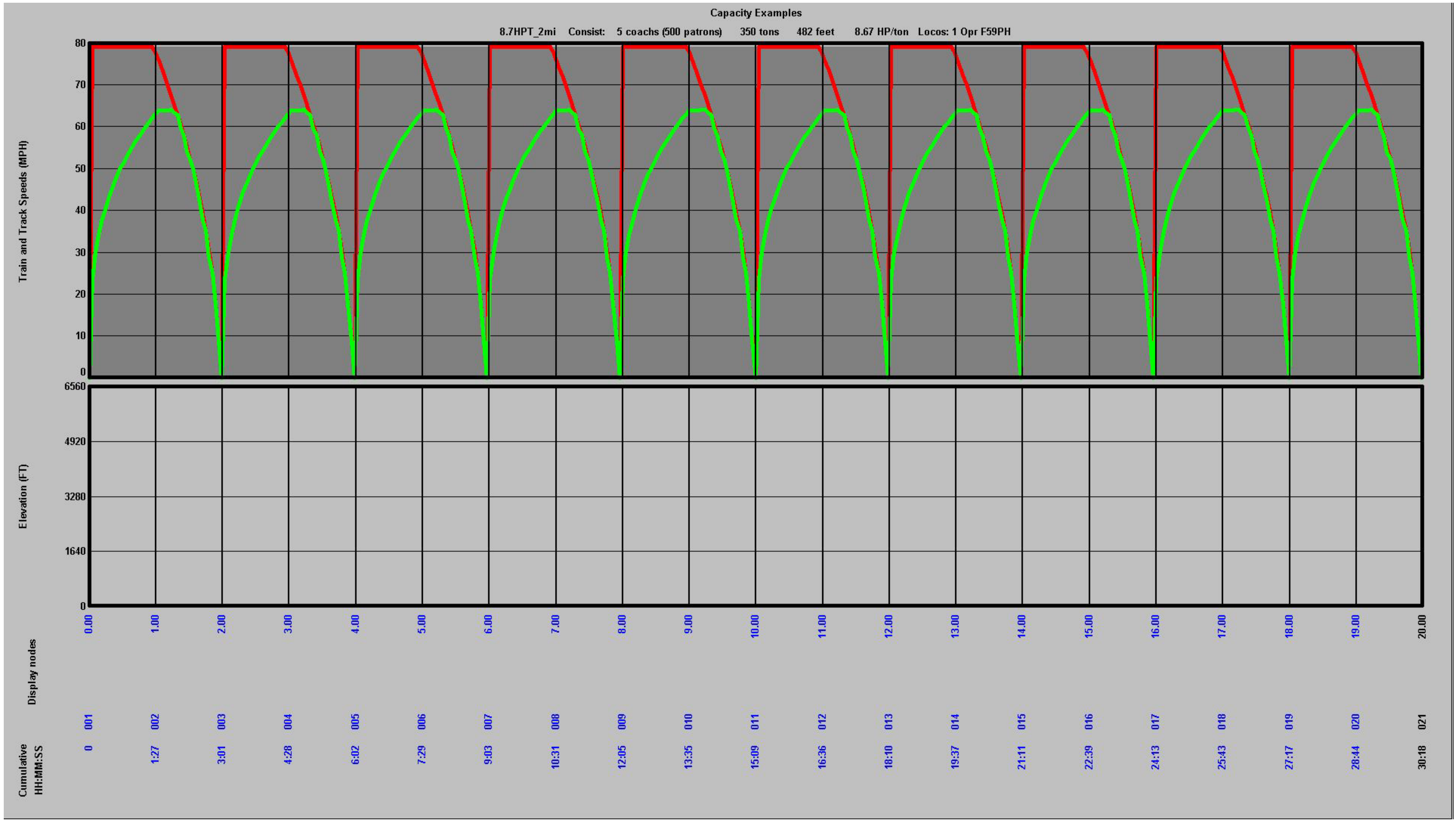



Figure 2-8 shows the effects of increasing station spacing to 5 miles, but using the original power-to-weight ratio of 2.9 horsepower per ton. The maximum speed is about 68 mph, and the total running time (not including station dwell times) is just under 28 minutes. These metrics are very similar to those achieved in Figure 2-7 with 3 times the power-to-weight ratio, but with stations spaced 2 miles apart instead of 5 miles apart. Clearly, there are tradeoffs between power-to-weight ratio and station spacing that should be considered in the design and operation of a commuter rail line.

Figures 2-5 through 2-8 also illustrate the effects of starting and stopping trains, and the resulting time spent running at slower speeds. Significant reductions in total trip time can be achieved by minimizing the amount of time stopped (station dwell time) and the amount of time running at slower speeds (braking to a station stop and accelerating from a stop).

**Figure 2-8**

*Train Speed (Green Lines) for Power-to-Weight = 2.9 horsepower per ton with Station Stops 5 Miles Apart*

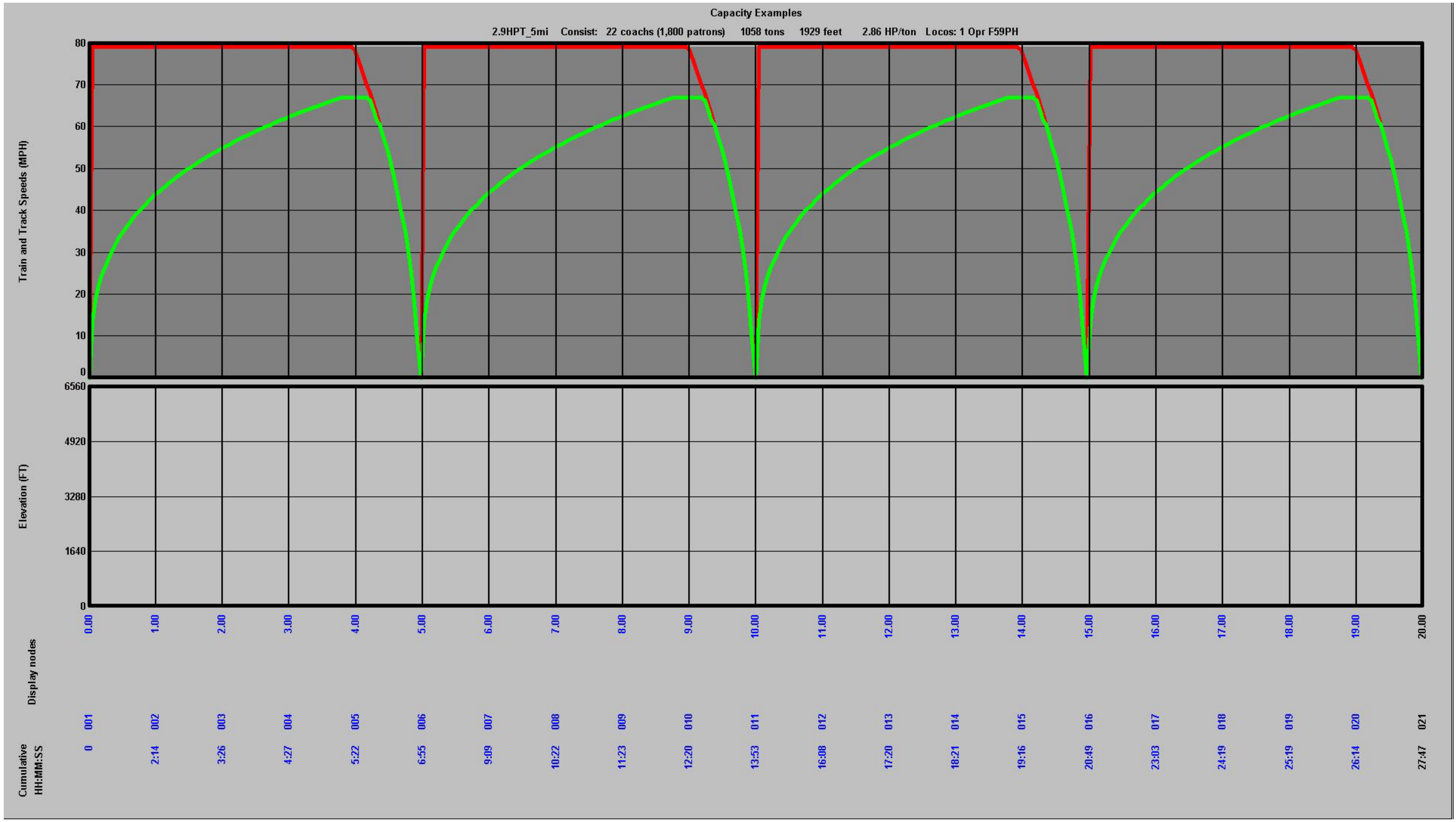



Table 2-2 summarizes the run time and average train speed for a variety of typical station spacings and power-to-weight ratios. The bold figures for average speed indicate the combination of station spacing and power-to-weight ratio needed to achieve an average speed of at least 40 mph. It is often considered desirable to maintain an average speed around 40 to 45 mph for commuter rail operations. The run times listed in Table 2-2 assume no dwell time at stations.

**Table 2-2**

*Commuter Operating Speeds with No Station Dwell Time*

| No Dwell Time | Run Time | Average Speed | Run Time | Average Speed | Run Time | Average Speed |
|---|---|---|---|---|---|---|
| P/W | 3.0 | | 5.8 | | 9.1 | |
| Stop every 1 mile | 61.3 | 19.6 | 49.0 | 24.5 | 43.9 | 27.3 |
| Stop every 2 miles | 41.5 | 28.9 | 33.8 | 35.5 | 29.3 | **41.0** |
| Stop every 4 miles | 30.5 | 39.4 | 24.7 | **48.6** | 22.2 | 54.0 |
| Stop every 5 miles | 27.8 | **43.2** | 22.7 | 53.0 | 20.8 | 57.8 |

Table 2-3 summarizes the same run times and average speeds assuming a 30-second dwell time at each station stop. Again, the bold figures for average speed indicate the combination of station spacing and power-to-weight ratio needed to achieve an average speed of approximately 45 mph.

**Table 2-3**

*Commuter Operating Speeds with 30-Second Station Dwell Times*

| 30 sec Average Dwell Time | Run Time | Average Speed | Run Time | Average Speed | Run Time | Average Speed |
|---|---|---|---|---|---|---|
| P/W | 3.0 | | 5.8 | | 9.1 | |
| Stop every 1 mile | 71.3 | 16.8 | 59.0 | 20.3 | 53.9 | 22.3 |
| Stop every 2 miles | 46.5 | 25.8 | 38.8 | 30.9 | 34.3 | 35.0 |
| Stop every 4 miles | 33.0 | 36.4 | 27.2 | **44.1** | 24.7 | **48.6** |
| Stop every 5 miles | 29.8 | 40.3 | 24.7 | 48.7 | 22.8 | 52.7 |

Table 2-4 summarizes the same run times and average speeds assuming a 60-second dwell time at each station stop.

**Table 2-4**

*Commuter Operating Speeds with 60-Second Station Dwell Times*

| 60 sec Average Dwell Time | Run Time | Average Speed | Run Time | Average Speed | Run Time | Average Speed |
|---|---|---|---|---|---|---|
| P/W | 3.0 | | 5.8 | | 9.1 | |
| Stop every 1 mile | 81.3 | 14.8 | 69.0 | 17.4 | 63.9 | 18.8 |
| Stop every 2 miles | 51.5 | 23.3 | 43.8 | 27.4 | 39.3 | 30.6 |
| Stop every 4 miles | 35.5 | 33.8 | 29.7 | 40.4 | 27.2 | **44.1** |
| Stop every 5 miles | 31.8 | 37.8 | 26.7 | **45.0** | 24.8 | 48.5 |

The above illustrations point out the effects of both power-to-weight ratio and station dwell time on commuter rail trip time and average trip speed. Improvements in capacity should keep a balance between power-to-weight ratio and station dwell time.

At typical stations, the most significant component of station dwell time is the boarding and detraining of passengers. So improvements that can ease the passenger entry and egress process can have significant capacity benefits. Factors to consider include the following:

- Number and size of doorways on cars
- Level of entry into passenger car
- Number and size of steps
- High level station platforms

Cars with two doors per side, each wide enough for three passengers abreast, are commonly used and represent one of the most efficient designs currently available. The doors are at a lower level, minimizing the number of steps between low level station platforms and the depressed car floor. The fastest passenger loading and unloading is possible with high level platforms, at the same level as car floors. But to use high level platforms on a line that also carries freight trains, provision must be made to provide clearance for wide freight loads. This might be accomplished by using an alternate track for freight traffic near stations, or by using a pocket track for commuter trains at stations. Appropriate signaling and train control systems need to be implemented as well. The dispatching system also needs to be able to distinguish between commuter trains and other trains.

An example follows to illustrate the types of improvements that might be possible on an existing commuter line. On a 19-mile route with 9 stations, old equipment included trains powered by one 1750 horsepower locomotive pulling 8 cars weighing 85 tons each, with single width doors at each end. The power-to-weight ratio was 2.0 horsepower per ton. Dwell time was 3 minutes at some of the most heavily used stations. Scheduled trip time was 45 minutes. New equipment for the route included a 4200 horsepower locomotive pulling 8 lightweight cars weighing 42 tons each. The power-to-weight ratio increased to 9.0 horsepower per ton. In addition, the newer cars had wider doors to facilitate faster boarding and detraining, resulting in decreased dwell time at stations. Achievable total trip time with the new equipment is 36 minutes, resulting in a savings of 9 minutes.

## Scheduling for Commuter Train Operation

To set schedules for commuter operation, the operational limits must first be determined. The first operating limits to determine are as follows:

- Maximum acceptable operating time from end point to end point
- Minimum run time based on power-to-weight ratio
- Number of station stops
- Station dwell times

After these basic operational limits are defined, then preliminary schedules for commuter and other passenger trains can be developed. Schedules need to include detailed plans for station stops and meet locations, as well as train passing locations. Operating tolerances need to be considered by adding extra time for unplanned delays and schedule recovery as appropriate.

After the preliminary commuter and passenger schedules are set, then freight traffic needs to be added. When adding freight traffic to the schedule, average meet and overtake delays need to be included. Additional physical plant capacity might be needed to accommodate freight operations. Plant capacity additions might include adding crossovers (applies to two or more track operations), replacing turnouts with higher speed turnouts, adding or lengthening sidings (applies primarily to single track operation), signal and train operating system upgrades (such as changing from current of traffic operation to bidirectional operation), and station platform improvements to facilitate longer trains or to reduce station dwell times.

Schedules should be negotiated with the freight railroad. And the freight railroad should be kept whole in terms of its ability to run trains to provide service to its customers. There might be a need for operation of freight trains during commuter peak periods. Sufficient physical plant capacity should be provided to operate commuter trains with windows for freight train operation as deemed appropriate by the freight railroad when the commuter operation is using the track of a host freight railroad, which might be achieved by setting commuter train schedules to allow threading a freight train between two commuter trains. If that does not provide the commuter train frequency desired, either a change in the signaling or train control system will be needed, and additional track will be required if freight operational flexibility is to be maintained.

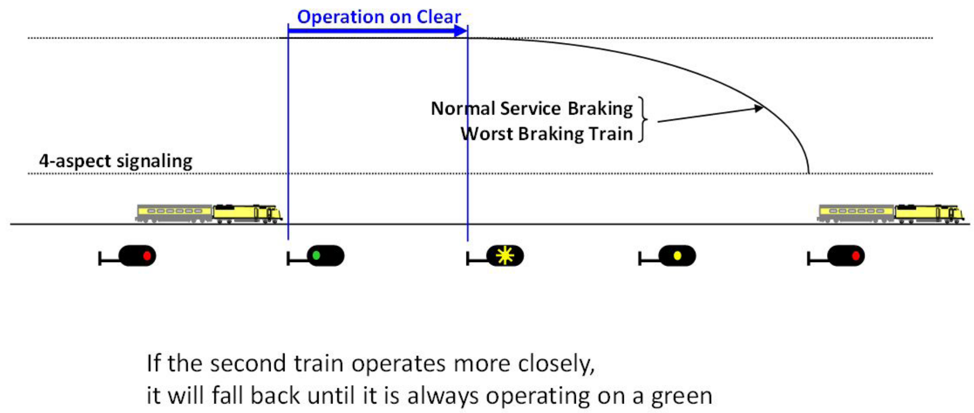
If other industries along the commuter corridor need service during the hours of the commuter operation, then a service track without signals can be provided to permit freight switching totally separated from the commuter operation.

## Train Spacing

Trains running in the same direction on the same track need to be separated a sufficient distance to always keep a safe braking distance between them. Most commuter trains operate in territory that has fixed blocks with either a 3-aspect or 4-aspect signal system. Figure 2-9 illustrates the fundamentals of a fixed block territory with a 4-aspect signal system to keep two trains safely spaced during operation in the same direction. Sufficient distance must always be provided such that under normal service braking, a train with the worst performing brakes will be able to stop short of a train ahead.

**Figure 2-9**

*Train Spacing in Fixed Block Territory with 4-Aspect Signal System*




In this illustration, the train on the left is following the train on the right. The following train can operate for one block length on a clear signal indication. Then it will encounter a flashing yellow aspect, indicating reduce to medium speed. Next it will encounter a solid yellow aspect, indicating proceed and be prepared to stop short of the next signal. The next signal aspect is red, indicating stop. If the following train operates more closely to the leading train than shown in the figure, it will enter the block before it has cleared to green and it will slow down and fall back until it is always operating on a clear signal, assuming the leading train is operating on clear signals and capable of maintaining its authorized track speed.

Figures 2-10 through 2-12 illustrate the use of time-distance diagrams to schedule commuter and freight operations on a line. These time-distance diagrams are known as signal wake diagrams, because they also show the stop and approach signals protecting against movement of following trains. Ideally, trains will be scheduled to run without encountering any restrictive signals for the length of their trip.

Figure 2-10 shows the signal wake diagram for a typical commuter train on a sample 17-mile line. Total trip time is about 30 minutes at an average speed of 34 mph. The maximum signal clear-up time is about 11 minutes.

**Figure 2-10**

*Signal Wake Diagram for Commuter Train*

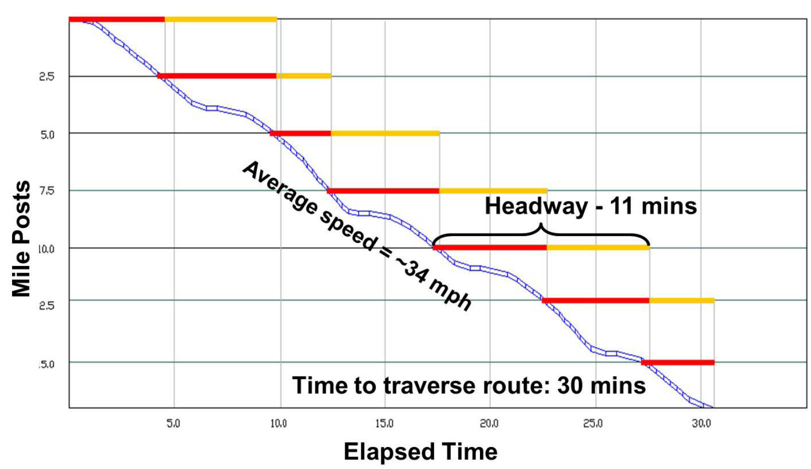


Figure 2-11 shows the signal wake diagram for a freight train on the same sample line. The freight train takes about 34 minutes to traverse the line at an average speed of 30 mph. Note there are no station stops planned for the freight train. Also, note that the blue line indicating train presence is wider, to account for a longer train as compared to a commuter train. Maximum signal clear-up time for the freight train is about 13 minutes.

**Figure 2-11**

*Signal Wake Diagram for Freight Train*

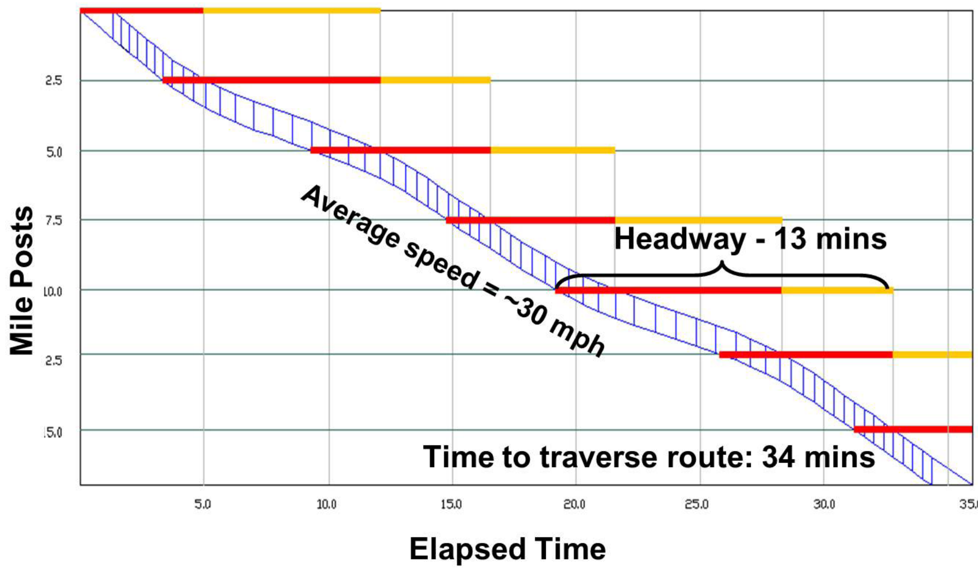



Figure 2-12 shows how the freight train can be scheduled to run between two commuter trains without any trains encountering a restrictive signal. This example requires a 30-minute window between commuter trains. If the commuter trains and freight trains operate at similar average speeds, such scheduling is relatively easy to accomplish. If the freight and commuter trains run at different speeds, it becomes more difficult, requiring larger windows of operation. Longer trip lengths add further complications. For example, scheduling a 15 mph coal train between 50 mph commuter trains over a 50-mile route would certainly be more challenging. In such a case, consideration might need to be given to provide additional trackage (sidings, or crossovers and bidirectional operating capabilities on multiple tracks) to facilitate train passing.

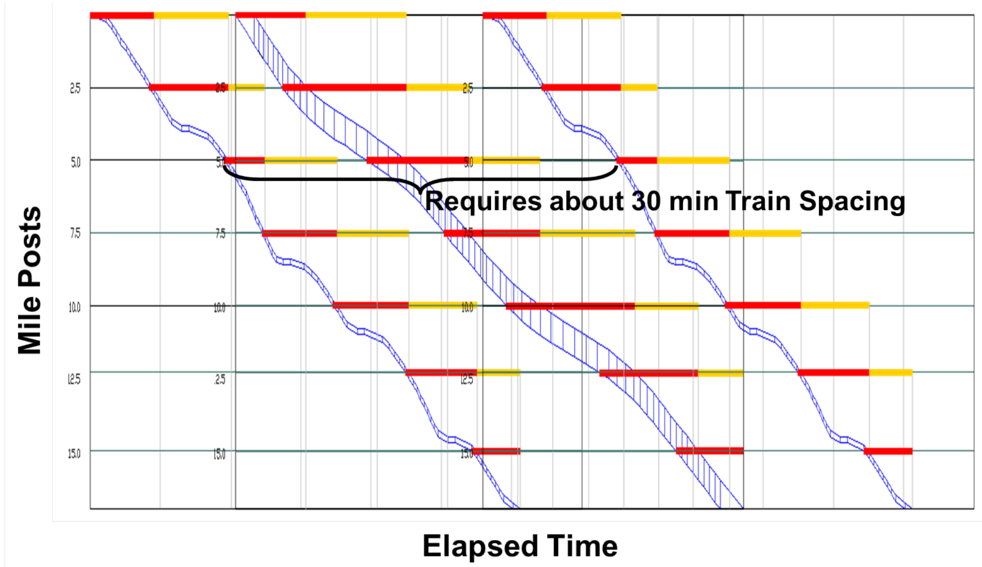



**Figure 2-12**

*Signal Wake Diagram Showing Schedule for Freight Train Between Two Commuter Trains*

Scheduling for operation of a freight train on single track line with bidirectional commuter train operation can be challenging as well. The following illustration is for a 30-mile single track line with sidings spaced 6 miles apart. Both main line and sidings are signalled for bidirectional operation. Sidings are 1.25 miles long with 40 mph turnouts at each end. The sample operating period lasts about 3 hours. Both commuter and freight trains operate at 35 mph, giving an unrestricted trip time of 52 minutes if no train meets or passes are encountered. Six commuter trains (three each direction) and one freight train need to be scheduled into the 3-hour peak period.

If the commuter trains are given absolute priority over the freight train, they can cover the line with a trip time of 82 minutes, including time for meets with commuter trains traveling the opposite direction. But the freight train is unable to operate, because it cannot get onto the line without causing some delay to a commuter train. If the freight train is given equal priority with the commuter trains, the commuter trains can complete their trips in 96 minutes, while the freight train can complete its trip in 104 minutes. The commuter trains each are impacted with 14 minutes of additional delay to get the freight train across the territory. The freight train takes twice as long to get over the territory as it would with no interfering traffic. All trains spend considerable time waiting for meets with other trains, as well as operating at low speeds while braking and accelerating before and after meets.

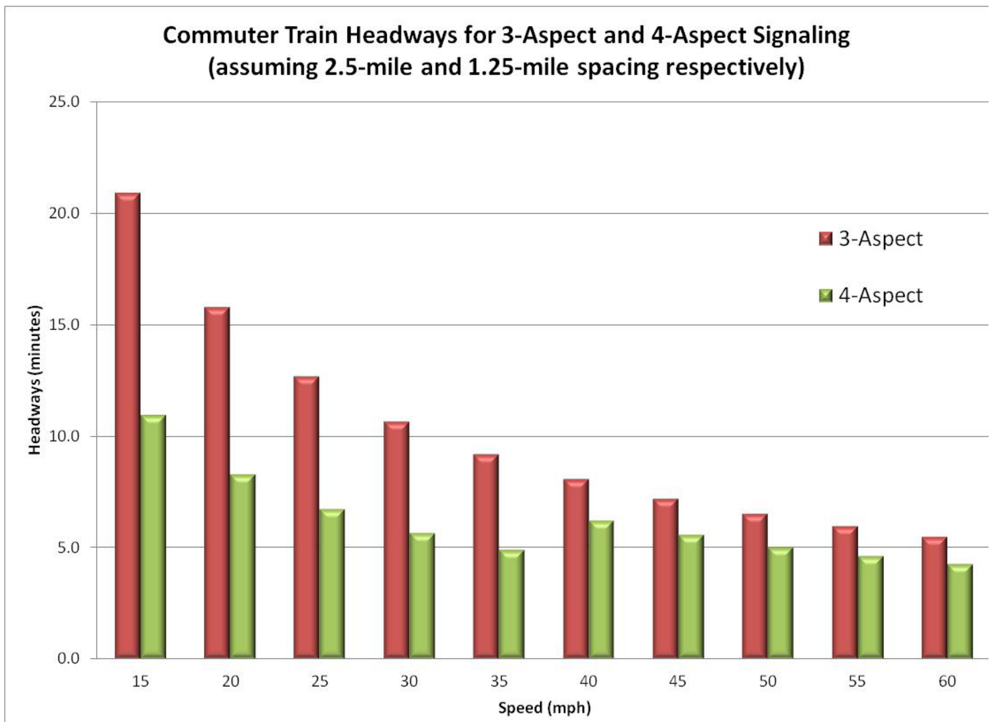
If the resulting trip times and delays are not acceptable, then physical plant capacity needs to be added. In this case, more sidings, or connecting sidings to form sections of two main tracks, are likely options to be considered. Adding sidings will reduce the variable delay per meet, i.e., the time spent waiting in sidings for the arrival of opposing trains. Adding sidings is a solution of diminishing returns, because the fixed delay per meet remains unchanged as second track is added. Joining sidings will reduce the fixed delays, because the probability of running meets is increased.

### Effect of Train Operating Speed on Train Spacing

Figure 2-13 illustrates the effect of train operating speed on train spacing for both 3-aspect and 4-aspect signal systems. The 4-aspect signal system requires about twice as many signals for a given length of territory, because they are spaced at half the distance. The result is that the time between trains approaches half of the time between trains as compared to a 3-aspect signal system at speeds below medium speed, in this case, 40 mph. For speeds above medium speed, the time between trains operating under a 4-aspect system approaches 75 percent of the time between trains as compared to a 3-aspect signal system.

**Figure 2-13**

*Effect of Train Operating Speed on Train Spacing for Two Common Signal Systems*




## Other Commuter Train Operational and Infrastructure Capacity Issues

To minimize deadhead moves, most commuter agencies construct a night layover yard beyond or close to the last station served on the line. Refueling and maintenance facilities might be located at this yard as well, if they are not located near the downtown terminal. Typically, a surveillance system is needed to protect against vandalism when the trains are parked overnight.

For operations where many trains operate only between the downtown area and an intermediate station, turn back sidings might be constructed to provide for end-of-zone turns.

Platforms serving both tracks are preferred at station locations with two tracks, because it provides for greater operational flexibility. Island platforms between the two tracks permit running in either direction on either track if necessary. Underpass or overpass structures should be provided so that passengers are not required to cross active tracks. Appropriate fencing can be provided to discourage last-minute passengers from attempting to cross a live track in an effort to catch a train. Although there are provisions for loading passengers across an active track using special protections (GCOR Rule 6.30), this can result in more slow speed operation for trains, and increased dwell time at stations for passengers boarding and detraining. It also restricts capacity on the track(s) across which passengers are boarding.

At stations where a precision train stop is required, e.g., for a wheelchair lift, additional slow speed operation can be expected.

For stations where parking and platforms are on opposite sides of the tracks, grade-separated pedestrian crossovers are preferred for passenger safety.

Also in multiple track territory, sufficient crossovers should be provided to allow run bys and diversions for other trains.

In single track territory, sidings are critical. Spacing of sidings, length of sidings, and siding locations must all be considered. Ideally, sidings should be spaced equally in terms of the time required to traverse the line, rather than spaced at equal distances. This means that in territory with curves or grades that reduce speed, sidings should be spaced more closely than in flat straight territory. Spacing of sidings and the run time between sidings determine the average delay that can be expected when trains meet. Where possible, stations should be located at sidings so that station dwell time can occur simultaneously with waits for opposing trains.

Sidings generally should be long enough to handle any trains that operate on the line. On lines carrying freight traffic, the freight trains will tend to be longer and govern siding length. One exception is that pocket tracks at commuter stations need only be long enough to hold a commuter train in the clear of other tracks. Finally, sidings should be located in areas without public highway grade crossings that would be blocked while trains wait for meets with other trains. In a capacity expansion project, it might be more cost-effective to construct a longer section of second main track than to construct a new siding that also requires building a highway grade separation.

# Issues Creating Long Headways and Restricting Capacity

Locations of slow speed operation can restrict capacity on a commuter line. A common source of slow speed operation is a junction where the commuter line merges with or crosses other railroad lines, either freight or passenger. At some junctions, the constraint is not conflicting traffic, but low speed curves and turnouts. At junctions with significant amounts of merging traffic, appropriate signalling and track configurations can minimize congestion. At busy crossing locations, one alternative might be construction of a flyover, which eliminates train delays, wasted fuel, signal complexity, and the high maintenance expense of a complex track structure, while providing significant capacity improvement for all affected lines.

Another cause for slow speed operation is the need for a precision train stop. Such a stop might be required at a station with a short platform, in a case where a train is stopping on the "wrong" main and passengers need to detrain at crossings of the other main track, or when spotting the train for use of a wheelchair lift. In all these cases, the engineer is likely to bring the train into the station at a slower speed to stop precisely without over running.

Uneven signal clear-up time can also lead to slow speed operation of a commuter train. This can be the result of signal spacing that might cause a train to operate through a long block on a restrictive signal. In some cases, the train might actually reduce trip time by waiting at a restrictive signal until a more favorable signal indication is displayed, allowing faster travel through the block in question. Possible improvements might include adjusting block limits and signal locations, or upgrading from a 3-aspect signal system to a 4-aspect signal system.

Unplanned delays can also lead to slow train operation. Some common causes of unplanned delays include:

- System failures (signals, frozen switches, etc.)
- Temporary speed restrictions
- Track maintenance
- Passenger causes — holding doors, injuries boarding and leaving train

Station dwell time is a critical element of headway, or spacing between trains. So stations with large numbers of passengers boarding or detraining can be locations of capacity constraints. Such stations should be carefully designed to maximize the flow of passengers and minimize dwell time for trains.

Since most commuter rail systems operate a hub and spoke network, there normally are not any interchange stations with high volumes of passengers transferring from one line to another. But as some metropolitan areas consider adding circumferential or belt service, junctions between the belt line and spoke lines will need to be assessed for passenger interchange configurations. Both track configuration and station configuration need to be considered. Also, whether the crossing is at grade or is grade separated will have implications for capacity on each line, as well as for transfer of passengers. Locations for the station building and platforms might be more constrained as well. And public street access might be challenging. Schedule coordination becomes another factor to consider in such an operation. Transfer times, as well as time between trains (in case of a missed connection) should be planned carefully at stations where significant numbers of passengers are expected to transfer. If entire trains are expected to transfer between a spoke line and a belt line, then a station at the junction or flyover can be avoided.

## Capacity Considerations for New Starts

When planning a new commuter rail operation, various types of operations should be considered. The selection of the type of operation will be based on service and capacity requirements, existing infrastructure, capital availability, and other constraints. Some common types of operation include unidirectional (either single track or multiple track), single track with primary flow of traffic, or single track with equal two-way traffic.

Unidirectional traffic on a line that is primarily single track will normally consist of inbound service in the morning and outbound service in the evening. A limited amount of bidirectional mid day service might be provided between the rush periods or during the evening hours. Similar unidirectional operation also can be provided on a multiple track line.

Another possibility for a single track line is to provide primary service in one direction, with a minimal amount of service in the opposite direction. In some cases such trips might be necessary to reposition equipment. Care should be taken to schedule such service to minimize delays as result of meets between trains running opposing directions. Dispatching priority also needs to be considered.

If a single track line is expected to provide service in roughly equal amounts in both directions, then the number and placement of sidings becomes crucial. Careful consideration needs to be given to the number, location, and length of sidings. Once again, scheduling and dispatching priority need to be considered carefully.

On a line with multiple tracks, similar services can be provided. On multiple track lines with sufficient crossovers and signalling for bidirectional operation there is more capacity and hence, more operating possibilities as compared to double track that is set up primarily for current of traffic operation. The possibilities of local and express services (as noted previously for servicing distant stations on a long line) are easier to implement, because passing is more easily accommodated. Multiple tracks also provide more capacity and flexibility for freight and long-distance passenger traffic.

When commuter rail operates on corridors shared with freight rail operators, the freight operators must be kept whole in terms of their ability to provide service as needed to their freight customers.

When considering adding trains to a single track line with traffic in both directions, note that run times increase exponentially with the number of trains. If too many trains are scheduled, there will be little or no opportunity to recover from unexpected delays. The line might become so congested that eventually all subsequent trains are delayed. And some trains might not be able to get out of the yard. These issues do not apply to lines with operations in only one direction.

When considering starting a commuter train operation on an existing freight railroad line, there are several items that should be discussed. First, is the freight railroad able to dedicate service windows during peak periods for operation of commuter trains only? Second, what is the relative time sensitivity of the freight markets served on the line? Third, what is the existing relationship between traffic volume (freight and other passenger) and capacity on the line before the commuter service is added? Fourth, what are the current track and signal system configurations, conditions, and operating speeds on the existing line? It is likely that any of these issues might point to the need for physical plant upgrades (track and/or signal systems) prior to the introduction of commuter traffic.

It is important for those considering a new commuter service to understand the issues regarding train spacing, train separation, braking distance, and signal systems required to operate safely, as illustrated in Figures 2-9 through 2-13. It is not possible to operate commuter trains safely at the same frequencies as with highway traffic. Train lengths, train weights, and the resulting braking distances change the physics of the operation considerably.

Some institutional issues should also be addressed. Although existing commuter operations on a freight railroad line might be accepted or tolerated due to their long history (often dating to operation by the host railroad itself), new starts might not be welcome. Contractual issues with a host railroad need to address basis for payments, whether the reimbursement is for avoidable costs only, or for fully allocated incremental costs. For train operations and dispatching, there might be an incentive performance clause, a penalty assessment, or a fixed fee contract. Costs of capital improvements to the physical plant (track and signal upgrades), as well as associated maintenance, need to be allocated appropriately between affected parties. In some cases the commuter agency might take over ownership of the right-of-way with a freight railroad retaining exclusive rights to provide freight service. Many of the same issues will need to be addressed, regardless of ownership.

## Considerations for Upgrading Capacity for Existing Operations

The same general principles apply to adding capacity to an existing system as apply to designing a new system. Again, the issue of physical capacity versus practical capacity comes into play.

### Increasing Number of Passengers per Train

For existing systems, one of the most straightforward ways to add capacity is to increase the number of passengers per train. A simple way to accomplish this is to add more cars to trains, provided the equipment is available. At some stations, it might be necessary to increase platform length to accommodate longer trains. At some point, track and platform lengths and configurations will limit the practical length of trains. Adding cars to trains will lower the power-to-weight ratio, unless additional locomotive power is added to the train. Otherwise, the trip time will become longer.

Another way to increase the number of passengers per train is to upgrade to equipment with the capacity to hold more passengers per car. Bi-level cars are a common solution for lines where clearances permit. Sometimes constraints such as overhead catenary, tunnel height, and/or platform configuration dictate the use of single level equipment only.

### Adding Trains to the Schedule

Additional capacity can be achieved by adding trains to the schedule, thereby reducing the scheduled headway between trains.

For operations planning, two important issues need to be considered:

- Sustainable capacity during an entire rush period, from which schedules are developed to account for normal service disruptions. Typically, this would include allowances for 95th percentile dwell times at stations. The goal is to establish headways that will accommodate most of the typical traffic and delays without disrupting schedules.
- Catch-up capability, which allows the system to recover from disruptions. This might involve trains running closer together on restrictive signals at some times. Overall trip time will be longer, but impact on schedules of subsequent trains will be minimized.

For systems already operating with schedules near these headway capacities, providing additional capacity might require solutions such as changing the train control system.

To fit more trains into a schedule, headways between trains will need to be reduced. If the system is already running at practical capacity, improved train control systems and signalling might be needed to provide additional capacity. Use of shorter signal blocks can help reduce spacing between trains. Implementing such a change might require a signal system upgrade, such as changing from 3-aspect signalling to 4-aspect signalling. There is, however, a limit to what gains can be achieved by reducing signal spacing, because minimum signal spacing is governed by the braking distance required for the worst braking train. For further reduction in headways, it might be necessary to implement communications-based train control (CBTC) such as a moving block system.

In complex interlockings, such as major junctions and terminal station throats where operating speeds are slow, implementation of sectional release might help to improve the flow of traffic. In standard control points, all switches in a route from entry point to exit point are locked until the train for which the route is intended has exited the entire interlocking. With sectional release, each switch or crossover in the route is released as soon as the train no longer occupies it, allowing the switch to be used in an otherwise conflicting route for another train before the prior train has exited the interlocking. In interlockings that may include dozens of switches and extend over thousands of feet where trains are operating at 10 to 20 mph, sectional release can result in significant time savings and increased operational capacity.

## Reducing Train Running Time

Reduction in train running time can also provide room in a schedule for additional trains. And it might make some equipment available for an additional run. The key to reducing train running time is to minimize time stopped and time running at slow speed. With the frequent station stops typical of commuter rail operations, top speed might not be achieved very often or for very long. To reduce train running time, maintaining a high average speed is a bigger factor than increasing top speed.

In a commuter rail operation, the two primary reasons for stops are for stations and to meet other trains, particularly on a single track line. With frequent station stops, dwell times can add up quickly to extra minutes of train run time. Attention to equipment and station platforms to minimize time for boarding and detraining of passengers is necessary to minimize station dwell time.

On a single track line, careful scheduling of meets can help minimize the time trains spend waiting to meet opposing trains in sidings. As discussed previously, siding locations are critical.

Minimizing time for trains running at slow speeds might require upgrades to equipment or a physical plant. Equipment with a higher power-to-weight ratio can provide faster acceleration from station stops. Platform configurations that require precision stops might be reconfigured to minimize the need for slow speed running by trains approaching the station. Signalled sidings can allow faster operation through sidings that otherwise must be operated at restricted speed.

Curves with speed restrictions can also slow operations. Higher allowable speeds through turnouts and crossovers require less slowing of trains. Note that easing of sharp curves and installation of high-speed turnouts and crossovers might be constrained by real estate available to the railroad. In addition, the longer length required for a high-speed turnout or crossover typically requires relocation of the associated signal equipment, assuming the appropriate sight distances are available.

For new starts in particular, the effect of station spacing on capacity should be considered, as illustrated previously. With long time existing operations, closing or moving stations is a difficult and lengthy process, and often it is not even considered as a viable option.

Efficient train scheduling can also provide capacity benefits and reduce train running times. For long routes, express service to a distant zone followed by distant zone local service can reduce run times and improve equipment utilization. Skip-stop service is another option to reduce run times for long routes. Skip-stop service might be a better option for single track lines with heavy traffic to avoid the need for passing locations that might be required to implement express service. In any case, good schedule planning can minimize slow speed running and stops associated with meets and passes. On single track lines it might be desirable to lengthen sidings, add sidings, or add sections of second main track to relieve congestion in bottleneck areas of the line. On multiple track lines it might be desirable to add crossovers and/or upgrade signal systems (e.g., from current of traffic operation to bidirectional operation) to provide for schedule improvements.

As noted for new start operations, when operating on a freight railroad, the freight operation must be kept whole. The freight railroad should still be able to provide service as needed to its customers. As changes in freight and passenger traffic demands change over the years, the dialog between host railroads and other operators needs to remain open. Also, when considering adding trains to a line, consider that run times increase exponentially with the number of trains added. If too many trains are scheduled, there will be little or no opportunity to recover from unexpected delays. And congestion can result quickly.

Cost considerations for various options are discussed in the next section.

## Issues Regarding Shared Use with Light Rail Transit (LRT) Equipment

There are some special issues to consider if a commuter agency wants to run LRT equipment on a line shared with freight or heavy rail passenger traffic. Because LRT equipment is not compliant with Federal Railroad Administration (FRA) requirements, particularly regarding crashworthiness, the FRA currently does not allow LRT and heavy rail equipment on the line at the same time. The traditional approach is to provide complete time-separation, as in done in the Salt Lake City area. Typically, the commuter agency uses track during the daytime, and the freight operator is restricted to using the track only at night. Strict hand-over procedures are in place between the two operations.

In some new starts, the commuter agency may own the trackage. Freight operators would share use, either retaining exclusive freight service rights, or turning freight service over to a short line operator.

Clearly, there are significant capacity restrictions for both freight and passenger operators in shared use corridors. Shared use corridors currently are only feasible for limited local freight service from a freight operator's standpoint.

At some point in the future, there will likely be the need for a fresh approach on this issue. Implementation of CBTC could be a key part of providing improvements in capacity for both freight and passenger operations.

SECTION
3

# Investment Alternatives for Increasing Capacity

To support the objective of increasing capacity for a commuter operation, there are a number of alternatives that can be considered. Determining which alternative is the most appropriate for the given operation depends on a number of factors specific to the circumstances. The operation must be analyzed to determine the capacity constraints; there is no single answer or method that will work for every operation. Cost and implementation time may be additional factors.

This section provides an inventory of investment alternatives intended to increase capacity for commuter operations. Depending on the specifics of the operation in question, some may be more appropriate than others, and some may not be applicable at all. Potential benefits of the various alternatives are discussed, as well as cost and implementation considerations.

## Identification and Description of Investment Alternatives

The investment alternatives are divided into two categories: (1) Operations and train control investments, and (2) Field infrastructure investments.

### Operations and Train Control Investments

- **Increase power-to-weight ratio** – Increasing the power-to-weight ratio of the trains allows them to accelerate from stops or slow speed operations more quickly, reducing the time spent at slow speeds, and thereby increasing average train speed and reducing train running time. This is generally achieved with either higher power locomotives or lighter trailing cars (or both). On a dedicated commuter line with high traffic density and frequent station stops, this can have a profound effect on capacity. In scenarios where commuter operations are limited by slower speed freight train operations, or where stops are infrequent, the effect of increased power-to-weight ratio may be limited.
- **Optimize station spacing** – Review station distribution and redesign to optimize frequency of stops, distance between station stops, and number of passengers loading at each station. This can optimize the time spent operating at slower speeds, accelerating and decelerating from station stops, and station dwell time to reduce the overall running time.
- **Improved planning/schedule coordination** – In some cases, analysis of the train schedules may reveal inefficiencies that can be resolved by improved planning, particularly in reducing the variable delay time for train meets or when scheduling to allow for freight operations.

- **Implement CBTC** – CBTC has the potential to reduce headways with the use of moving block or virtual block operation, which allows trains to follow at approximately the safe braking distance, rather than by fixed signal blocks. This is achieved through accurate onboard train location determination and authorities transmitted electronically through a mobile communications network. Moving Block CBTC can provide more constant headway over a broad range of speeds, quicken recovery from disruptions, streamline communications between train crews and dispatcher, and reduce life cycle costs by minimizing the amount of vital wayside equipment.
- **Increase number of passengers per train** – Increasing the number of passengers per train allows for increased passenger throughput without affecting the operation. This can be achieved by adding vehicles to trains or by investing in higher capacity vehicles. This may affect the time it takes to load and unload passengers at stations, and it affects the power-to-weight ratio of the train. Further discussion of passenger car equipment is provided below.
- **Improve passenger loading and unloading** – Dwell time at stations can be reduced by streamlining the passenger loading and unloading process, reducing train running time. The following methods can be used to improve the process:
  - **Platform crowd control** – Limiting entry to the platform can prevent last minute passengers from delaying train departure.
  - **High platforms** – High platforms can make passenger loading and unloading more efficient, but cannot be implemented with freight train operations, unless another track is provided for the freight operation around the station, or to move the station platform away from the freight track.
- **Vehicle entry and egress design** – Increasing the number of passengers that can load and unload at a time can improve the passenger loading and unloading process. Vehicles with two sets of wider doors that allow three passengers abreast to board or detrain are among the best available for commuter service. Figure 3-1 shows some typical commuter rail car designs. Bi-level cars have capacity for more passengers compared to single level cars. However, tunnel heights and other clearance restrictions on a line need to be sufficient to handle the extra car height. The bi-level cars with a lowered floor level between the wheels provide for faster loading and unloading of passengers, because there are fewer stairs and steps required to enter the body of the car, which also helps to reduce station dwell times. For operations in winter weather, consideration should be given to types of doors and effort required to keep them operating properly in snow and ice conditions. Pocket doors can be particularly troublesome in winter conditions, because the pockets fill with snow and ice.

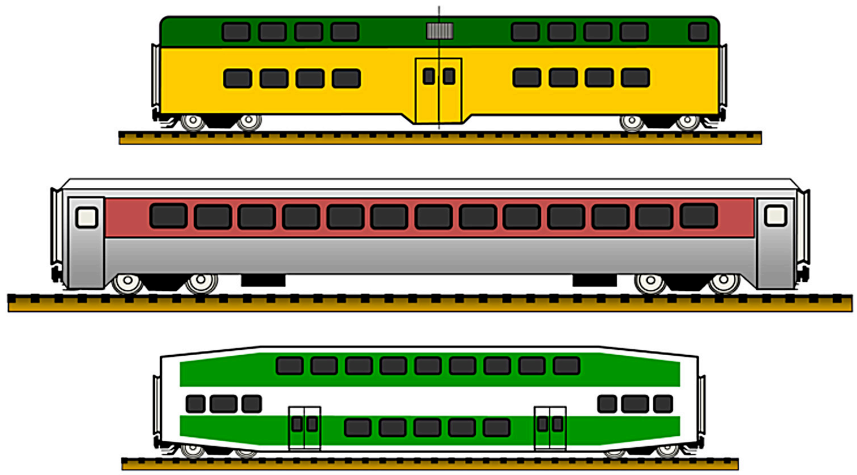


**Figure 3-1**
*Typical Commuter Rail Passenger Cars*

## Field Infrastructure Investments

- **Eliminate inefficient track configurations**. Eliminate track configurations that are speed limiting (track geometry, curvature, or switch configuration) in routes used by trains in regular operation. Realign sharp curves where possible to increase allowable speeds. Set superelevation in curves to handle higher speeds if necessary.
- **Increase turnout and crossover speeds**. Replace or reconfigure low speed turnouts and crossovers that are used by trains in regular operation. Note that higher speed turnouts and crossovers will be longer, and associated signal hardware will also need to be relocated.
- **Improve operation flexibility**. Implement track structure improvements such as adding sidings, lengthening sidings, adding crossovers, or adding alternate tracks at junctions and stations, to allow for better scheduling, schedule recovery, and flexibility for accommodating failures and unplanned events.
- **Optimize signal system and spacing**. Reduce signal spacing where long blocks restrict capacity. Upgrade from 3-aspect to 4-aspect signalling where beneficial. Convert double track lines from current of traffic operation to bidirectional operation where beneficial.

# Benefits of Investment Alternatives

The analysis of the investment alternatives is essentially driven by issues the agency perceives, which are based on current constraints and anticipated demand forecasts such as projected ridership, plant expansion, equipment life, and projected life of other systems and facilities (including track, structures, power distribution (for electrified territories), signals, communications, and stations).

As each agency has its own constraints and characteristics, it is not possible to determine a single rule that can be applied to any agency to determine the best investment alternatives.

Investments usually cannot also be evaluated in isolation from other investments, as most times they are inter-related. For example, improving the track infrastructure to support higher speed trains to be able to reduce travel times may not be worthwhile if the distance between stations is so short that trains will barely reach the maximum speed before reducing speed for the next stop. In this case, the power-to-weight ratio of the rolling stock should also be investigated to try to achieve the expected benefits.

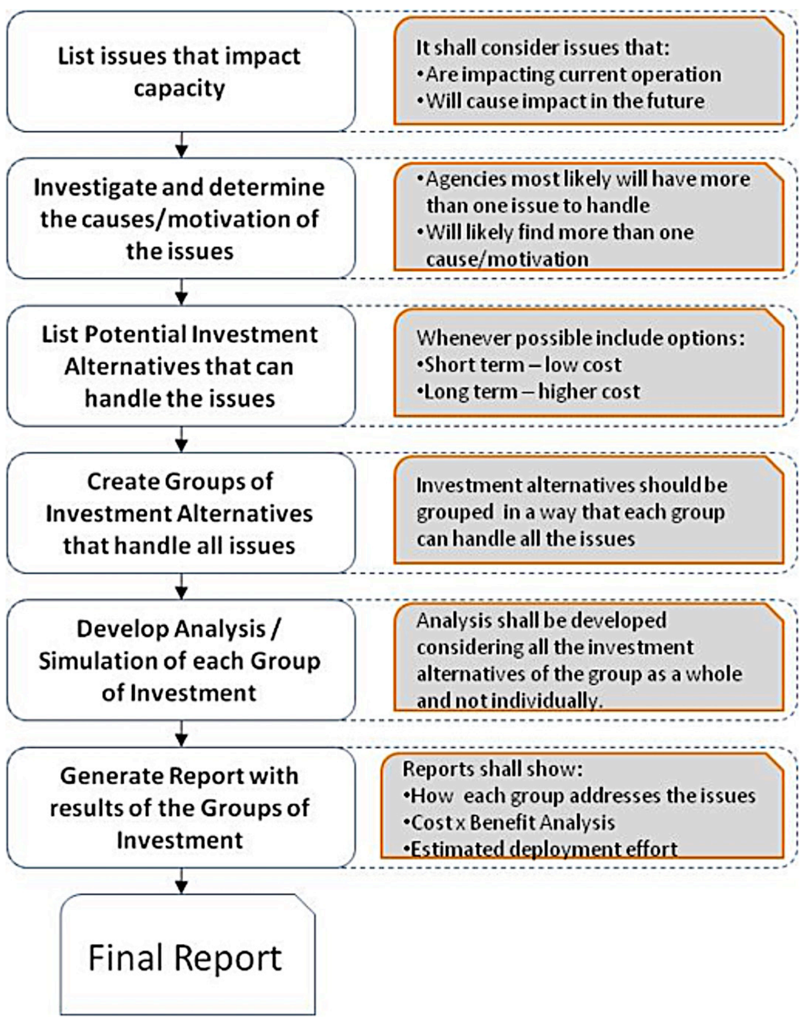
The following methodology provides a sequence of steps to help agencies identify potential investment alternatives and make comparisons among them.

## Guideline Methodology

The guideline is based on a methodology, composed of a sequence of steps, as illustrated in Figure 3-2.

**Figure 3-2**

*Guideline Methodology for Developing Investment Alternatives for Capacity Enhancements*



***Step 1 – List issues that impact capacity.***

The first step is to create a list with the issues that the agency understands that are impacting the current operation or will impact future operations, such as:

- Current operational problems, like excessive train delays in peak hours, stations and/or trains that are overcrowded
- Current reliability problems, such as excessive train failures or excessive track maintenance problems or slow orders
- Bottleneck areas that limit capacity and prevent expanding the operation
- Projected ridership that will exceed the capacity of the system
- Limited fleet size preventing expansion or ridership increase
- Expansion plans like new stations or new lines
- Equipment and/or systems close to end of their reliable service lifetime

***Step 2 – Investigate and determine causes.***

For each item on the list of Capacity Impacts, list the cause (or causes, when there is more than one identified cause). For example, excessive train delays in current operation, caused by long train dwell times in stations at peak hours. The same type of analysis can be developed for projected scenarios. For example, projected ridership is demanding more trains than the capacity of the system resources. In this case, the cause could be either not enough operational cars to handle passengers or train headways that can't be reduced as the system reaches capacity.

***Step 3 – List potential investment alternatives.***

Associate potential alternatives that can handle each cause listed in the Capacity Impact list. For example, an insufficient number of operational cars could be handled by adding more cars to the fleet, or a combination of additional cars and improvements in the current fleet (to make more cars available for operation), or partial replacement of the fleet. In many cases, the investment alternative may address more than one issue. For example, buying new cars to increase the availability of the system also addresses a problem of an aging fleet (when cars are reaching the end of their reliable service life).

***Step 4 – Create groups of investment alternatives.***

Group the alternatives in such a way that each group will provide the full amount of the desired additional capacity. Some groups might include only one alternative. Some might require several investments in various aspects of the systems to achieve the desired capacity increase. Some investment alternatives might be included in several groups.

***Step 5 – Develop analysis and simulation of each investment group.***

Once the alternatives are grouped appropriately, the next step is the analysis of scenarios that combine selected alternatives. It is not possible to determine a single formula that can be applied to any scenario; however the analysis should include some of the following developments:

- Theoretical studies of optimal and/or worst-case scenarios
- Simulations of the operation
- Comparative analysis among the scenarios
- Comparison of predicted costs and benefits of various scenarios

***Step 6 – Narrow the potential investment alternatives.***

The analysis of the investments should be "tailored" to the specific issues the agency is handling. Not all the possible investment alternatives need to be investigated and most times no more than three need to be analyzed in detail. This section provides a list of questions that should narrow the list of alternatives to be considered for each case.

***Step 7 – Generate final report.***

Generate a report listing alternatives considered, recommended alternatives, and predicted costs and benefits. Subsequent sections describe how to develop the investment alternatives.

## Implementation Considerations

Implementation considerations should be discussed including costs and timing of various alternatives. Also, sequence and phasing of implementation needs to be considered. For example, lengthening of station platforms would need to be completed before adding cars to trains. Similarly, changes to signal and train control systems will need to be coordinated to maintain existing operational safety and capacity during installation and conversion to a new system.

SECTION
4

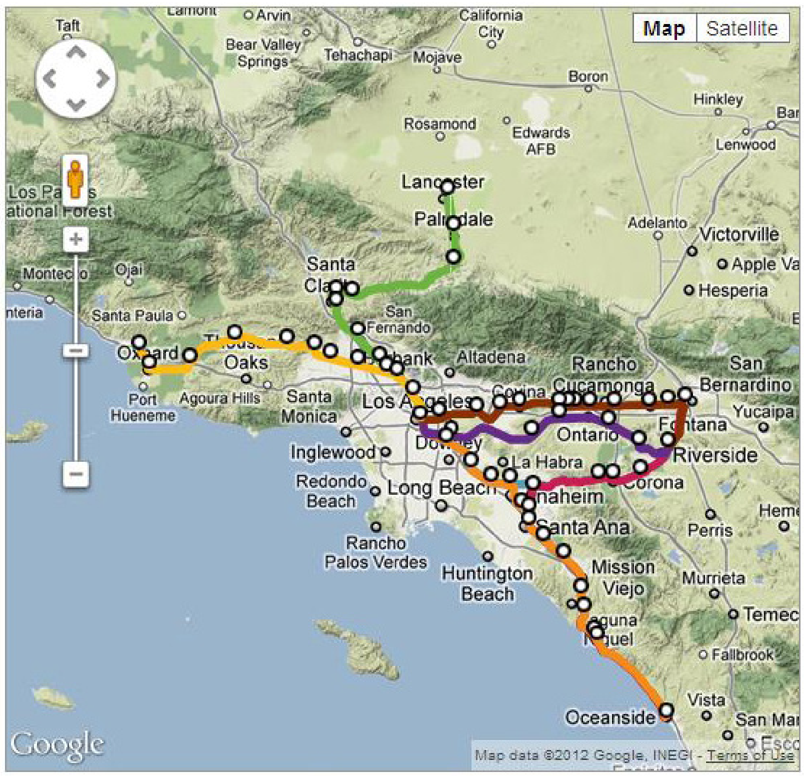
# Case Study – Metrolink Operation

## Overview of Operation

Metrolink provides commuter rail service to southern California residents. The operation includes seven lines that carry an estimated 40,000 daily passengers over a 512 route-mile network. Metrolink shares track with freight operators, BNSF Railway and Union Pacific Railroad. Figure 4-1 shows the Metrolink service map.

**Figure 4-1**

*Metrolink Lines in Southern California*




## Focus Areas

Four specific areas were identified to focus the study of the Metrolink operation: the Antelope Valley line, the San Bernardino line, the Orange County line, and the Los Angeles Union Station (LAUS) terminal trackage, as they represent a variety of the types of operation discussed in previous sections.

### Antelope Valley Line

The Antelope Valley line runs from Lancaster to LAUS, a distance of approximately 76 miles. The line is single track with sidings from Lancaster to

Burbank, where there is a junction with the Ventura line, approximately 12 miles from LAUS. The remainder of the line is multiple track. The Antelope Valley line is a low-density dedicated line, with the majority of the trains supporting rush-hour traffic. There are a total of 15 commuter trains run in each direction each day. Of these, 10 of the inbound trains are run in the morning, and 10 of the outbound trains are run in the afternoon, creating only a few trains opposing the primary direction of traffic.

## San Bernardino Line

The San Bernardino line operates between San Bernardino and LAUS. The San Bernardino line is approximately 56 miles of primarily single track, but with some extended sidings and short sections of double track. The line joins with the Orange County and Riverside lines at Pasadena Junction and continues on multiple track to LAUS, approximately 2 miles. The San Bernardino line is higher density than the Antelope Valley line, with a total of 21 commuter trains operating each direction each day. The traffic flow is similar, in that the majority of the morning traffic is inbound and the majority of the afternoon traffic is outbound. However, in addition to the increased number of commuter trains, there are also some limited freight train operations on the line.

## Orange County Line

The highest-density line in the Metrolink operation is the Orange County line. It operates from Oceanside to LAUS, approximately 88 miles. The line is lower density single track with sidings from Oceanside to Laguna Niguel/Mission Viejo, a distance of approximately 34 miles. Between Laguna Niguel/Mission Viejo and Fullerton, approximately 28 miles, the line is higher density double track. At Fullerton, there is a junction with the BNSF San Bernardino Subdivision, and the Orange County line runs on BNSF multiple track from there to Hobart Junction, approximately 21 miles. The remaining five miles of the line is multiple track into LAUS.

In addition to the Metrolink Orange County line traffic, there are a number of other operations on the Orange County line. From Oceanside to Orange, the Inland Empire line runs on the same track as the Orange County line. At Orange, the Inland Empire line diverts toward Riverside, while the Orange County line continues on to LAUS. Amtrak also runs passenger train service along the entire Metrolink Orange County line, stopping at many of the Metrolink stations, and continues on to San Diego. Finally, there are limited freight trains operating along the Orange County line to Fullerton, and a large number of freight trains operating between Fullerton and Hobart Junction on the BNSF line.

Between Oceanside and Laguna Niguel/Mission Viejo, where the line is single track with sidings, there are eight Metrolink commuter trains run each way each day. These are primarily inbound in the morning and outbound in the afternoon, with a few trains opposing this flow of traffic. Additionally, there are 11 Amtrak trains each way each day that run between LAUS and San Diego along this line, which are spread more evenly throughout the day.

Between Laguna Niguel/Mission Viejo, where the line is double track, there are 20 Metrolink commuter trains, in addition to the 11 Amtrak trains run each way each day. The operation is bidirectional all day (i.e., no primary direction of traffic flow), but the majority of the commuter trains are run during the morning and afternoon peak times (6–10 AM; 4–8 PM).

## LAUS

LAUS is a major transportation hub with Metrolink commuter service, Amtrak long-distance passenger service, Amtrak Pacific Surfliner passenger service, and Metro bus, and heavy rail transit service. The station is a stub-end terminal with 12 platform tracks available for Amtrak and Metrolink use and six island platforms. In addition, there are three escape tracks between platform tracks. The terminal trackage has a five-track throat with a low-speed curve and connects with BNSF and UP main lines at Mission Junction.

Stub-end terminals by their nature tend to congest more easily than run-through terminals, because every train needs to reverse direction and depart through the same trackage on which it arrived. In addition to the scheduled train movements, there are typically a number of empty train movements (deadhead movements) that need to be accommodated. Inbound commuter trains during or near the end of the morning rush need to vacate station tracks to make room for more inbound trains, so they must exit the terminal and head to the coach yard beyond Mission Junction. Similarly, during the early part of the afternoon rush period, trains will need to come into the passenger terminal from the coach yard for outbound revenue moves. Furthermore, since the coach yard at this terminal is accessed from only one side, there are a large number of crossover movements to get to or from the assigned platforms. Long-distance passenger trains also will typically exit a stub terminal station for servicing. Some short-distance trains might require little or no servicing and be able to depart the station in a relatively short time, requiring no deadhead movement to a coach yard between scheduled runs.

Because of capacity concerns, FRA and the California Department of Transportation have studied the addition of run-through tracks to LAUS to improve the operation (http://www.fra.dot.gov/downloads/rrdev/larunexsumm.pdf, accessed October 5, 2012).

SECTION 5

# Metrolink Capacity Assessment

## Capacity with Current Infrastructure

Improvements in the train scheduling or train control systems might allow reduced train headways, thus increasing the capacity of the Metrolink commuter rail system. For a system of this complexity, a detailed model was necessary to perform the necessary simulations and to develop metrics for comparison.

TTCI used the RTC model developed by Berkeley Simulation to model the railroad system in southern California. The model was previously used by TTCI as part of other non-FTA projects using models provided by Metrolink, BNSF, and UP, with additional enhancements and additions by TTCI. The RTC model was used to analyze the system in the following four focus areas: the Antelope Valley Line, the San Bernardino Line, the Orange County Line, and the LAUS area. The objectives of the modeling effort were to illustrate concepts presented in Section 2.

## RTC Model Used

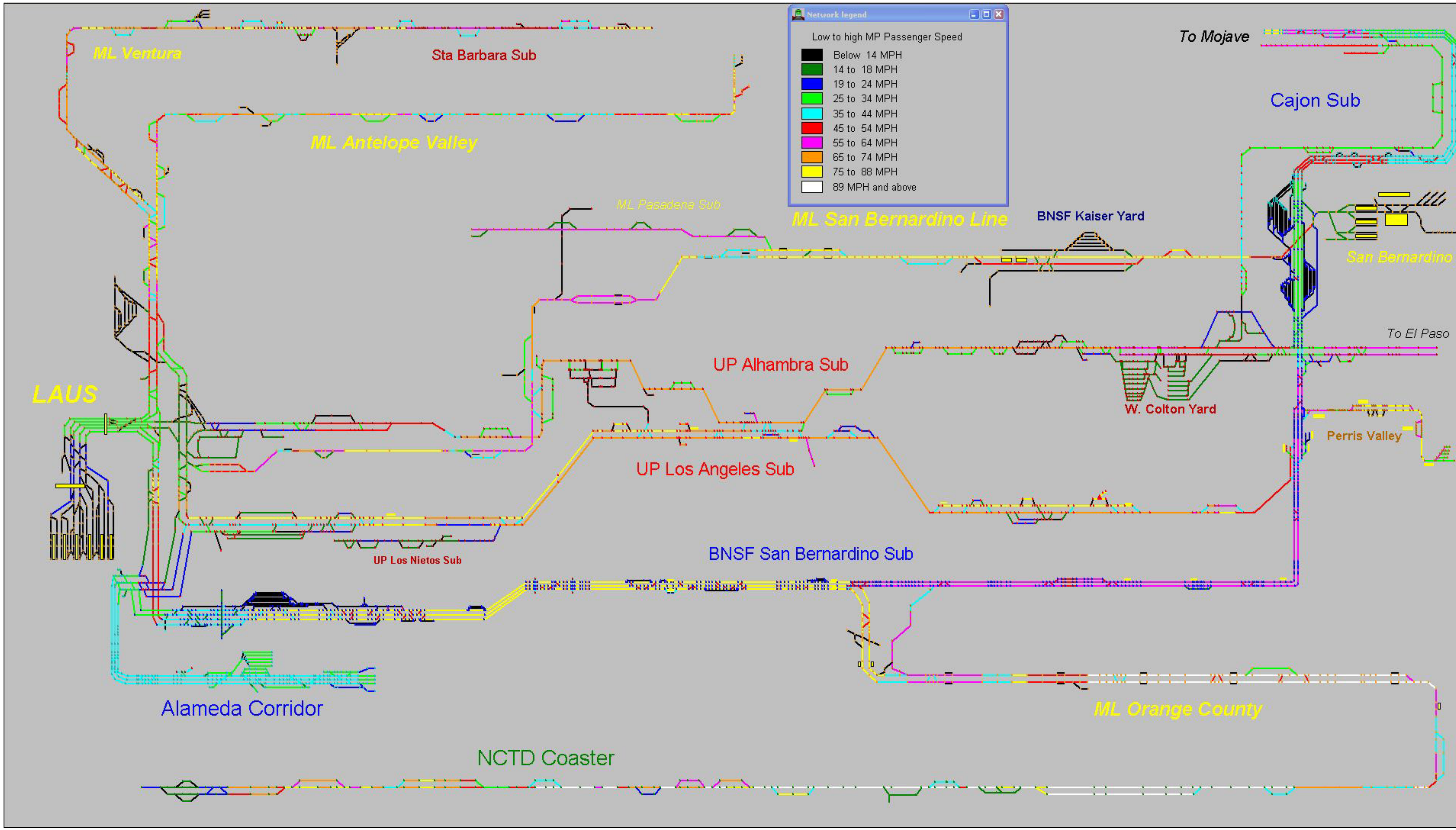
The RTC model is a discrete event model. It includes the entire southern California railroad network, with nearly 1,500 miles of track, 2,100 individual trains, 8 distinct lines, and 55 stations, along with signal blocks, speed limits, signal speeds, and signal sets. The model includes almost everything needed to analyze train operations in the Los Angeles Basin and outlying areas. For purposes of this study, TTCI created specific models derived from the original model to analyze the effects of potential changes in train control and signal systems, train schedules, and track configurations.

To minimize model run time, only routes that pass through points of interest were chosen for analysis of each particular area of interest. Having individual train sets traversing specific routes created the option of modifying each set individually, thereby allowing multiple aspects of a route to be analyzed more simply.

Figure 5-1 shows the schematic from the RTC model for the entire southern California region.

**Figure 5-1**

*Schematic of Metrolink System from RTC Model*



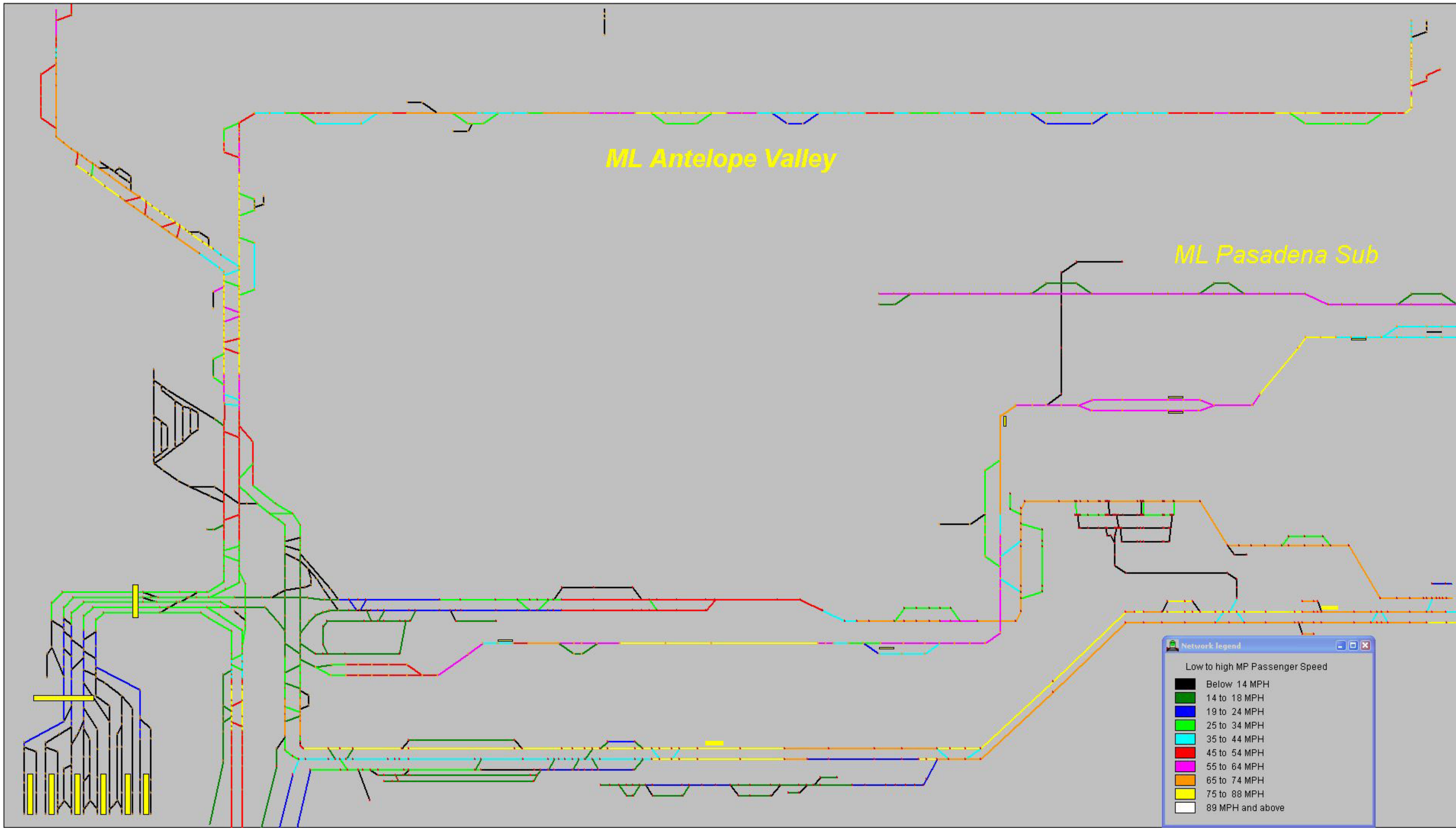
To analyze the overall effect of changes to individual aspects of the system, modified models were created to manipulate and study each facet in the system. Train headways were changed to force trains to interact at specific points or to determine the minimum achievable headway. Public timetables were used to enter initial passenger train schedules and station dwell times.

## Antelope Valley Line

For the Antelope Valley Line, the model was used to analyze the length of the route and the best scheduling to optimize capacity as well as utilization of equipment. Figure 5-2 shows the route for Antelope Valley trains including the route into LAUS (in the lower left).

**Figure 5-2**

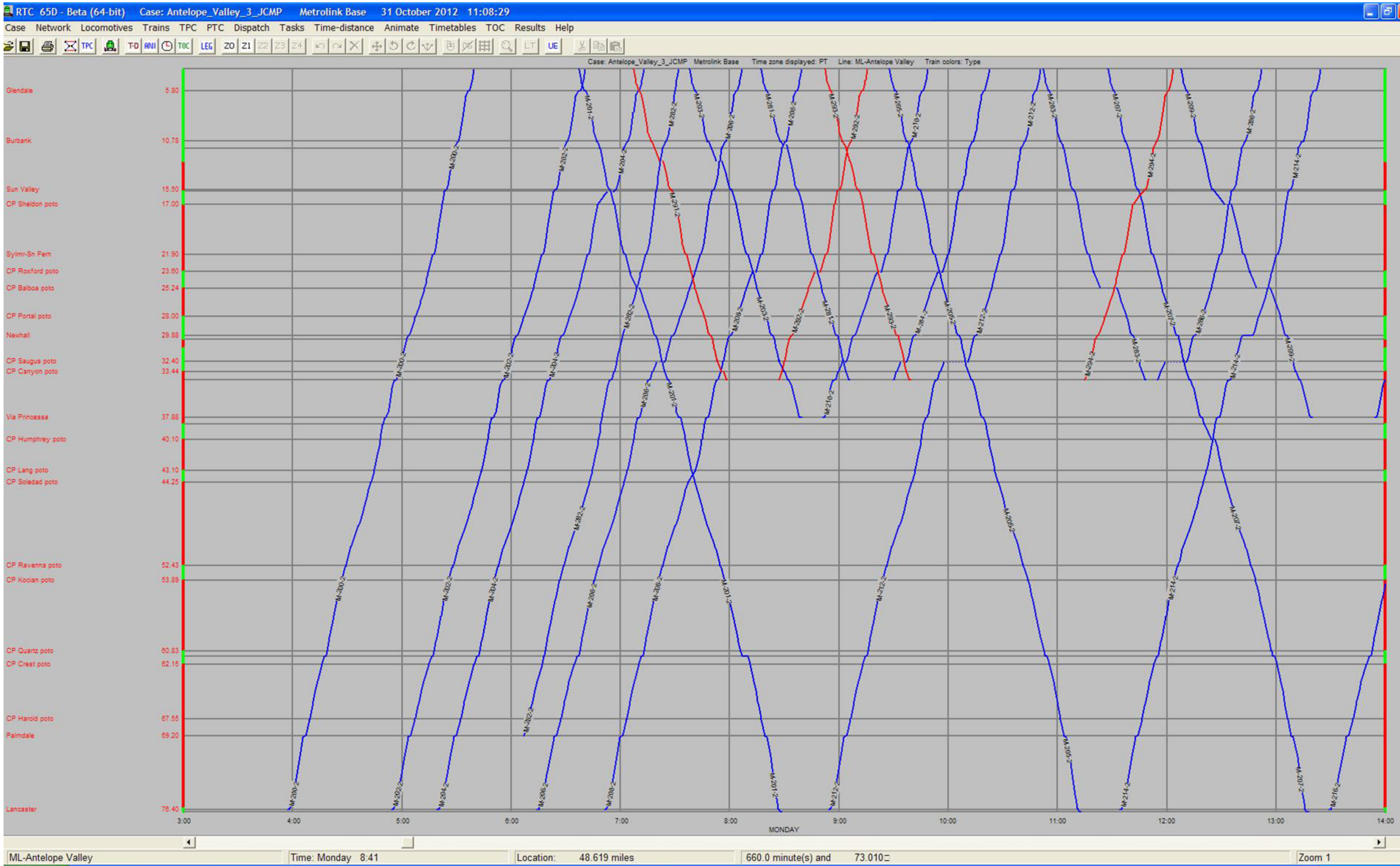
*RTC Model of Metrolink Antelope Valley Line*



Metrolink currently operates some trains the entire length of the route. Two additional morning trains operate only on the portion closest to Los Angeles. The train equipment for these "short turn locals" is the equipment from the early morning arrivals into LAUS. They turn back and operate in the outbound direction, primarily as a repositioning move to an intermediate station. Then, they turn once again, providing an additional inbound schedule on the portion of the route closest to LAUS. If additional capacity is needed on this route, it is possible to add two more short turn locals to the morning schedule, as shown in Figure 5-3. The blue lines indicate the current schedule. The red lines indicate the trains that have been added. No additional equipment is required. In similar fashion, it is possible to add capacity to the afternoon schedule.

**Figure 5-3**

*Time-Distance Diagram for Antelope Valley Trains Showing Two Additional Short Turn Local Trains Closer to Los Angeles During Morning Hours*



Los Angeles is at the top of the graph in this time-distance diagram. The two new short turn local trains added to the current schedule are the second and fifth trains outbound from Los Angeles, with inbound trips from Santa Clarita departing at about 8:30 AM and 11:15 AM. The second new train could depart inbound 30 to 45 minutes earlier if desired. These new trains serve 8 out of 11 stations on this particular line. This type of scheduling can improve equipment utilization on long routes, because the equipment can run more revenue miles per day, and capacity can be added without purchase of any new train sets.

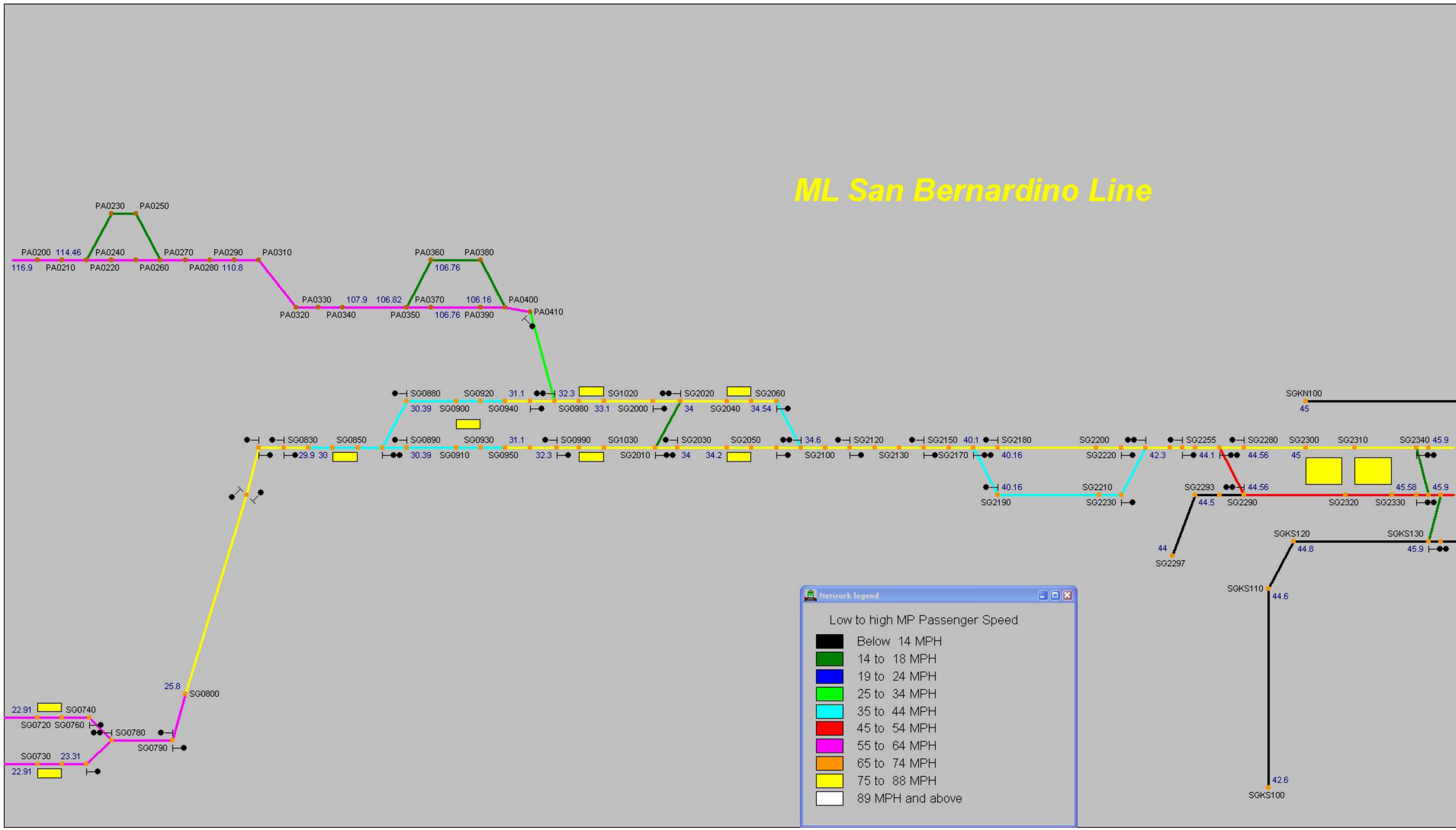
In this case, two additional trains of capacity from an intermediate station are added without the need for constructing any new track infrastructure. Both new short turn locals use equipment from trains that arrived in Los Angeles earlier in the day on the same line. It is often the case that more passengers are generated near the mid section of a line than at the outer reaches. So the additional capacity is provided where the demand is also the greatest.

## San Bernardino Line

The San Bernardino Line was chosen to illustrate the effect of closely spaced stations on train schedules. The RTC model schematic in Figure 5-4 shows a number of closely spaced stations towards the middle portion of the line.

**Figure 5-4**

*RTC Model of Middle Portion of Metrolink San Bernardino Line Showing Several Closely Spaced Stations (Yellow Rectangles Denote Platforms)*

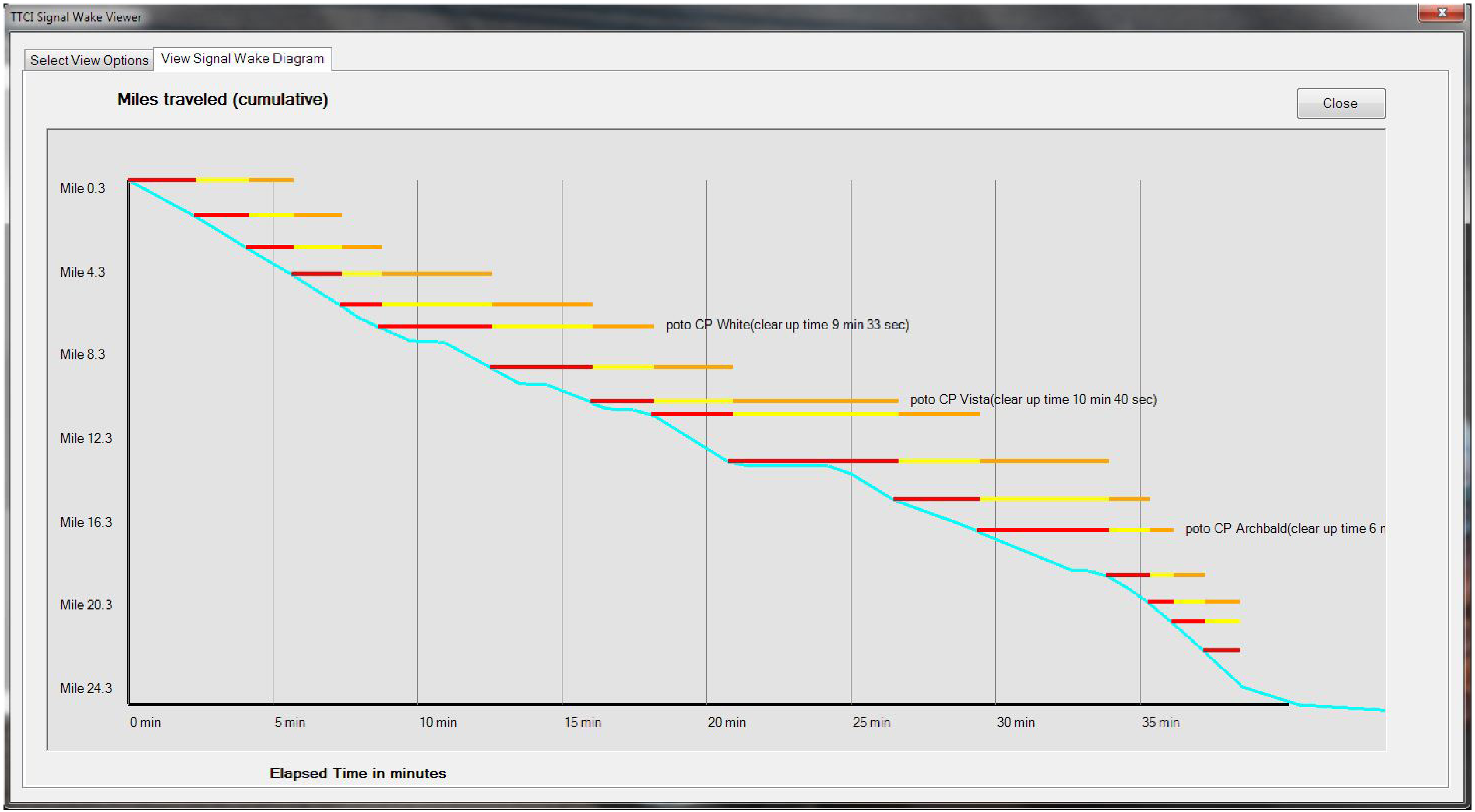


A signal wake diagram for a typical commuter train on this line is shown in Figure 5-5. Note the long signal clear-up times towards the center of the route caused by the slow average speed resulting from the closely spaced stations and station dwell times. The station near mile post (MP) 13 with the 3.5-minute dwell time near the center of this segment is causing a backup at the two previous stations. This long dwell time might be scheduled to accommodate a meet between opposing trains. Maximum signal clear-up time on this route is more than 10 minutes. Trains following closer than that will be running on restrictive signals.

In this case, some adjustment of the signals on the line might be helpful. The signal blocks are relatively long in the slow speed portion of the route prior to MP 13. Shortening signal blocks should help to reduce the signal clear-up time in this area.

**Figure 5-5**

*Signal Wake Diagram for a Metrolink Commuter Train on the San Bernardino Line (Note 3.5-Minute Station Dwell Time at Station Near MP 13)*



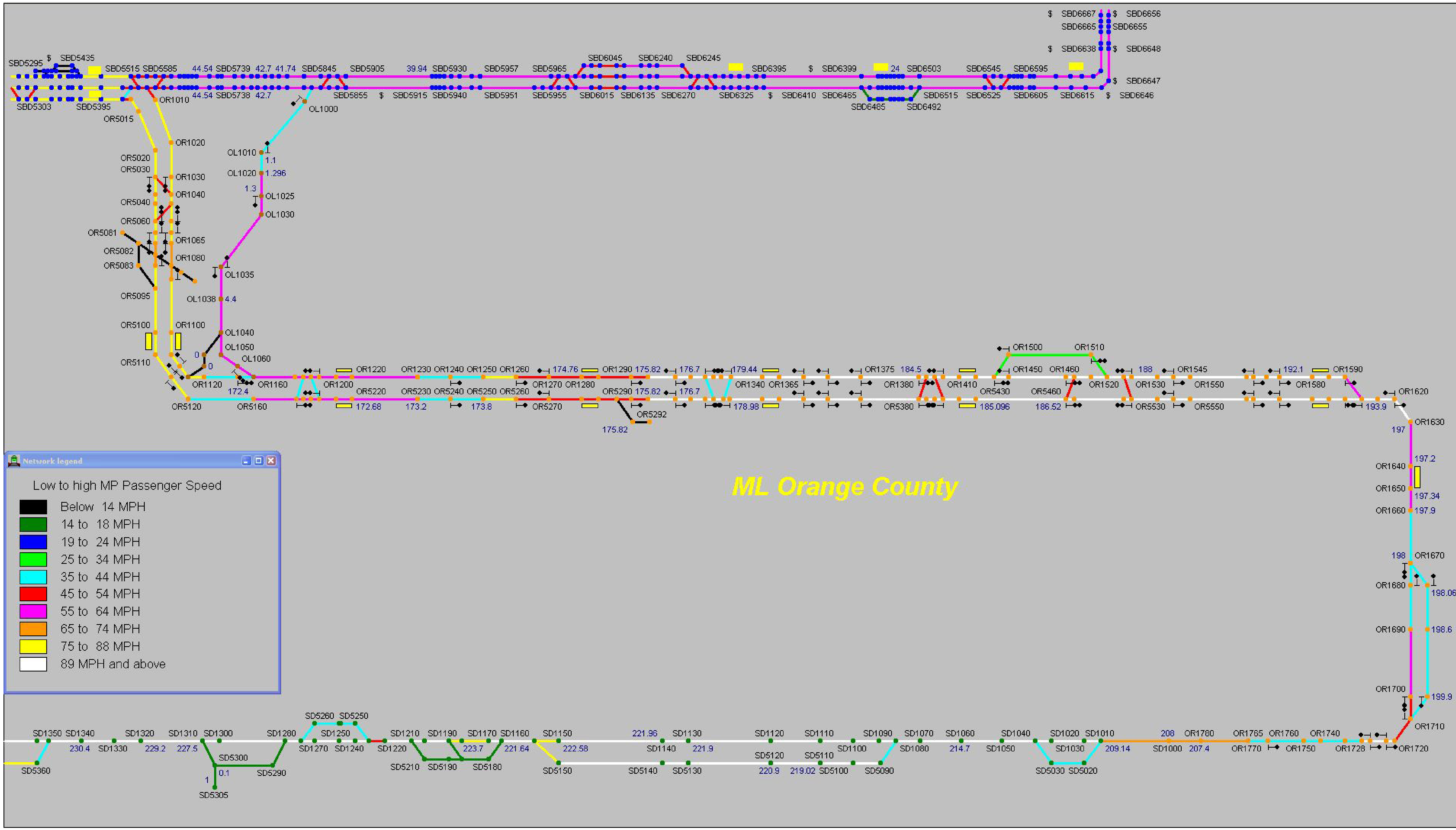
## Orange County Line

The Orange County line was selected to illustrate scheduling to provide windows for operation of freight trains between commuter trains, as well as Amtrak trains between commuter trains. Freight trains are generally longer than commuter trains with lower power-to-weight ratios, but no station stops. Heavy freight trains tend to have a lower average speed. Amtrak long-distance trains are generally somewhat longer than commuter trains, with somewhat lower power-to-weight ratios, and fewer station stops. Amtrak short distance trains, such as the Los Angeles to San Diego Surfliner trains on this line, are very similar in terms of train length and power-to-weight ratio as the Metrolink commuter trains. The primary difference is that the short distance Amtrak trains make fewer station stops than the commuter trains and thus have a higher average speed.

Figure 5-6 shows the RTC model schematic for the portion of the Orange County Line used for the study. This analysis focused on the two track portion of the line south of Fullerton.

## Figure 5-6

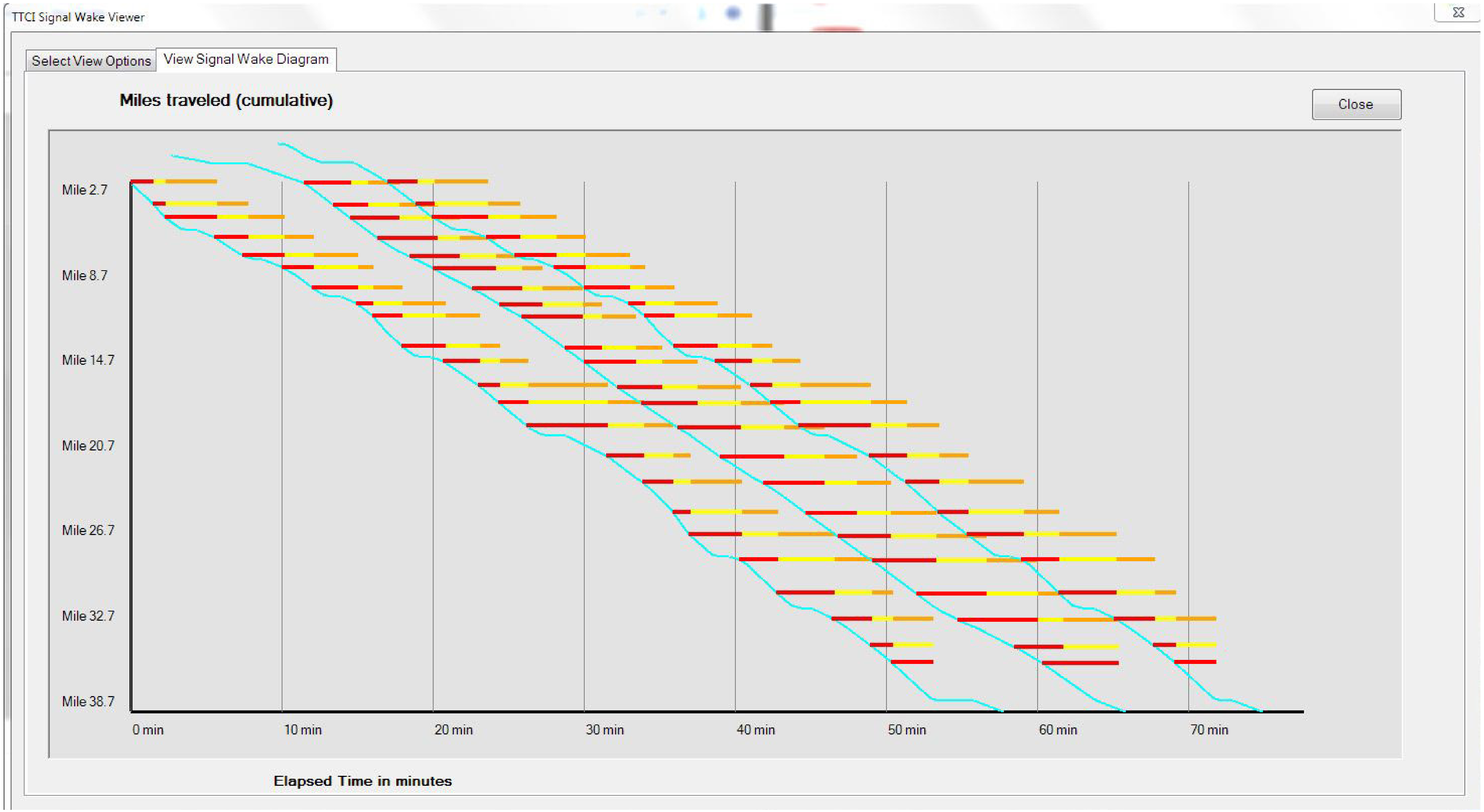
*RTC Model of Metrolink Orange County Line*



The signal wake diagram in Figure 5-7 shows three trains: first, a Metrolink commuter train; second, an Amtrak Surfliner train; and third, another Metrolink commuter train. In this example, both the Metrolink and Amtrak trains have a power-to-weight ratio of about 5. Note that the Amtrak train can be scheduled between two Metrolink trains as shown. The Amtrak train only encounters one restrictive signal, an approach medium, on the approach to a station near the end of the route shown. Because the Amtrak train is slowing for a station stop, this signal does not delay the Amtrak train.

## Figure 5-7

*Signal Wake Diagrams Showing Metrolink Commuter, Amtrak Surfliner, and Metrolink Commuter Trains in Succession on Orange County Line*

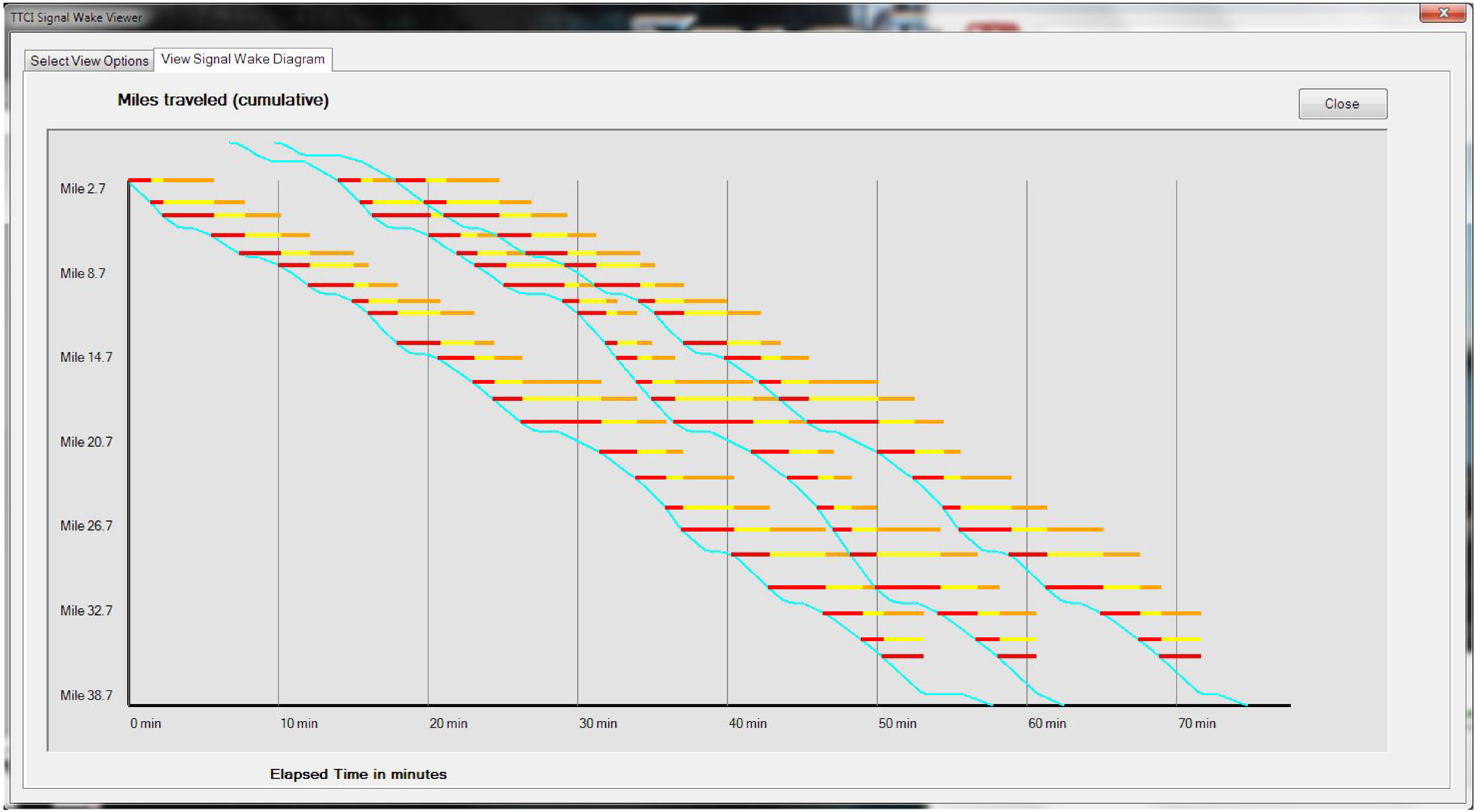


The Metrolink train following the Amtrak train is often running on restrictive signals at the beginning of the route. Again, because the Metrolink train is slowing for station stops, it is not delayed. Eventually the Amtrak train gets far enough ahead of the second Metrolink train that the signals behind the Amtrak train clear up before arrival of the second Metrolink train. The Metrolink trains in this example are running on a scheduled headway of less than 20 minutes.

A fast freight train is shown running between two Metrolink commuter trains in Figure 5-8. This freight train has a power-to-weight ratio of about 3 horsepower per ton. Because the fast freight train has no station stops, it actually has a faster running time over the route than the commuter trains. In this respect, it is somewhat similar to the scheduling of an Amtrak train between commuter trains, as discussed above. Again, the Metrolink trains are able to run at a scheduled headway of less than 20 minutes without delay to the second train.

### Figure 5-8

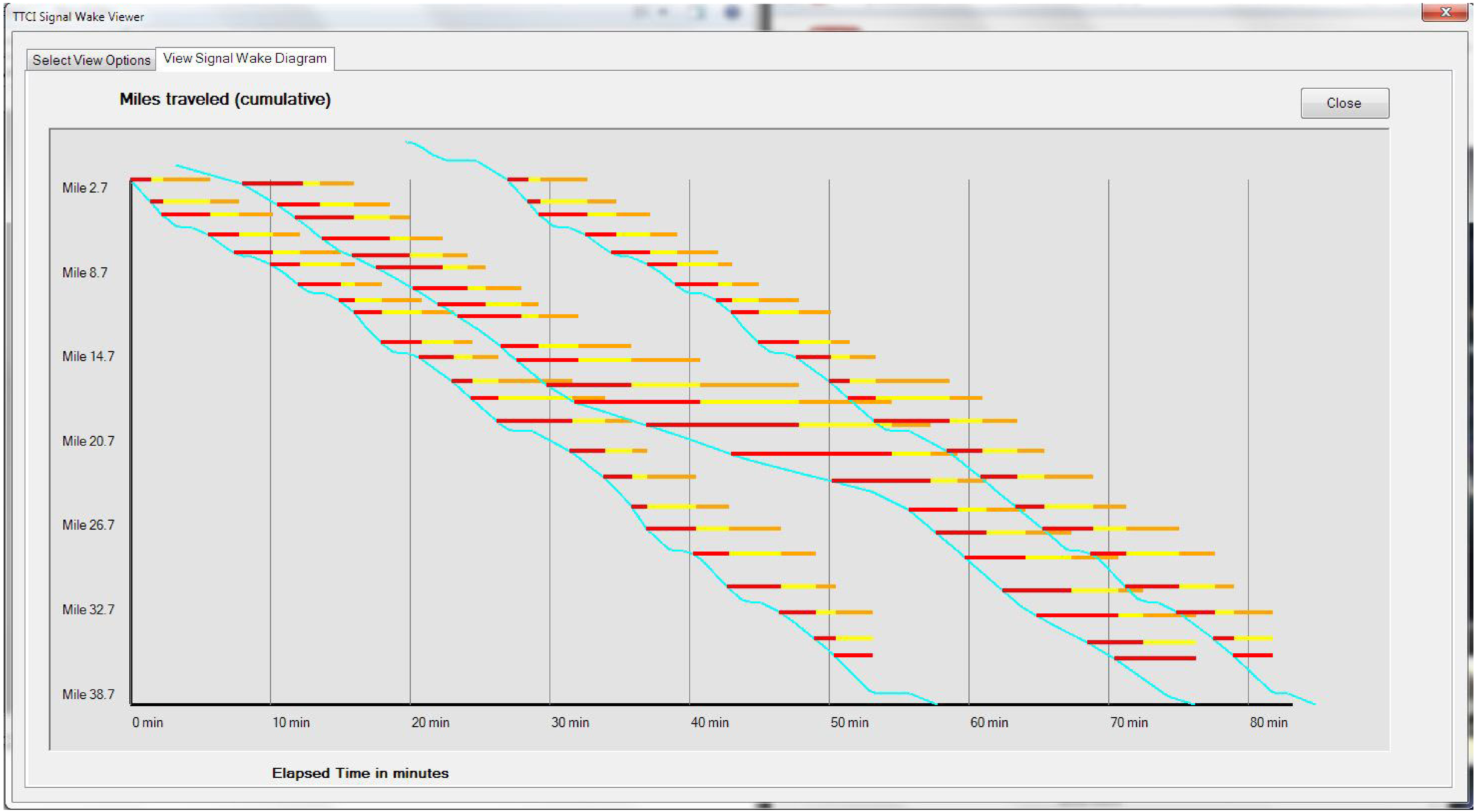
*Signal Wake Diagrams Showing Metrolink Commuter, Fast Freight, and Metrolink Commuter Trains in Succession on Orange County Line*



A slow freight train between two Metrolink commuter trains is shown in Figure 5-9. This freight train has a power-to-weight ratio of about 1 horsepower per ton. Even though the fast freight train has no station stops, it has a slow average speed because of its low power-to-weight ratio. Its speed is also affected more by grades on the line. In this case, the Metrolink trains are running on a scheduled headway of just under 30 minutes to provide an acceptable window to operate the freight train.

**Figure 5-9**

*Signal Wake Diagrams Showing Metrolink Commuter, Slow Freight, and Metrolink Commuter Trains in Succession on Orange County Line*



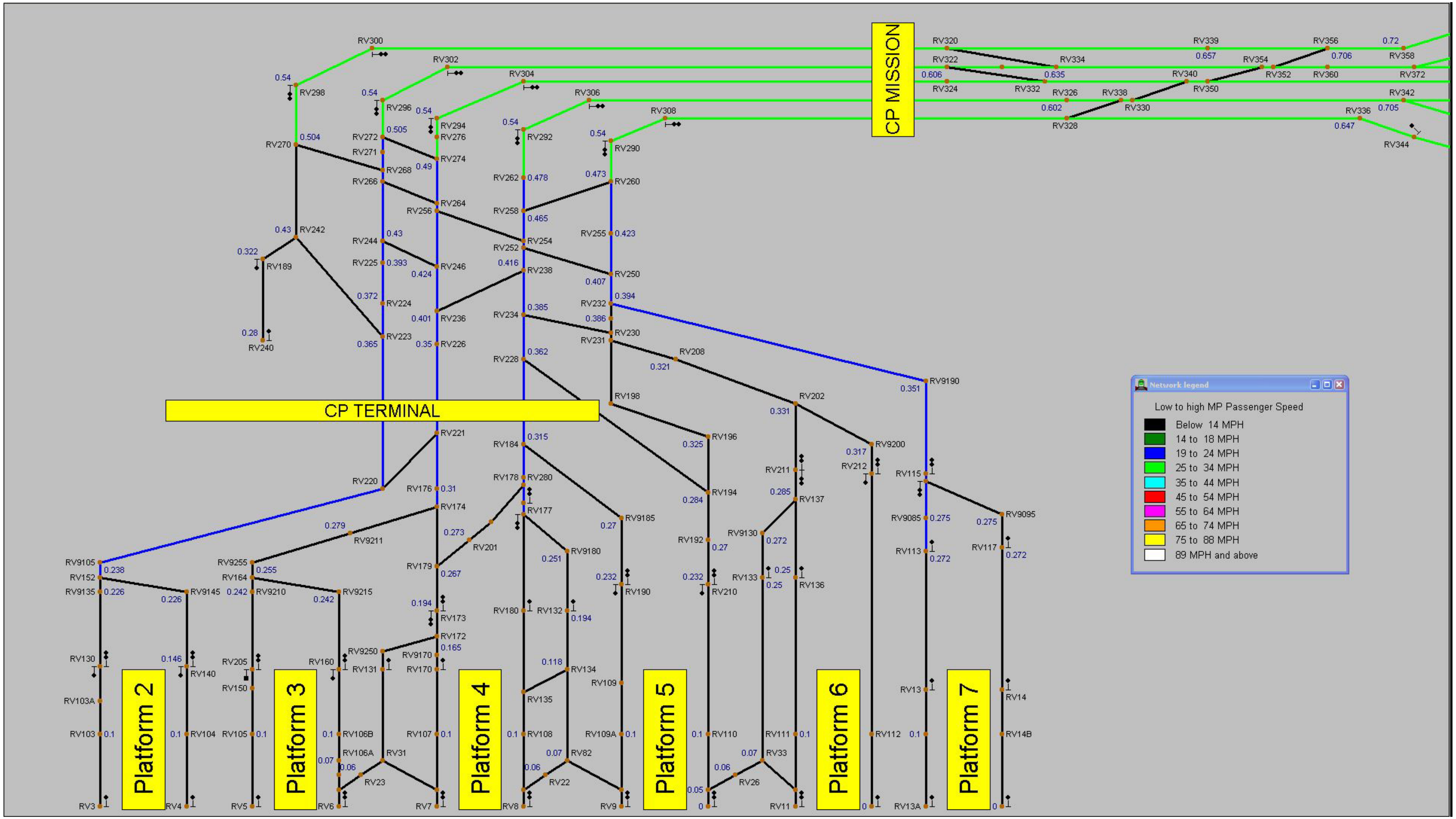
The current Metrolink schedule shows rush period headways of about 30 minutes or more, with one pair of trains spaced about 20 minutes apart during both morning and evening rush periods. So the current Metrolink schedule is able to accommodate Amtrak trains and fast freight trains at all times. During morning and evening rush periods, a slow freight train might need to wait for an additional 20 minutes for an operating window, or one commuter train might sustain about 10 minutes of additional delay if a slow freight train is operating.

## LAUS

The LAUS area was selected to assess the effect of signal system modifications on the ability to move trains in and out of the terminal. Movements in the terminal are currently governed by two large interlocking plants, CP Terminal, and CP Mission, as shown in the RTC model schematic in Figure 5-10. The proposed modification is to implement section release, a method whereby individual portions of the interlocking, such as a turnout or crossover, become available for the next movement as soon as they are cleared, instead of when the train clears the entire interlocking plant.

**Figure 5-10**

*RTC Model of LAUS*



A simulation of the LAUS terminal was set up to determine the potential benefits of sectional release. The simulation was set up to necessitate many crossover movements. With sectional release implemented, an additional four trains per hour could depart the terminal, or about one more train every 15 minutes, compared to the case without sectional release.

The implementation of sectional release would certainly be a less expensive option to increase capacity as compared to constructing run-through tracks at LAUS. (The proposed run-through tracks would require a long section of elevated track on a curving viaduct.) However, it is unclear whether or not sectional release could provide as much additional capacity as a few run-through tracks. Further analysis would be needed prior to making a decision.

## Recommendations for Increasing Capacity

For the current Metrolink system, the best way to increase capacity at this time seems to be to add trains. In some cases, existing equipment might be used for additional runs, as discussed above. For the most part, the existing track and signal infrastructure seems to be handling the existing traffic adequately on this system.

SECTION

6

# Summary and Conclusions

The report describes principles and concepts related to capacity for commuter rail operations. Topics include track and station configuration, rolling stock, train operations, and signal issues. TTCI identifies promising potential improvements and additions to infrastructure to increase capacity (emphasizing cost-effective technology solutions). Discussion is provided on investment planning to increase commuter rail system capacity by making the various improvements noted. The study also discusses the benefits, effectiveness, and life cycle costs of the various solutions.

To illustrate these principles, TTCI has evaluated various aspects of the present capacity limitations versus ridership for a large commuter rail system in the United States to determine capacity constraints and to identify areas where improved capacity might be needed. Two sections present an overview and selected case studies of the Metrolink system operating in the Los Angeles regional area, with analysis of various capacity issues.

In each case study, different aspects of commuter rail capacity are examined. In some cases, suggestions are offered where improvements could be made that would increase system reliability.

The following specific conclusions are noted:

1. Capacity issues for commuter rail lines can be very different depending on the type of operation, i.e., single or multiple track, single or bidirectional operation.
2. Key factors affecting commuter rail capacity include time between trains, operating speeds between stations, acceleration and deceleration capabilities of trains, station dwell time, signal system, and rolling stock, both cars and locomotives.
3. Key factors affecting commuter rail trip time include length of route, number and distance between stations, and passenger perception of trip length and delay.
4. In commuter rail operations on corridors shared with freight operations, the freight operators must be kept whole in terms of their ability to provide service to their freight customers.

5. Scheduling for commuter rail operations needs to take into consideration the long braking distances and relatively long time between trains needed to operate safely.
6. In developing schedules for commuter rail operations, consideration should be given to allow operating windows for various freight and long-distance passenger operations, as well as track maintenance, temporary speed restrictions, equipment problems, and schedule recovery time.

# GLOSSARY

BNSF – BNSF Railway

CBTC – communications-based train control

DMU – diesel multiple unit

EMU – electric multiple unit

FRA – Federal Railroad Administration

FTA – Federal Transit Administration

LAUS – Los Angeles Union Station

LRT – light rail transit

MP – mile post

RTC – Rail Traffic Controller

TTCI – Transportation Technology Center, Inc. (the company)

UP – Union Pacific Railroad

. i

l Tran ı ı ı i


U.S. Department of Transportation
Federal Transit Administration
East Building
1200 New Jersey Avenue, SE
Washington, DC 20590
*http://www.fta.dot.gov/research*