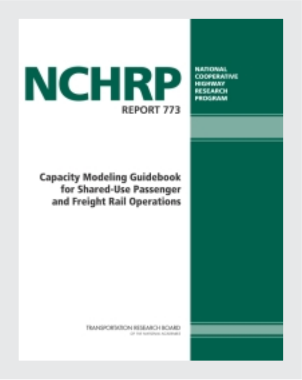


Capacity Modeling Guidebook for Shared-Use Passenger and Freight Rail Operations

DETAILS

98 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-30816-8 | DOI 10.17226/22245

AUTHORS

Fox, Justin; Hirsch, Paula; and Om Kanike

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 773

Capacity Modeling Guidebook for Shared-Use Passenger and Freight Rail Operations

Justin Fox
Paula Hirsch
CDM SMITH
San Francisco, CA

Om Kanike
CDM SMITH
Maitland, FL

IN ASSOCIATION WITH

David P. Simpson
DAVID P. SIMPSON CONSULTANTS, LLC
St. Paul, MN

Andrew J. Cebula
A.J. CEBULA, INC.
Pierrefonds, QC, Canada

Alan J. Bing
Kittery Point, ME

Emmanuel S. "Bruce" Horowitz
Alexandria, VA

Subscriber Categories
Railroads • Passenger Transportation • Planning and Forecasting

Research sponsored by the American Association of State Highway and Transportation Officials
in cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2014
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 773

Project 08-86
ISSN 0077-5614
ISBN 978-0-309-30816-8
Library of Congress Control Number 2014953662

COPYRIGHT INFORMATION

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

The Transportation Research Board of the National Academies, the National Research Council, and the sponsors of the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. C. D. Mote, Jr., is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Victor J. Dzau is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. C. D. Mote, Jr., are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

COOPERATIVE RESEARCH PROGRAMS

CRP STAFF FOR NCHRP REPORT 773

Christopher W. Jenks, *Director, Cooperative Research Programs*
Christopher J. Hedges, *Manager, National Cooperative Highway Research Program*
Lori L. Sundstrom, *Senior Program Officer*
Megan A. Chamberlain, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Maria Sabin Crawford, *Editor*

NCHRP PROJECT 08-86 PANEL

Area Eight: Transportation Planning—Forecasting

Rodney P. Massman, *State of Missouri, Jefferson City, MO* (Chair)
Edgar Bryant, *Florida DOT, Tallahassee, FL*
William Glavin, *Texas DOT, Southlake, TX* (retired)
John H. Hovatter, Jr., *Maryland Transit Administration, Baltimore, MD*
Tracy D. Larkin-Thomason, *Nevada DOT, Las Vegas, NV*
Jerome M. Lutin, *Jerome M. Lutin, PhD, LLC, Monmouth Junction, NJ*
Peter W. Murgas, *Norfolk Southern Corporation, Atlanta, GA* (retired)
Anthony D. Perl, *Simon Fraser University, Vancouver, BC*
Paul E. Vilter, *National Railroad Passenger Corporation (AMTRAK), Philadelphia, PA*
Randall E. Wade, *HNTB Corporation, Madison, WI*
Randy Butler, *FHWA Liaison*
Leonard R. Evans, *FRA Liaison*
Leo Penne, *AASHTO Liaison* (retired)

FOREWORD

By Lori L. Sundstrom
Staff Officer
Transportation Research Board

This report provides state departments of transportation (DOTs who are starting or expanding passenger rail service on privately-owned and shared-use rail corridors) with technical guidance to aid in their understanding of the methods host railroads use to calibrate and apply capacity models to determine if adequate capacity exists to support new or increased passenger rail service or if infrastructure improvements may be necessary. A shared understanding of these methods will aid all parties—including state DOTs—in the negotiation of service outcome agreements. This report should be of immediate use to transportation professionals charged with the responsibility for planning passenger rail service and negotiating shared-corridor service agreements with host railroads.

The concept of passenger and freight operations co-existing in shared-use corridors is central to the expansion of intercity and commuter passenger rail service in the United States. All current Amtrak service is on shared-use corridors and most of the future plans developed by states for enhanced rail service are based on the shared-use corridor concept. Passenger service providers are interested in on-time performance and minimizing delays. Freight railroads are interested in minimizing delays and maintaining fluidity.

The Passenger Rail Investment and Improvement Act of 2008 and the American Recovery and Reinvestment Act of 2009 contain federal funding guidelines for high-speed rail projects on shared-use corridors that require states, host railroads, and Amtrak to reach service outcome agreements regarding frequency, trip time, and reliability before federal project funding is provided. This requirement is designed to ensure that adequate infrastructure is in place to support service outcomes when new or expanded passenger service commences.

Capacity models that are designed to simulate passenger and freight movements in a given corridor within a network are often used by host railroads and passenger service operators to identify capacity issues in a given shared-use corridor and to determine the level of track, signal, and structure improvements that are required in order to add additional passenger service in a manner that supports all operations. These models have the potential to simplify the time-consuming negotiations among states or other agencies operating passenger rail systems, Amtrak, and host railroads that are currently necessary to establish the required service outcome agreements. The methodology and ground rules for using these models can vary greatly depending on how the modeling analyses are structured, the needs and preferences of the particular railroad, and the specifics of the rail corridor and proposed project(s) that are intended to increase capacity.

Under NCHRP Project 08-86, CDM Smith was asked to build upon *NCHRP Report 657: Guidebook for Implementing Passenger Rail Service on Shared Passenger and Freight Corridors* and produce a guidebook that state transportation agency staff and other stakeholders may use to better understand the modeling processes and results that support the negotiation of service outcome agreements for the shared use of rail lines for freight, intercity, and commuter rail operations. The guidebook examines the modeling processes and results that are used to define, measure, simulate, and evaluate railroad capacity. It addresses the appropriate use of modeling as a component of collaborative decision-making on operational strategies, maintenance activities, and infrastructure configurations; the relevant measures of capacity and performance (e.g., speed, delay, throughput, and operational flexibility) that differ and are common for different railroad operators; and the modeling assumptions requiring agreement among the parties. The guidebook should be of immediate use to state rail program staff in supporting their understanding and use of capacity modeling on shared-use rail corridors.

CONTENTS

1 **Chapter 1** Introduction
1 1.1 Introduction, Purpose and Overview of This Guidebook
1 1.1.1 Introduction
1 1.1.2 Purpose of Report
2 1.1.3 Overview of Report
2 1.2 Outreach to Stakeholders
2 1.2.1 Introduction
2 1.2.2 Freight Railroads
4 1.2.3 Commuter Railroads
4 1.2.4 State Sponsored Services
5 1.2.5 Amtrak
5 1.2.6 The Federal Railroad Administration
6 1.3 Realities of Railroad Operation
6 1.3.1 Signaling and Safety
7 1.3.2 Management of Train Movements
9 1.3.3 Capacity and Capacity Analysis
9 1.3.4 Positive Train Control (PTC)
10 1.3.5 Rail Line Planning Versus Highway Planning

12 **Chapter 2** Synthesis of Stakeholder Input
12 2.1 Introduction
12 2.2 What is "Rail Capacity" and Why Is It Important?
14 2.3 A Building Block for Project Execution
14 2.4 Transparency of Modeling Inputs
15 2.5 Doing the Homework
16 2.6 The Long View
16 2.7 Phasing Finesse
16 2.7.1 California Corridor Services
17 2.7.2 Cascades Services
17 2.7.3 North Carolina Services
18 2.8 Communications and Capacity Assessment
18 2.9 The Wide View
19 2.10 Railways Are Not Highways
19 2.11 What the Models Leave Out
20 2.12 A Model Is Not a Strategy
20 2.13 Capacity Modeling—The Bottom Line

22 **Chapter 3** Analytical Approaches to Line Capacity in Shared-Use Corridors
22 3.1 Introduction
23 3.2 Complexity of Shared Railroad Operations
25 3.3 Main Line Capacity Factors

26 3.4 Rail Line Capacity Analysis Methodologies and Applications
26 3.4.1 Introduction
26 3.4.2 Scoping Models and Building Blocks
31 3.4.3 Operations Simulation Analysis Methods
32 3.4.4 Modeling Objectives and Model Data Requirements
32 3.5 Detailed Simulation Models
32 3.5.1 Technical Modeling Process and Data Needed
36 3.5.2 Descriptions of Individual Capacity Models

40 Chapter 4 Best Practices
40 4.1 Introduction
40 4.2 LOSSAN Corridor Capacity Investment Planning
40 4.2.1 Introduction
41 4.2.2 Existing Corridor Services
41 4.2.3 Planning for the Future
41 4.2.4 Grid Time Analysis
43 4.2.5 Future Train Volumes and Required Improvements
44 4.2.6 LOSSAN Grid Time Analysis Summary
45 4.3 New Haven-Hartford-Springfield Corridor Planning
45 4.3.1 Introduction
46 4.3.2 Existing Corridor Operations
46 4.3.3 Simulation Parameters
49 4.3.4 Simulation Results
49 4.3.5 NHHS Operations Simulation Summary
50 4.4 North Sound Rail Assessment Comparisons
50 4.4.1 Introduction
51 4.4.2 North Sound Rail Operations Simulation
56 4.4.3 North Sound Grid Time Analysis
64 4.4.4 North Sound Web-based Shared-use Tool Analysis
66 4.4.5 Comparison of RTC, Grid Analysis and SU Tool Results

68 Chapter 5 Taking Shared-Use to the Next Level: Chicago–Saint Louis High Speed Rail
68 5.1 Introduction
68 5.2 Background
69 5.3 Freight Carrier Perspective
70 5.4 A Timely Example
70 5.5 Project Vision—Illinois DOT
71 5.6 Project Environment
71 5.7 Corridor Analysis and Development of the Upgrade Program
73 5.8 Translation of the Corridor Analysis into the Engineering and Investment Program
73 5.9 Service Outcomes Agreement
74 5.10 Track Maintenance Agreement
74 5.11 Next Steps
76 5.12 Conclusion

77 **Appendix A** Discussion of Train Prioritization and Effect on Line Capacity

81 **Appendix B** Discussion of Positive Train Control and Effect on Line Capacity

83 **Appendix C** Glossary of Railroad Terminology Appearing in This Guidebook

---

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

CHAPTER 1

Introduction

1.1 Introduction, Purpose and Overview of This Guidebook

1.1.1 Introduction

A broadened understanding of rail capacity is an essential cornerstone for building the partnerships required for successful implementation of passenger rail operations on shared-use corridors. The product of such understanding is an ability for corridor partners to deal with service proposals and challenges in a dispassionate, objective manner. Public agency sponsors of passenger operations are frequently frustrated by the numerous challenges associated with developing an operation that must simultaneously address public benefits and legitimate private sector concerns. A well-structured, transparent modeling structure to assess rail capacity can serve to confirm the design and scale of proposed changes as well as to educate those who are unfamiliar with the complexity of the rail environment.

Unlike highways, most rail corridors are privately owned and are likely to remain in private hands even after substantial public investment. Public sponsors, including the U.S. Department of Transportation (USDOT), want assurances that anticipated public benefits are realized once taxpayer funds have been expended. Rail capacity modeling is an important tool to determine appropriate shares of needed investment by each of the corridor partners. Depending on the circumstance, rail capacity modeling may establish the baselines for negotiation of ongoing contributions to upkeep and maintenance.

For the foreseeable future capacity planning for shared-use corridors, and the use of such analytical methods discussed in this guidebook, will be a fact of life for freight and passenger railroaders. As of September 2013, apart from Amtrak long-distance national network trains, there were 18 mostly state sponsored, short-distance Amtrak operated passenger rail services which operate on shared-use corridors. There were also 24 commuter rail operations. Twelve operate at least in part on track owned by private freight railroads, 16 run on their own tracks, 7 do both, and 4 run at least in part on Amtrak's Northeast Corridor.

1.1.2 Purpose of Report

The purpose of this guidebook is to equip state Departments of Transportation (DOTs) and other public agency sponsors of passenger operations with an understanding of main line rail capacity analysis and planning. Specifically, it explains how freight railroads, Amtrak, and commuter railroads consider the effects of implementing new passenger rail services on freight railroads and on publicly owned corridors, or shared-use corridors, such as Amtrak's Northeast Corridor. This enhanced understanding of rail capacity issues will foster improved levels of trust and communication and will support the overall objective of building solid and respectful partnerships for the use of such alignments.

This is a guidebook on how state DOTs and other passenger rail service sponsors can successfully partner with rail corridor owners in addressing the capacity issue as a core element of successful shared corridor operations. It is meant as a complement to *NCHRP Report 657: Guidebook for Implementing Passenger Rail Service on Shared Passenger and Freight Corridors*, which explored the fundamental steps required for establishing new passenger services on freight railroads.

1.1.3 Overview of Report

The guidebook consists of the following chapters.

The remaining sections of **Chapter 1** describe the outreach effort to shared-use corridor stakeholders, which occurred through the summer of 2012, followed by a summary of the "realities" of railroad operations.

Chapter 2 is a synthesis of the responses obtained from the stakeholders. The feedback is organized in terms of major themes that were distilled from their comments. It includes a summary of guiding principles which public agency sponsors of new passenger rail service might consider in their discussions with host rail carriers for access.

Chapter 3 lists the various line capacity analysis methodologies that are available, and cites their respective strengths and where they are typically used.

Chapter 4 provides three case studies, where three different methodologies were employed to assess line capacity. The results of the three analyses are then compared.

Chapter 5 is a description of recent planning for a shared-use corridor set to see the deployment of high speed trains in the near future.

There are also three appendices. **Appendix A** is an explanation of the basics of rail capacity analysis. **Appendix B** discusses the history and implications on line capacity of Positive Train Control. Lastly, **Appendix C** is a glossary of railroad terminology that appears throughout the guidebook.

1.2 Outreach to Stakeholders

1.2.1 Introduction

During the summer of 2012, this guidebook's investigative team discussed issues surrounding line capacity and operations assessments with freight railroads, commuter railroads, state Departments of Transportation, Amtrak, and the Federal Railroad Administration. A listing of the stakeholders interviewed and the dates on which the discussions occurred appear in **Table 1-1**. The discussions were either face-to-face or via teleconference. Brief summaries of these entities and their shared corridor interests appear herein. Entities identified in the table by abbreviation have their proper names noted in the text.

1.2.2 Freight Railroads

BNSF Railway hosts both intercity passenger services operated by Amtrak and various states, as well as commuter rail services. Amtrak services include the *Southwest Chief* and portions of the *Coast Starlight*, *California Zephyr, Empire Builder* and *Texas Eagle.* State sponsored services

Table 1-1. Stakeholder outreach discussion venues and dates.

Stakeholder	Participants	Venue	Date
Freight Railroads			
BNSF Railway		Interview	June 14, 2012
CSX Transportation		Interview	July 25, 2012
Norfolk Southern Railway		Interview	July 19, 2012
Union Pacific Railroad		Teleconference	August 22, 2012
Commuter Railroads			
MARC		Interview	August 8, 2012
Metra		Interview	July 9, 2012
OCTA		Interview	June 22, 2012
Sounder		Interview	July 12, 2012
VRE		Interview	August 6, 2012
State DOTs			
Caltrans		Teleconference	July 10, 2012
Capitol Corridor JPA		Interview	July 2, 2012
Connecticut DOT		Interview	June 27, 2012
Illinois DOT		Teleconference	August 28, 2012
North Carolina CDOT		Teleconference	June 25, 2012
Pennsylvania DOT		Teleconference	July 10, 2012
Washington DOT/Oregon DOT		Teleconference	July 25, 2012
Amtrak		Interview Interview/ teleconference	June 26, 2012 July 31, 2012
FRA		Interview	July 25, 2012

include the *Illinois Zephyr* in Illinois, and the *Heartland Flyer* in Texas and Oklahoma, along with portions of *Cascades* in the Pacific Northwest, the *Pacific Surfliner* in Southern California, and the *San Joaquins* in northern and central California. Commuter rail services include: the Sounder in Washington State, Metrolink in the Los Angeles area, and Metra in Chicago. BNSF crews operate both Sounder commuter trains and Metra trains on BNSF lines in Chicago.

CSX Transportation (CSXT) hosts both intercity services operated by Amtrak and various states, as well as commuter rail services. Amtrak services include the *Auto Train*, *Silver Meteor*, *Silver Star*, *Palmeto*, and the *Cardinal*, and portions of the *Lakeshore Limited*, *Capitol Limited* and the *Carolinian.* State sponsored services include the *Empire Service* in New York, the *Hoosier State* in Illinois and Indiana, and the *Pere Marquette* in Michigan. Commuter rail services include the Virginia Railway Express (VRE) service in Virginia and Maryland Area Regional Commuter (MARC) service in West Virginia and Maryland. CSXT provides train crews for the MARC as well.

Norfolk Southern Railway (NS) hosts intercity services operated by Amtrak and commuter rail services. Amtrak services include the *Crescent* and the portions of the *Capitol Limited* and *Lakeshore Limited.* State sponsored services include the *Piedmont Services* in North Carolina and portions of the Chicago-Detroit-Pontiac, Chicago-Lansing-Port Huron, and Chicago-Grand Rapids Services. NS hosts commuter trains operated by Virginia Railway Express (VRE) in northern Virginia, Metra in Chicago, Southeast Pennsylvania Transit Authority (SEPTA) in Philadelphia, and New Jersey Transit (NJ Transit) in New Jersey.

Union Pacific Railroad (UP) hosts intercity services operated by Amtrak and various states, as well as commuter rail services. Amtrak services include the *Sunset Limited*, and portions of the *Coast Starlight; California Zephyr* and *Texas Eagle.* State sponsored services include the *Lincoln Service* in Illinois and the *Capitols* in California, and portions of the *San Joaquins* in California and the *Cascades* in Oregon. Commuter rail services include Metrolink in the Los Angeles area, Metra in Chicago, and Caltrain and the Altamont Commuter Express (ACE) in northern California. UP hosts and operates Metra lines in Chicago.

1.2.3 Commuter Railroads

Maryland Area Regional Commuter (MARC), administered by the Maryland Department of Transportation, operates commuter rail services on two routes between Baltimore and Washington: one on the Amtrak's Northeast Corridor and the other on CSX Transportation; and on CSXT between Washington and Harpers Ferry, WV, and Frederick, MD.

Metra, the commuter rail operation in Chicago, operates numerous commuter rail services over lines belonging to UP, BNSF, NS, Canadian Pacific Railway (CP), and on a dedicated electrified line purchased from Canadian National Railway (CN).

Orange County Transportation Agency (OCTA) is a member agency of the Southern California Regional Rail Authority (SCRRA), which operates the Metrolink commuter rail services in the Los Angeles area. OCTA is planning a joint service along with the North County Transit District (NCTD) in San Diego County for a new through commuter rail service between Fullerton (Orange County) and San Diego utilizing Metrolink and NCTD services. OCTA owns trackage utilized by both UP and BNSF freight trains, and *Pacific Surfliner* corridor services.

Sounder, the commuter rail operation of the Sound Transit regional public transit agency, operates trains on BNSF between Seattle and Everett and between Seattle and Tacoma. It is presently building an extension of its south line over a new alignment and BNSF south of Tacoma.

Virginia Railway Express (VRE), owned jointly by the Northern Virginia Transportation Commission and the Potomac and Rappahannock Transportation Commission (agencies of the Commonwealth of Virginia), operates commuter trains on the CSXT between Fredericksburg, VA, and Washington, DC, and on NS between Manassas, VA, and Alexandria, VA.

1.2.4 State Sponsored Services

Caltrans, also known as the California Department of Transportation, sponsors or funds three intercity rail corridor services:

- The *Capitols* between San Jose, Oakland, Sacramento and Auburn on UP.
- The *San Joaquins* between Oakland, Stockton, Fresno and Bakersfield on UP and BNSF lines; and also between Stockton and Sacramento on UP.
- The *Pacific Surfliner* between San Luis Obispo, Santa Barbara, Los Angeles, Anaheim, and San Diego on lines belonging to UP, BNSF, OCTA and NCTD.

Caltrans' Division of Rail manages the two latter services directly. The *Capitol* service is operated by a public agency as noted immediately below. The *Surfliners* still receive some operating funding by Amtrak, though this will cease in October 2013, after which Caltrans will be the sole funding source.

Capitol Corridor Joint Powers Authority (CCJPA) manages the state-funded *Capitol* trains. CCJPA is a Joint Powers Authority, staffed by employees of the Bay Area Rapid Transit District (BART). Funding for operations comes from Caltrans.

Connecticut Department of Transportation (ConnDOT) owns a portion of Amtrak's NEC from New York / Connecticut state line to a point just east of New Haven Union Station. On this line, ConnDOT hosts Metro North commuter trains and Amtrak *Acela* and *Regional* intercity trains. ConnDOT also sponsors Shore Line East commuter service between New London, New Haven and Stamford on the NEC. ConnDOT plans to implement new commuter rail service on Amtrak's Springfield Line between New Haven, Hartford and Springfield in 2016. Amtrak will operate the new service.

Illinois Department of Transportation (IDOT) sponsors Amtrak operated intercity services including the aforementioned *Illinois Zephyr* and *Lincoln Service; Illini Service* between Chicago and Carbondale over CN lines; as well as the Illinois portion of the Chicago-Milwaukee *Hiawatha* Service. IDOT is also leading the implementation of high speed rail intercity service on the UP between Chicago, Springfield and St. Louis.

North Carolina Department of Transportation (NCDOT) sponsors the Amtrak operated intercity *Piedmont Service* and *Carolinian* between Raleigh and Charlotte over tracks owned by North Carolina Railroad, a state entity whose freight rail haulage services are leased to NS.

Pennsylvania Department of Transportation (PennDOT) sponsors Amtrak operated intercity services: the *Pennsylvanian* between Pittsburgh, Harrisburg, and Philadelphia over tracks owned by NS and Amtrak; and a high frequency, high speed *Keystone Corridor* between Harrisburg and Philadelphia.

Jointly the **Washington Department of Transportation (WSDOT)** and the **Oregon Department of Transportation (ODOT)** sponsor the *Cascades* services between Eugene, Portland, Tacoma, Seattle, Bellingham and Vancouver, BC, over UP and BNSF lines.

1.2.5 Amtrak

Amtrak, also known as the National Railroad Passenger Corporation, provides intercity passenger rail services throughout the United States. Amtrak owns the majority of the NEC between Boston and Washington, DC, and hosts both commuter trains and freight trains on the NEC along with its regional and high speed trains. Amtrak owns segments of track in Michigan, and hosts Michigan state sponsored services there. Amtrak also runs its long-distance network trains on all major freight railroads in the U.S. and on numerous short lines.

Amtrak crews operate state sponsored services, including:

- *Capitol Corridor*, *San Joaquin* and *Pacific Surfliner Services* in California.
- *Cascades* in the Pacific Northwest.
- *Heartland Flyer* in Oklahoma and Texas.
- *Piedmont* and *Carolinian Services* in North Carolina.
- *Blue Water*, *Pere Marquette* and the *Wolverine Services* between Chicago, northern Indiana and Michigan.
- *Hiawatha Corridor* in between Chicago and Milwaukee.
- *Empire Service* and *Adirondack Services* in New York.
- *Vermonter* and *Ethan Allan Services* between New York City, New York, Connecticut and Vermont.
- *Downeaster* in Massachusetts, New Hampshire and Maine.

1.2.6 The Federal Railroad Administration

Federal Railroad Administration (FRA) is an agency of the U.S. Department of Transportation with the primary responsibility of federal oversight for the safety of the nation's railroad system as well funding and oversight of railroad research and development. It also provides training and technical assistance. Since the passage of the Passenger Rail Investment and Improvement Act (PRIIA) in 2008, FRA has taken on additional responsibilities for approving and administering applications for federal funding of freight and passenger rail projects, including higher and high speed rail initiatives. FRA also oversees all Amtrak funding; leads the development of the National Rail Plan; sets standards for and reviews state rail plans; and has ownership interest in the Pueblo, CO, Transportation Technology Center.

1.3 Realities of Railroad Operation

A general description of railroad operations is needed to understand the discussions in this report. The following paragraphs provide a basic description of U.S. freight and passenger operations, including the control of train movements over a segment of track, how safety is assured through the application of signals and train control systems, and how dispatchers manage train movements to meet service quality goals. Common railroad terminology used to describe operations and used in capacity modeling is included. The descriptions are amplified in Appendix A on Train Priorities and Line Capacity Effects and in Appendix B on Positive Train Control (PTC).

The focus of this description is on shared passenger and freight operations on a railroad line segment equipped with wayside signals and Centralized Traffic Control (CTC), as explained below. Almost all passenger services likely to be the subject of serious capacity analysis will fit this description.

1.3.1 Signaling and Safety

Safe train operations (avoidance of collisions) depends on dividing up a single line, or each line where there are two or more tracks, into signal blocks, typically two to 10 miles in length.

Block lengths on a railroad may be a function of several factors, but the overriding safety requirement is that any train entering a block at its maximum permitted speed must be able to stop before the end of the block, thus maintaining a safe separation between trains. The minimum block length is the greatest braking distance of any train expected to operate over the line segment, plus an appropriate safety margin. Blocks must also be greater than the longest train that normally travels over the line segment, otherwise a single long train would occupy two signal blocks. Once minimum block length conditions are satisfied, block length is determined by desired line capacity. Increasing block lengths increases the minimum distance between trains and reduces capacity.

In signaled territory, wayside signals are positioned at the start of each block. Referring to the simple track diagram, Figure 1-1, only one train (“Train 1”) is permitted to occupy a block in normal operations.

A following train (“Train 2”), which has a clear block ahead, will see a yellow signal, indicating it must be prepared to stop at the next (red) signal by reducing speed. The signals are controlled by a track circuit, using low-voltage electrical currents in the rails. The electrical connection provided by the train’s wheels “shunts” the track circuit to detect the presence of a train and control the block signals. Thus an occupied track is always protected by a red signal. The yellow signal seen by “Train 2” provides an advance indication of the stop signal behind “Train 1.” This is called an approach signal. In railroad terminology, this signaling system is called an Automatic Block System (ABS).

A train traveling in the opposite direction (“Train 3”) must enter a passing siding to allow Train 1 to continue. An event where trains are traveling in opposite directions and passing each other at a siding is called a meet. A faster train overtaking slower train at a siding is called a pass.

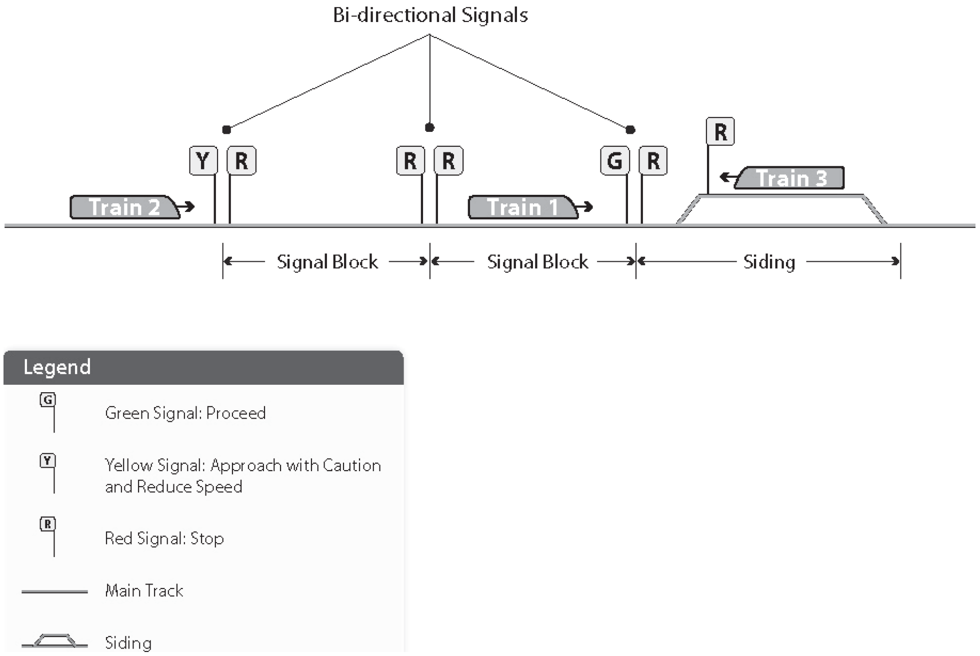


Figure 1-1. Opposing train conflict resolution.

Entry and exit switches can be controlled manually by the train crew, or with their accompanying signals, controlled by an interlocking. An interlocking is a mechanism that is either controlled locally from a signal tower (almost extinct) or remotely from a control center. A combination of signal indications, switch position detectors and siding track circuits, combined with electrical or electronic logic, ensures occupied tracks are protected by a stop signal and trains cannot move through a wrongly aligned switch. More complex interlockings may be used at crossovers and junctions. Where controlled remotely, interlockings are called Control Points (CP) on many railroads. The combination of interlockings and the ABS will prevent collisions and misaligned switch derailments, provided that locomotive engineers always obey signals.

To reduce accident risks, railroads have developed systems that provide audible and visual warning in the cab of the aspects displayed by approach and stop signals, sometimes with enforced brake application if the engineer fails to start slowing the train. A variety of systems and technologies are in limited use, called Automatic Train Stop (ATS), Automatic Cab Signals (ACS) and Automatic Train Control (ATC). Current FRA safety regulations limit speeds to below 80 mph in the absence of one of these systems, which is why passenger train speed is currently limited to 79 mph on many routes. Positive Train Control (PTC), described later, is a comprehensive safety system that enforces adherence to speed limits and work zone restrictions, as well as preventing collisions, and which will enhance or supersede other automatic systems.

1.3.2 Management of Train Movements

The systems described in the previous section are designed to ensure safety, but do not manage railroad operations in any way. Operations management is the function of the dispatcher, who uses a variety of means to transmit operating instructions to each train operating on a track segment regarding train priorities for meets and passes and other operating details. On lines not equipped with remotely controlled switches, the dispatcher's instructions are conveyed by structured voice radio messages to a train crew; these messages are called train orders. Switches are operated locally by a signal tower operator or manually by the train crew. However, most rail

Photo by KJ Yaeger

Figure 1-2. A typical dispatcher's desk.

segments likely to be of interest in capacity studies have power switches that can be operated remotely by the dispatcher. The dispatcher's workstation (usually called a dispatcher's desk) is equipped with displays showing train locations, switch positions, etc., and switch and signal controls, as well as displays showing train positions on adjacent track segments. This system is called CTC (or Train Control System [TCS] on some railroads) and gives the dispatcher full control of railroad activity on the line segment. Figure 1-2 is an illustration of a typical dispatcher's desk. Figure 1-3 is a close-up of a typical dispatcher's screens.

The efficient operation of a line segment depends very much on the dispatcher's skill and experience, often aided by computer simulations (Computer Aided Dispatching [CAD]) that can recommend pass and meet locations to the dispatcher. Poor choices by the dispatcher can slow operations, reduce effective capacity, and delay trains. In considering the dispatcher's role, it is worth noting that many American rail freight operations are not scheduled, especially when

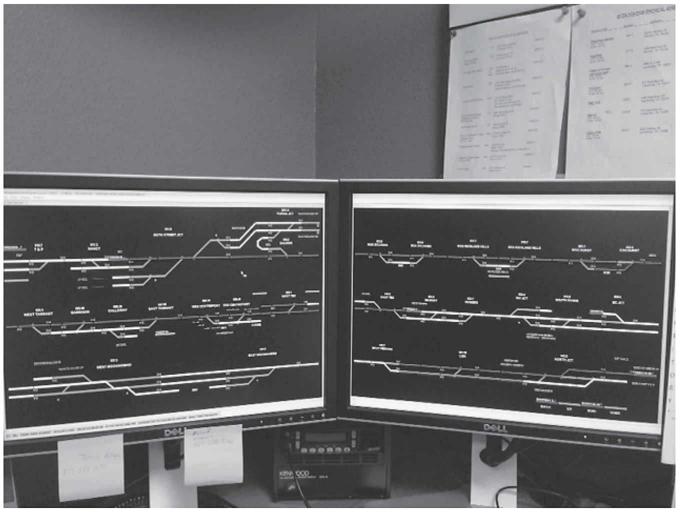


Photo by KJ Yaeger

Figure 1-3. A typical dispatcher's screens.

compared to, for example, a commuter rail service; and there is substantial randomness in when trains arrive on a line segment.

The U.S. main line freight environment is in sharp contrast to lines where passenger traffic is dominant, such as on busy commuter railroad lines or most rail lines in Europe where most service takes place on a predictable scheduled pattern and dispatching skills have less influence on overall train performance.

1.3.3 Capacity and Capacity Analysis

The primary subject of this report is railroad capacity and the methods used to analyze and estimate capacity. The short definition of capacity is the ability of a railroad line segment to carry a given volume and mix of traffic (freight and passenger, if present) while meeting service quality goals for each type of traffic. Capacity is a function of:

- Physical characteristics of the line segment, such as single or double track, distance between passing sidings, signal system characteristics, permitted speeds for different train types, curvature, and gradients.
- Traffic volume and characteristics, such as the numbers of trains of each type traveling over the line in a specific period of time (typically 24 hours), speeds, train length and weight, locomotive power assigned to each train, and stops for passenger stations or to drop off and pick up freight cars from industry sidings.
- Management practices and protocol, including dispatch procedures, safety regulations, and treatment of train movements through passenger terminal areas.

Capacity may be defined as adequate when each user of the line segment is able to meet service quality goals for rail services using a line segment. For a passenger service operator, the service quality goal may be to achieve a given percentage of on-time arrivals and/or ensuring that individual train and aggregate delays do not exceed an agreed level. For a freight service operator, service goals will depend on service type. For example, an intermodal train may be required to meet punctuality goals reflecting commitments made to customers by the railroad, but for other train types the railroad's primary objectives may be to minimize delays and unnecessary stops and starts that add to fuel, employee, and other costs.

Capacity analysis is the process of estimating the extent to which traffic planned to operate over a given line segment can meet the service goals, and, if not, what modifications to infrastructure or operations will enable it to do so. An individual line segment cannot be considered in isolation, since the ability of adjacent line segments to also support traffic volume is critical. It is usually necessary to analyze several contiguous line segments. The practical impact of this need is that capacity analysis of the impacts of a proposed passenger operation must often include adjoining rail service territories that extend beyond the physical limit of the proposed operation.

The analysis must also take proper account of any randomness in rail traffic volumes and timing, as well as consideration of the ability to recover from typical service delays. Appendix A provides a more detailed description of how train priorities and track layout affect capacity. Chapter 2, following, provides a more detailed definition of capacity, why it is important, and how service quality goals for different rail traffic types relate to capacity.

1.3.4 Positive Train Control (PTC)

Development of new systems to control train operations and to extract greater operations efficiency has been of interest to North American freight railways for at least three decades. New train control and signaling technologies have been researched and tested for many years, but systems complexity, constant evolution of underlying communications and computing technologies, and the lack of common industry standards had frustrated implementation of such concepts.

A new sense of urgency and political focus occurred with the fatal collision between a Metrolink commuter train and a Union Pacific Railroad freight train in Chatsworth (Southern California) in 2008. Following this accident, Section 104 of the Rail Safety Improvement Act of 2008 (RSIA) required that by December 31, 2015, PTC be installed on all rail lines carrying regularly scheduled commuter and intercity service as well as lines transporting toxic-by-inhalation hazardous materials. PTC functionality is required to:

"*. . . prevent train-to-train collisions, over-speed derailments, incursions into work zone limits, and the movement of trains through a switch left in the wrong position . . .*" (49 USC § 20157—Implementation of positive train control systems)

FRA was tasked with overseeing and approving plans for implementation of PTC by rail corridor operators and owners. While the outcomes-based definitions of the statute could conceivably result in different technical approaches on different corridors, the widespread sharing of assets by freight rail carriers creates a strong incentive for adoption of common standards and approaches. Since passage of RSIA, the railroad industry and FRA have been working to implement the Act. Because of the short timeline specified in the Act, the railroad industry decided to adopt an overlay version of PTC. This means adding PTC to enforce existing signals and operating rules, without otherwise changing how railroad operations are managed. It is this specific approach to PTC that is referenced in this guidebook. As an overlay system, PTC cannot provide any capacity benefit, and it may introduce new operating constraints that would have the effect of reducing capacity. Any detailed analysis of rail capacity for post-2015 operations must consider the PTC system proposed for the rail line under study and take account of PTC-related capacity impacts.

One particularly vexing challenge for the implementation of PTC is the appropriate calibration of braking algorithms for the almost unlimited combinations of car types, train weights, and locomotives. Requiring trains to slow or stop prematurely will ensure a safe operation, but at the cost of significant loss of line capacity beyond that which would occur with traditional manual train operation. Considerable time and energy is being devoted by the rail carriers on this specific technical issue, attempting to tailor as precisely as possible the true required braking distances associated with each train consist.

In the longer term, certain elements of the 2015 PTC architecture offer the promise of increased capacity without costly changes to the physical infrastructure by introducing "moving blocks" which protect a safety zone around a train as it travels and which can be tailored to the specific stopping distance of a specific train consist. A more detailed description of PTC and the issues raised by its implementation can be found in Appendix B.

1.3.5 Rail Line Planning Versus Highway Planning

As both highways and rail lines are linear and handle high volumes of traffic in opposing directions, it is tempting to think that planning for them would be similar. However, the realities of public versus private ownership and the differences in characteristics of the traffic handled require distinct planning approaches.

Highways are, for the most part, public assets. Their construction and maintenance costs are covered out of the public purse. Accordingly, they are open to all users. These range from motorists in private automobiles to delivery trucks to 16-wheel "big rig" trucks, and just about everything in between. Users both drive to work and drive as work. There are as many reasons to take to the highway as there are drivers, and the highway has to accommodate them all. Traffic patterns on highways will be more or less the same throughout the year. In maintaining highways, the overarching goal is to ensure safe driving conditions.

Most rail lines, on the other hand, are owned by private for-profit railroads. A railroad earns fees for hauling rail traffic across its lines, and these fees contribute to the maintenance of the line. Access to a rail line is controlled by the owning entity primarily for use by its own trains. Use by other passenger or freight rail systems is only permitted if the owner issues trackage rights for those services. Volume on some lines can be very commodity specific. For example, the majority of traffic on a rail line could be coal bound to a coal-burning utility, and the volume may change depending on the season—more in summer and less in winter. Generally the line will be maintained only to the extent required to move the traffic cost effectively as well as safely.

Further complicating the comparison are the following:

- There is probably a similar variation in power-to-weight ratios between rail and highway borne traffic; however, trains have much bigger variability in top speed and train length than do trucks.
- Most importantly, most rail lines are only single or double track. They are like operating a one- or two-lane highway with opportunities to pass or overtake only at one place every several miles. The ability to carry large volumes of passengers or freight on each train means that a rail line is capable of very high throughput, but at the cost of flexibility.
- The rail network itself is far more limited than that of highways, with few routing alternatives between city pairs. The impact of a derailment or other unplanned track disruption may quickly ripple across the service network of a given carrier for many hundreds of miles. Highway mishaps or failures generally impact service over a few dozen miles at most given the availability of redundant or secondary routes.
- Passenger trains with their schedules create a dynamic in rail planning unlike anything on the highway side. Passenger trains have priority, and freight trains cannot impede passenger trains. Thus planning for fluid passenger and freight operations often means extending existing sidings, adding new ones, installation of double track, or even operations changes (e.g., with freight trains operating when passenger trains are not).
- Raw data gathering for highway traffic volumes is a matter of observation. Planners use cameras or other tools to capture the ebbs and flows and traffic during the day as a tool for planning improvements. However, observations of rail traffic, to discern patterns to fluctuations, are impractical given the nature of around-the-clock rail operations, seasonality, and cyclicality inherent in rail traffic. One day observations are essentially meaningless. Rail planners, accordingly, rely on rail traffic data from the corridor’s owning railroad that spans several days, weeks, or even a month or a year in order to capture the true nature of the line operations.

Given these differences, the implications for planning approaches are enormous. In a phrase, one system is an open one, open to all users. The other is a closed system, with access permitted by the owning railroad. For the former, planners will strive for fluid conditions by adding lanes and thus improving volume-to-capacity ratios. With fewer resources, private railway planners may instead prioritize rail line use to traffic that earns the railroad the highest revenues.

CHAPTER 2

Synthesis of Stakeholder Input

2.1 Introduction

As noted, this guidebook's research team discussed issues surrounding line capacity and operations assessments with public and private rail planners. The goal of the effort was to understand how these planners approach shared-use opportunities and to discover if there were any common themes and/or concerns in line capacity planning.

The team sought to interview a broad spectrum of shared-use stakeholders, composed mostly of Class I freight railroads (carriers with annual carrier operating revenues of $433.2 million or more) hosting large scale passenger operations, state Departments of Transportation sponsoring passenger services, and commuter rail agencies. Intercity passenger service provider Amtrak and the industry regulator, the FRA, were interviewed as well. The interviews occurred during the summer of 2012. The interviews were conducted either face-to-face or via conference call.

The guidebook's research team developed a series of interview questions which were sent 2 to 3 weeks in advance of the actual interviews. The questions were customized according to the circumstances of each target interview group; they were developed to frame the stakeholder discussions and to draw out common themes. The team was provided detailed, thoughtful feedback by all survey participants. Common themes and particular concerns are summarized herein.

The questions were customized according to the circumstances of each target group. The surveys were developed to frame the stakeholder discussions and to draw out common themes rather than tabulate results from various groups. The team was provided detailed, thoughtful feedback by all survey participants. Common themes and particular concerns are summarized herein.

In the discussion that follows are references to operations simulation, often just called modeling. These references pertain to computer programs that mimic train operations on track segments shared by two or more trains. Operations simulations and the computer programs that perform them are detailed in Chapter 3. It is becoming standard practice in the railroad industry to perform operations simulation when planning for introduction of new passenger services on freight railroad tracks. Indeed for federal support of such new passenger service implementation, operations simulation is a requirement of the FRA.

2.2 What Is "Rail Capacity" and Why Is It Important?

Railway "capacity" has no value in and of itself. What is of value to rail stakeholders is the capability of a given set of facilities, along with their related management and support systems, to deliver acceptable levels of service for each category of use. What is deemed "acceptable" varies widely even within broad user categories:

- High speed passenger train operations in Japan are flagged as "off-schedule" when delays exceed 30 seconds for trains arriving and departing terminals.
- Amtrak considers trains to be "on-time" if they are within 10 minutes of schedule.
- Many carload freight shippers consider "day of delivery" to be an acceptable service definition.
- Dedicated intermodal trains operate to within 60-minute standards and carry "just in time" freight on a wholesale basis for major motor carriers.

The scale and configuration of the fixed physical plant sets the upper boundaries for service delivery. Within those boundaries, however, a variety of management, operations practices, and support system elements determine the effective service delivery capability of a given corridor. In addition, several other factors must be incorporated into any serious assessment of "rail capacity." They include:

- Dispatch performance, including the "style" of an individual dispatcher and the support systems provided to the dispatchers in delivering movement instructions. One freight road in particular noted an "optimistic" bias for operation simulation modeling in multiple main track territories thanks to an assumption that dispatchers are more comfortable in arranging overtakes and "reverse running" than is actually the case.

  The biggest impact of dispatch "style" relates to the willingness of a given dispatcher to make use of all technically described available routes within a given corridor to expedite traffic. For example, dispatchers who insist on a greater buffer between trains than is required by safety rules and signaling systems may reduce the effective capacity of an alignment below that described by a modeling tool such as Rail Traffic Controller (RTC).
- Train length and horsepower/ton ratios for different classes of train service.
- Communications protocols and support systems.
- Reliability of train operations beyond the physical boundaries of the shared-use corridor.
- Recovery resources to move operations back to a "normal" status following unplanned events such as: equipment failures, derailments, severe weather, and grade crossing incidents.
- Track maintenance and capital renewal strategies.
- Determining the level of infrastructure or systems redundancy appropriate to mitigate the risk of unplanned events (equipment failures, grade crossing incidents, track defects, etc.) is equal parts art and science, and is at the root of many conflicts over the required level of corridor investments. Modeling of specific incidents or inclusion of random events in train service performance simulation is an approach that will better define system robustness and service recovery capabilities.

It is extremely important to develop early consensus on the scenarios to be modeled. A clear and unambiguous technical definition of "success" will serve to narrow the range of feasible infrastructure solutions, straightening the path to a formal agreement for needed investments.

For illustration the targets for a given facility might include:

- Intercity passenger operations within 10 minutes of schedule 92% of the time, provided trains are "in slot" at the time of entry into the service corridor.
- Commuter rail operations within 5 minutes of schedule 95% of the time.
- Intermodal freight operations within 1 hour of schedule 90% of the time provided trains are "in slot" at the time of entry into the service corridor.
- Manifest and bulk commodity trains—no deterioration of average train speeds or increase in average minutes of delay.

2.3 A Building Block for Project Execution

Those who have completed major rail projects and federal oversight agencies such as the FRA have noted the importance of a robust operations and capacity assessment. The operations and capacity assessment creates the link between the infrastructure and operating plans, and informs an Environmental Impact Study (EIS) that is required under the National Environmental Policy Act (NEPA) for approval of federal funding participation.

The analysis also serves to define project phasing and puts into context short or intermediate term investments that are ultimately required as part of the long term service plan. Without this context it may be difficult for sponsoring agencies to gather political support for investments that may be essential to the long term vision but that fail to deliver, on their own, tangible service benefits in the short term.

A particular case study, discussed in Chapter 4, was responsive to this point. The 2010 *LOSSAN Corridor Strategic Assessment* was aimed at illustrating for public sponsors the types of public investments required over a 15-year time period to improve passenger train performance and attract more riders; and at the same time preserve service quality for the freight railroads on the corridor.

2.4 Transparency of Modeling Inputs

A recurring theme from all public sector stakeholders is the need to improve the level of transparency associated with capacity simulation inputs and outputs. On corridors they own, freight carriers fully control the technical assessment of the operations for proposed and existing shared-use territories even when the passenger rail sponsor underwrites the cost of such an analysis.

Knowledgeable independent consultants can be valuable in helping a passenger rail agency and a host railroad reach a mutually acceptable agreement regarding capacity enhancements needed to meet specific train frequency and trip time requirements. The freight railroad is assured that its operating constraints and requirements are properly understood, and the passenger rail agency has assurance that it is not being expected to agree to unreasonable conditions. In most cases Amtrak is also a party to the negotiations, as the proposed operator of the passenger service, and brings wide experience of capacity analysis.

This noted, public sponsors in some instances have pulled back from performing independent assessments with their own in-house or consulting experts after discovering that the work is eventually re-done by the host freight road in any case. While the FRA prefers to see independent, third-party consultants involved, the approach to performing the technical analysis is ultimately negotiated between the host carrier and the sponsoring state or agency.

The trend with respect to simulations transparency has been to provide greater access to the process for passenger rail sponsors. All freight carriers emphasize the need to protect sensitive commercial data and will not share client or commodity-specific information beyond some broad commodity categories (viz., merchandise carload freight, bulk commodities, and intermodal). In some cases host carriers provide full disclosure of current and anticipated physical volumes while other roads allow sponsors to "view" the results of a simulation but not to record any details of the modeling inputs.

Host freight carriers are called upon by the FRA to justify freight growth projections that vary widely from assumptions embedded into the "Freight Analysis Framework" from the Federal

Highway Administration (FHWA) which foresees a general, year-over-year growth trend of 1.5%-2.0%. Discrete additions above the general trend may be explained by the dominance of identified, high-growth commodities or special facility and corridor initiatives such as those that target domestic intermodal freight.

Other inputs, such as assumptions on track maintenance levels and train schedules, can vary widely. What is key is that stakeholders in an operation simulation buy-in to the input assumptions, and transparency of inputs facilitates such buy-in.

2.5 Doing the Homework

No stakeholders brought forward examples of shared corridor proposals that were undeserving of formal, detailed capacity and operations assessment. Freight railroads and the FRA caution sponsors of new services to withhold judgment and to avoid public articulations of service speed and frequency goals until such time as a formal assessment can take place. In general host carriers would prefer to have a conversation at the earliest possible phase of consideration of a new service in order to provide feedback on whether or not a given service lane is even feasible to pursue at a reasonable level of investment.

Carriers' willingness to invest time and energy in ongoing discussions of passenger rail service hinges in part on an assessment of the resources available to the project sponsor. As a general rule the passenger service sponsor is required to underwrite the cost of the associated technical operations and capacity assessment. If funding is not available for this purpose the host carrier may be expected to turn its attention to other priorities.

The size and complexity of some projects may warrant the assignment of a "dedicated" rail carrier employee to the public agency project. Typically the sponsoring agency would underwrite the salary and direct expenses associated with that role. In considering such an arrangement the passenger service sponsor should consider the additional expense in the context of:

- Greater flexibility and management discretion for evaluation of multiple service scenarios.
- Easier scheduling of meetings and public outreach activities.
- Other project elements uniquely associated with publicly funded projects.

The time (and cost) required for a technical RTC-based corridor capacity analysis is a product of the following:

- Track network complexity.
- Train operations complexity.
- Number of alternative operations and track upgrade scenarios to be evaluated.

A simple assessment for a modest commuter operation over a medium density freight corridor might be done in a couple of months for $70,000 to $100,000. At the opposite extreme, a complex, multi-phase corridor upgrade program such as the Chicago-Saint Louis project might require six to eight months of modeling work and cost several hundred thousand dollars. While this is a considerable sum, it is certainly not out of scale with the overall project investment of over $1 billion and should be considered an investment in the proper allocation of scarce capital funds for a long term service infrastructure. It should also be recognized that a modeling platform lives on as a management tool for future projects and potential service changes, provided the model is refreshed and updated as physical plant changes occur.

2.6 The Long View

The FRA, host freight carriers, and many state DOT's emphasize the need to first define the long term (minimum 20-year) service scenario for a new passenger operation and to then work backward to define logical steps of investment and service speed/frequency associated with reaching that goal. The advantages to such an approach include:

- Consideration of discrete project investments as contributing to a long term operations and infrastructure configuration. Avoidance of "cheap" fixes that do not allow for future growth.
- Early identification of the limits of "shared-use" and, where appropriate, the establishment of benchmarks for segregated infrastructure.
- Preservation of abandoned or lightly used rail alignments as required in protecting the long term service vision.
- Creation of a more stable planning environment for public agencies and private carriers alike, narrowing the range of uncertainties that accompany the regular political cycle. With a long view in mind, capacity-enhancing projects may be implemented far more quickly if and when funding is made available as described in the "Phasing" discussion below.

2.7 Phasing Finesse

Public rail funding programs are in their infancy in many jurisdictions, giving rise to rail project proposals that are just that—projects—rather than positioning the rail mode as an integral part of a long term multimodal transport improvement regime. States that have a longer history of state rail investment for passenger operations, such as California, Washington State, Illinois, Maryland, and North Carolina, have learned the advantages of longer term planning for rail. These long term plans can best be progressed through collaborative analysis of service goals and associated investments, with capacity and operations simulations tools used to define the discrete projects that make possible each new level of passenger service improvement. Three examples of successful long term planning are highlighted herein.

2.7.1 California Corridor Services

Caltrans (California Department of Transportation) corridor improvement projects are directly managed by a Joint Powers Authority (JPA) consisting of the relevant transportation authorities in the San Jose-Oakland-Sacramento-Auburn *Capitol Corridor* alignment. *San Joaquin* train service in the Central Valley and the *Pacific Surfliner* along the Central and Southern California coasts will evolve into similar management structures. Planning for rail programs statewide is managed, however, through Caltrans' Division of Rail at Caltrans head offices in the state capital, Sacramento.

- Caltrans officials in Sacramento establish a 25-year statewide vision for service and offer the first communication to potential host freight carriers of the public uses envisioned for various rail corridors.
- The official 10-year State Rail Plan is the first articulation of a financially constrained public rail investment program. Development of this plan includes an invitation to the freight railroads to help establish investment priorities for the various alignments, based primarily on the cost-effectiveness of each project in delivering service improvements as articulated in the statewide plan. Participation by the freight railroads at this juncture is uneven, with BNSF more fully embracing a participatory role in the long term planning regime.

- The Caltrans 5-year rail plan (revised bi-annually) coincides with the state's general budget cycle and gives rise to development of specific public-private partnership contracts, funding appropriations and project start-ups.

Caltrans has sponsored passenger rail service for decades. Its sponsorship of the *San Joaquin* service began in 1976. It began funding of the *San Diegan* service in 1979; the train was rebranded the *Pacific Surfliner* in 2000. The state has funded the *Capitol Corridor* trains since their introduction in 1991.

2.7.2 Cascades Services

The Washington State *Cascades Service* enjoys a long term history of support that has enabled the state to take full advantage of funding opportunities as they arise. In 1993 BNSF and WSDOT began collaboration on development of a detailed operations simulation/capacity modeling platform that enabled tests of alternative investment approaches. The long term service goal for Seattle-Portland trains is 13 daily round trip frequencies with a 2 hour 30 minute total transit time. The detailed simulation work revealed that the state's goals could most cost effectively be met through construction of a dedicated, passenger-only third main track between Tacoma and Vancouver, WA, on the Columbia River. The dedicated track provides not only additional train movement capacity, but enables passenger trains to move at higher average speeds through improved track geometry and increased super-elevation (banking) in curves.

A plan that includes more modest, incremental investments to improve speeds and frequency serves to kick-start corridor improvements if and when funding opportunities arise. Five trains per day currently ply the Seattle-Portland route. A sixth frequency will be made possible by construction of a passenger-dedicated "Point Defiance Bypass" that will serve to segregate passenger from freight operations in the congested Tacoma waterfront area. Segregation of freight and passenger service in this area will support higher maximum service speeds for the *Cascades* and improve schedule integrity by moving passenger trains away from the congested Port of Tacoma terminal area.

The *Cascades* formally began, with sponsorship of the states of Oregon and Washington, in 1999.

2.7.3 North Carolina Services

North Carolina DOT sponsors intrastate passenger rail service in the *Piedmont/Carolinian* Corridor, connecting the major population centers of Charlotte, Greensboro, and Raleigh through operations over a combination of Norfolk Southern and state-owned North Carolina Railroad right-of-way. As in Washington State, a long history of collaboration and joint planning with NS has produced a multi-phase road map for further improvements in speed and frequency. Long term infrastructure assessment has identified new capacity and urban bypass requirements for upgrades in service frequency. Longer term improvements incorporate upgrades in speed associated with eventual extension of high speed rail operations northward to Virginia and a connection to the Northeast Corridor. One element of improving service capacity and reliability that has gained national recognition is NCDOT's "sealed corridor" highway-rail at-grade crossing improvement program that has dramatically reduced grade crossing incidents in the *Piedmont* Corridor between Charlotte and Raleigh. Sealed corridor investments have also served to increase service capacity and schedule integrity, giving planners in other states some valuable, real-world data on the impact of grade crossing improvements and elimination.

With support from both Amtrak and the North Carolina DOT, the *Carolinian* service began in 1990, and the *Piedmont* service began in 1995.

2.8 Communications and Capacity Assessment

States and agencies with longer term rail support programs as described above also noted the development, over time, of greater levels of technical collaboration and trust in assessing the service capacity of targeted corridors. Investment scenarios are vetted through the host railroad's local and regional field operations managers as well as the host carrier's service design staff. Service improvement scenarios are discussed informally in the course of routine corridor review sessions that track and manage current shared operations. Typically such joint review mechanics include a day-long monthly or quarterly meeting, a report on key metrics, and problem solving to address chronic patterns of service shortfalls. Participants include the service operator (Amtrak, a public transit agency, or contract operator); the service sponsor (a state or local government); the host freight carrier; local municipalities; and facilities owners.

By the time a formal service change proposal is released, the broad outlines of an initiative are well known to the affected stakeholder groups. Freight carriers in particular have noted the damage that "surprise" service announcements can have on the development of long term partnerships with the public sector.

2.9 The Wide View

Host rail freight carriers have long insisted that assessments of operations from a new passenger operation take into account the network service impact that may extend well beyond the geographic limits of the passenger rail operation itself. Railroad freight train operations typically extend many hundreds of miles, and carriers are unwilling to bear the disruptions associated with an embargo of freight operations over a shorter section of track during, for example, commuter rush hour periods.

One approach to mitigating such impacts is to protect the same level of freight service capacity in the area of passenger operations as had existed previously. This "replace what you use" philosophy has been practiced for all recent projects reviewed by the research team; the existence of "latent" freight capacity at the time passenger service is initiated appears to have little impact on the total capital investment required. Protection of "latent capacity" has become the *de-facto* standard for the "arms length" corridor agreements negotiated between state sponsors and host freight carriers; it is not related to the "unreasonable delay" standard for freight operations incorporated in the governing statutes that guarantee Amtrak access to the lines of freight carriers (49 USC 24308).

Crewing and dispatch procedures require that the operational assessment extend at minimum to the geographic limits of the crew district(s) in question or (rarely) to the second crew change point in a given alignment.

Protecting the service integrity of freight service may occasionally be most effectively addressed by incorporating infrastructure improvements that are well removed from the area slated for new passenger operations. Funding to allow a recent expansion of service in the *Capitol Corridor* includes track upgrades for Union Pacific in the mountainous Donner Pass area as the most cost-effective mitigation for the impact of new passenger operations west of Sacramento. The same approach has been used on several occasions by Maryland Transit Administration's MARC investing in "off-line" improvements for host railroad CSXT to improve commuter rail operations. Such scenarios most often come to play where the area of new passenger service is in a congested urban environment or where topographic challenges are severe and very costly to address.

2.10 Railways Are Not Highways

Persons who are unfamiliar with railway operations and infrastructure are often unfamiliar with the far more restrictive conditions that govern the movement of trains. Long stopping distances, restrictive engineering specifications, and a general lack of routing and diversion options mean that impacts on a modest section of track can have far-ranging network service implications. Appendix A attempts to describe some of the more common elements that directly play into the ability of a given corridor to support reliable train service.

A major aim of this guidebook is to arm users with a better understanding as to why detailed technical analysis is essential in planning of shared corridor operations. The limitations of a typical rail corridor are in sharp contrast to the flexibility and routing options available to users of the highway network. Some observers would like to see a "hierarchy of improvements" defined that would list, in order of effectiveness, the investments that best deliver increases in capacity and service quality. Unfortunately, no such list exists. The unique physical characteristics of each corridor dictate the most cost-effective order of investments.

As an example, simple, parametric corridor modeling might indicate the addition of a passing siding to be the best initial improvement, but on-the-ground conditions in a more populated area often preclude the construction of sidings due to grade crossing obstruction or right-of-way limits. Finer calibration and spacing of train control signals may improve the density of traffic, but the benefit of such improvements will be limited where long, heavy trains with long stopping distances dominate the alignment. At the end of the day there are no major shortcuts to performing the "real" assessment of service capacity for the corridor under consideration.

2.11 What the Models Leave Out

As noted above, the service capacity of a given service alignment is a product of far more than the scale and configuration of the fixed physical plant. Stakeholders identified a number of elements that should be taken into account that are not automatically included in a technical capacity modeling exercise:

- *Access and egress timing and congestion at freight terminals; adequacy of yard leads to accommodate the longest trains now in service.* Carriers have taken advantage of distributed power technology to dispatch longer trains than were deemed feasible even 10 years ago, but fixed plant infrastructure around terminals has not, in many cases, been adjusted to accommodate the longer train lengths.
- *Service recovery capabilities.* The FRA suggests that a number of random events should be inserted into the simulation exercise to reflect derailments, grade crossing incidents, equipment failures, severe weather impacts, etc., in order to test the network's capability, over time, to return to normal operations.
- *Routing alternatives.* Parallel diverging routes through an interlocking provide flexibility in case of unplanned events and support service recovery efforts as described above. A simple simulation may give no credit to such features as part of the base infrastructure configuration.
- *Capital and maintenance practices.* Simulation modeling is generally configured to assess "normal" operations and is poorly suited to contrasting the impacts of alternative maintenance and capital renewal strategies. Greater constraints on track time availability in shared-use corridors increase the value of a disciplined, well planned approach to maintaining and renewing the physical plant.

Development of clear strategies to address each of these elements will support the formal requirements of FRA in approving applications for new service as well as the corollary project funding requests. The FRA specifically requires plans to guarantee a "state of good repair" for the fixed plant as well as "Service Outcomes Agreements" with the service provider, service sponsor, and host railway corridor owner.

2.12 A Model Is Not a Strategy

A common caution expressed by stakeholders from each of the major target groups was the danger of simply relying on the technical modeling tools to define investment approaches and timing. Simulation models are "tactical, not strategic" and should be employed as one of several tools to define the best approach for developing a shared-use corridor.

The preceding section above summarizes the shortcomings of capacity and simulation technical tools that must be acknowledged and managed as part of the planning for shared operations. Today's freight rail environment is dynamic, with nearly abandoned lines being brought back into full service and entire new markets emerging from the shift in America's energy development priorities. Trade patterns are shifting, and some experts forecast a major repatriation of consumer manufacturing to the U.S. over the next 10 years. Rail intermodal service is viewed as more competitive for domestic freight, owing to rising fuel prices and continuing challenges with long haul truck driver recruitment and retention.

Host freight carriers have, in response to these trends, become even more protective of freight service integrity than in the past. Better management tools have highlighted the true network costs of unplanned events and out-of-position resources. Penetration of shorter-haul freight intermodal markets will require more stringent performance standards, with some trains operating at levels of scheduling discipline once exclusively preserved for passenger service. Finally, the rapid emergence of entirely new markets for rail has shaken the traditional, conservative forecasting bias that assumed that rail freight would grow only as a product of freight market segments where the rail mode has traditionally been strong.

For passenger service sponsors, the challenges may lie in understanding the underlying infrastructure and service design details that may in turn drive significant changes in the outcome of a capacity/operations assessment for a given line. Speed differentials for passenger and freight, peak period frequencies, and station track configurations may be tested for their impacts on total required new investment.

The FRA notes time and again the value of having all stakeholders around the table in developing a new service. Sharing of knowledge, building of trust, and joint exploration of alternatives can get the required partnerships off on the right foot and mitigate the inherent risks associated with the transition into a more complex operations environment.

2.13 Capacity Modeling—The Bottom Line

Stakeholders emphasized the need to do specific, detailed capacity and service assessment as a foundation for developing new passenger rail services on a multi-user corridor. While the technical analysis must be specific to the corridor, there remain some common process principles that apply generally to new service assessments:

- Obtain up-front, transparent agreement on the technical definitions for service performance by all classes of trains—on-time performance, transit times, service reliability, and the ability for service to recover from unplanned events.
- Obtain up-front agreement on the long term volume of trains that each class of users intends to move through the corridor at the end of a 20-year period. The corridor should first be

assessed for that 20-year scenario and the analysis then worked backward to determine logical breakpoints for service frequency, speed, and investment.

- Appreciate the limits inherent in railway physical plant and the need, more often than not, to extend an analysis to points beyond the physical boundaries of the proposed new passenger operations.
- Explore all of the drivers of service capacity rather than focusing exclusively on the fixed physical plant. Dispatch systems and protocol, capital maintenance and renewal practices, and rail terminal fluidity each have a major impact on effective service delivery but are not automatically captured in a modeling and simulation exercise. Stress tests can be performed to account for unplanned events, such as extreme weather or other natural events.

The chapters that follow elaborate on these principles and show how they have played out in real-world shared corridor situations.

CHAPTER 3

Analytical Approaches to Line Capacity in Shared-Use Corridors

3.1 Introduction

This chapter provides a detailed description of capacity analysis methods and tools to assess the ability of a rail line segment to carry a given volume and mix of railroad traffic, while meeting the service quality goals of the operator or operators. Capacity is a function of:

- Physical characteristics of the line segment, such as single or double track, distance between passing sidings, signal system characteristics, permitted speeds for different train types, curvature and gradients.
- Traffic volume and characteristics, such as the numbers of trains of each type traveling over the line in a specific period of time (e.g., 24 hours), speeds, train length and weight, locomotive power assigned to each train, and stops for passenger stations or to drop off and pick up freight cars from industry sidings.
- Management practices and protocol, including dispatch procedures, safety regulations, and treatment of train movements through passenger terminal areas.

As discussed earlier, capacity may be considered adequate when each user of the line segment is able to meet service quality goals for its rail services using a line segment. For a passenger service operator the service quality goal may be to achieve a given percentage of on-time arrivals and/or ensuring that individual train and aggregate delays do not exceed an agreed level. For a freight service operator, service goals will depend on service type, e.g., an intermodal train may be required to meet punctuality goals reflecting commitments made to customers by the railroad; but for other train types the railroad's objectives may be to minimize delays and unnecessary stops and starts that add to fuel, employee and other costs.

Given the large number of factors that must be considered in assessing a rail line's capacity to carry a defined traffic volume and mix, use of a structured analysis method is essential. These vary from relatively simple manual methods used on low-traffic lines or for simple scoping studies, up to complex simulation models for busy lines. This chapter provides detailed discussions of the following aspects of capacity analysis:

- The complexity of railroad operations, and why structured analyses are essential for the successful planning and implementation of rail passenger service on shared corridors.
- The principal factors that affect line capacity and which must be addressed in capacity analyses.
- The principal classes of capacity analysis tools and their application to rail service planning. This includes both preliminary or scoping analysis, and highly detailed analysis to support major infrastructure investment decisions and contractual commitments.
- Descriptions of individual capacity models. These include data requirements and strengths and weaknesses.

3.2 Complexity of Shared Railroad Operations

Section 1.3 of Chapter 1 provided a short introduction to railroad operations, describing some of the major features and defining common terminology. This section amplifies that discussion by introducing some other key factors that must be considered in capacity analysis. In particular, rail operations are confined to rails and must be actively managed to work efficiently. This is unlike highways, where individually operated vehicles are free to navigate the highway network as they wish provided they observe traffic laws and signals. Some of the key factors are as follows.

- *Most rail lines and certainly lines shared by freight and passenger trains have to accommodate trains with very different performance characteristics.* A loaded bulk commodity trains, such as a 120-car coal unit train, could weigh 18,000 tons (including four locomotives), have a maximum speed of 40 mph, and be assigned locomotives providing only one horsepower per ton (hp/ton) of train. Acceleration and braking are slow. An intermodal train, carrying highway trailers or shipping containers, will be assigned 2 to 4 hp/ton and will accelerate more quickly, but could be up to two miles in length and slow to enter and exit sidings through low speed switches. In contrast, an intercity passenger train will be relatively short, be provided with up to 9 hp/ton power, be able to brake and accelerate relatively quickly and be quick to enter and exit sidings. This variability of train lengths, power and braking characteristics presents dispatchers with a typical dilemma: stop a freight train at a passing siding, causing a substantial delay and possible capacity impacts; or stop a passenger train at a siding to allow the freight train to pass at line speed, maximizing capacity but delaying the passenger train.

  Please see Figures 3-1, 3-2, and 3-3 showing aforementioned train types, and Table 3-1 showing illustrative characteristics of these train types.
- *Train performance over a line segment is a simple function of geography.* Permitted speeds on curves differ between passenger and freight trains, and uphill speeds on grades are a direct function of train power-to-weight ratios. As with the other factors mentioned in the previous bullet, these have to be considered by the dispatcher in managing operations over a line segment.
- *Many freight trains and some passenger trains travel long distances between terminals.* Distances can vary from several hundred miles to over 2,000 miles, for example, between the West Coast and Chicago. Operating events several hundred miles away can affect operations over a specific

Photo by Walt Schuchmann

Figure 3-1. Coal unit train.

Photo by Justin Fox

Figure 3-2. Intermodal train.

Photo by Justin Fox

Figure 3-3. Intercity corridor passenger train.

line segment, causing delays that can propagate quickly through a large railroad system. This is why it is often necessary to perform capacity analysis well beyond the territory proposed for passenger service. Large railroads have concentrated most of their operations management and dispatching in network-wide centers so as to better manage operations over a wide area.

- *Track and signal systems must receive regular inspections and maintenance to function reliably.* This requires access to the track for maintenance crews, preferably in daylight, and for movements by automated inspection vehicles. Even with well managed inspection and maintenance programs, unplanned failures of any element in the system will occur, especially in extreme weather. Ice and snow will clog switches, high temperatures cause track to buckle laterally,

Table 3-1. Illustrative characteristics of different train types.

Train Type	Length	Gross Weight in Tons	Typical Max Speed	Horsepower per Ton
Coal unit train	6,500	18,000	40	1
Intermodal	7,500	8,000	60	2 to 4
Corridor/commuter trains	600	600	80	6 to 9

and locomotives can fail for a variety of reasons. Operations must be managed taking into account regular inspection and maintenance requirements, and an expectation of typical unplanned delays.

The above paragraphs are an introduction to the complexity inherent in railroad operations. In general terms, the complexity is similar to other transportations systems, but operation on fixed tracks limits flexibility and places a premium on skilled operations management. Of course, it is also operation on fixed tracks combined with centralized management and the use of automated systems that enables railroads to move high volumes of freight and passenger traffic safely and without interference from other surface transportation systems.

3.3 Main Line Capacity Factors

The goal of capacity analysis is to determine the maximum practical traffic volume and mix that can be accommodated on a specific line segment, while meeting service quality expectations for each traffic type. Some of these factors are fixed in the medium term, such as track and signal system characteristics, while others may vary by time of day, day of week, or seasonally. Traffic volumes are particularly subject to short term variability, as well as allowances for maintenance and typical service disruptions. In summary, these factors are:

Infrastructure capacity factors

- Number of tracks and distance between passing sidings and crossovers.
- Curves and grades.
- Signaling and train control method, such as ABS, CTC, ATC or PTC as defined in Section 1.3.
- Allowable speeds for each type of train, taking into account curvature, grades, switch types, and signal and train control method used.

Operational capacity factors

- Volume and mix of traffic: the number of trains per day for passenger trains and each type of freight train.
- Expected variability in traffic mix, including daily, weekly, and seasonal variations.
- Train characteristics: number of cars and locomotives assigned to each freight and passenger train, with aggregate train weight and locomotive horsepower.
- Train priorities.
- Availability of train crew and other operating personnel, especially at crew change locations. Train crew must be replaced when they reach the maximum hours of service prescribed by FRA regulations. Unplanned crew changes away from regular crew change points are very disruptive and must be avoided.
- Estimated time periods and locations when track will be unavailable for service for maintenance or to respond to unplanned events.

Taken together, these factors govern the usable capacity of a line segment. Capacity is not a hard mathematical number. Rather, the capacity of the line segment is better expressed in terms of average delay to each type of train. A capacity limit is reached when delay statistics exceed acceptable limits for each type of traffic. Operations may still be feasible with more trains, but the delays will prevent the railroad from meeting customer expectations and ultimately damage the business and/or increase costs.

When traffic increases, the negative effects of rail traffic congestion increase, requiring the railroad to become more efficient or invest to increase capacity. Physical infrastructure changes, such as adding sidings and crossovers or shortening signal block lengths, are obvious measures, but are likely to be costly. Operations changes to increase capacity are likely to be less costly and can be implemented more quickly, but may be limited to smaller incremental improvements. Some examples are:

- *Lengthening freight trains, including using distributed power* (remote-control locomotives inserted part way along a train or at the end). However, train lengths may be limited by the length of passing sidings on the line segment.
- *Working with freight customers to enhance rail efficiency at industry sidings.* For example, a longer siding may mean that main track is not occupied while cars are dropped off and picked up at the siding.
- *Working with all users of the line segment to adjust schedules and train sequencing to reduce conflicts.*
- *Reducing the variability in train mix, where possible.* This may be an option where a railroad has alternative routes and can concentrate traffic types by route.
- *Improving inspection and maintenance equipment and practices to reduce maintenance track time and the need for unplanned repairs.* One passenger service provided funding for overnight maintenance to free up capacity for daytime passenger operations.
- *Investing in freight yard and terminal infrastructure and efficiency, especially additional track to accommodate trains entering the yard.* This will reduce the need for trains to occupy the main line while waiting to enter the yard.
- *Provide for directional running where parallel lines exist.* This will eliminate meets of opposing trains and thus enhance capacity and fluidity.

It is important to note that most operations changes are to freight operations, and a freight railroad hosting a passenger service will look for win-win opportunities where the change benefits both parties: providing capacity for the passenger service at the same time as maintaining or improving service to freight customers.

3.4 Rail Line Capacity Analysis Methodologies and Applications

3.4.1 Introduction

This section discusses the principal methodologies used in rail capacity analysis, as distinct from individual proprietary software packages available to the railroad industry. Together with the analyses, the discussion provides guidance as to when the analyses should be used. Simple analysis that can be accomplished in a few days might be suitable for initial screening of a wide range of rail service options, whereas complex simulation modeling will be needed for the detailed planning of a major infrastructure investment. Another factor is data requirements. A simple analysis might make basic generic assumptions about infrastructure and operations from basic line geography and daily train numbers, whereas the detailed analysis requires comprehensive data on train schedules and make-up, as well as relevant track and signal system information. The following paragraphs identify and describe the various modeling methodologies used in rail line capacity modeling, including analyses that are important elements in capacity modeling.

3.4.2 Scoping Models and Building Blocks

This section discusses less detailed modeling processes suitable for initial scoping capacity analysis. Scoping analyses might be used to compare alternative routes, or to compare between major alternatives for a transportation corridor, such as between minor upgrades to an existing line, a major upgrade providing higher speeds and more frequent service, or constructing an all-new right-of-way. This section also describes common modeling building blocks that are not complete models in themselves, but are often elements in a capacity model. The methods described are:

- Train Performance Calculator
- String Line Analysis
- Grid Time Analysis
- Other Preliminary Planning and Scoping Approaches

3.4.2.1 Train Performance Calculator (TPC)

A TPC (sometimes called a Train Performance Simulator or TPS) is used to calculate unconstrained journey time for a single train over a rail line segment. The train related inputs are train weight, locomotive power characteristics such as a speed versus tractive effort curve, train resistance from rolling friction and aerodynamic drag, and brake performance characteristics. Infrastructure and operations data include gradients, curvature, speed limits and location, and dwell time at station stops.

A TPC does not include any consideration of other trains operating on the corridor, but it is common to add a percentage to the minimum journey time to estimate a practical scheduled time for planning purposes. A TPC can also be used to estimate journey time changes resulting from increasing locomotive power, raising speed limits, adding or removing station stops, and similar changes. As an element in a capacity model, TPCs are used to calculate travel times between points where a train must slow or stop for a meet or pass, or to use a crossover or siding entry switch.

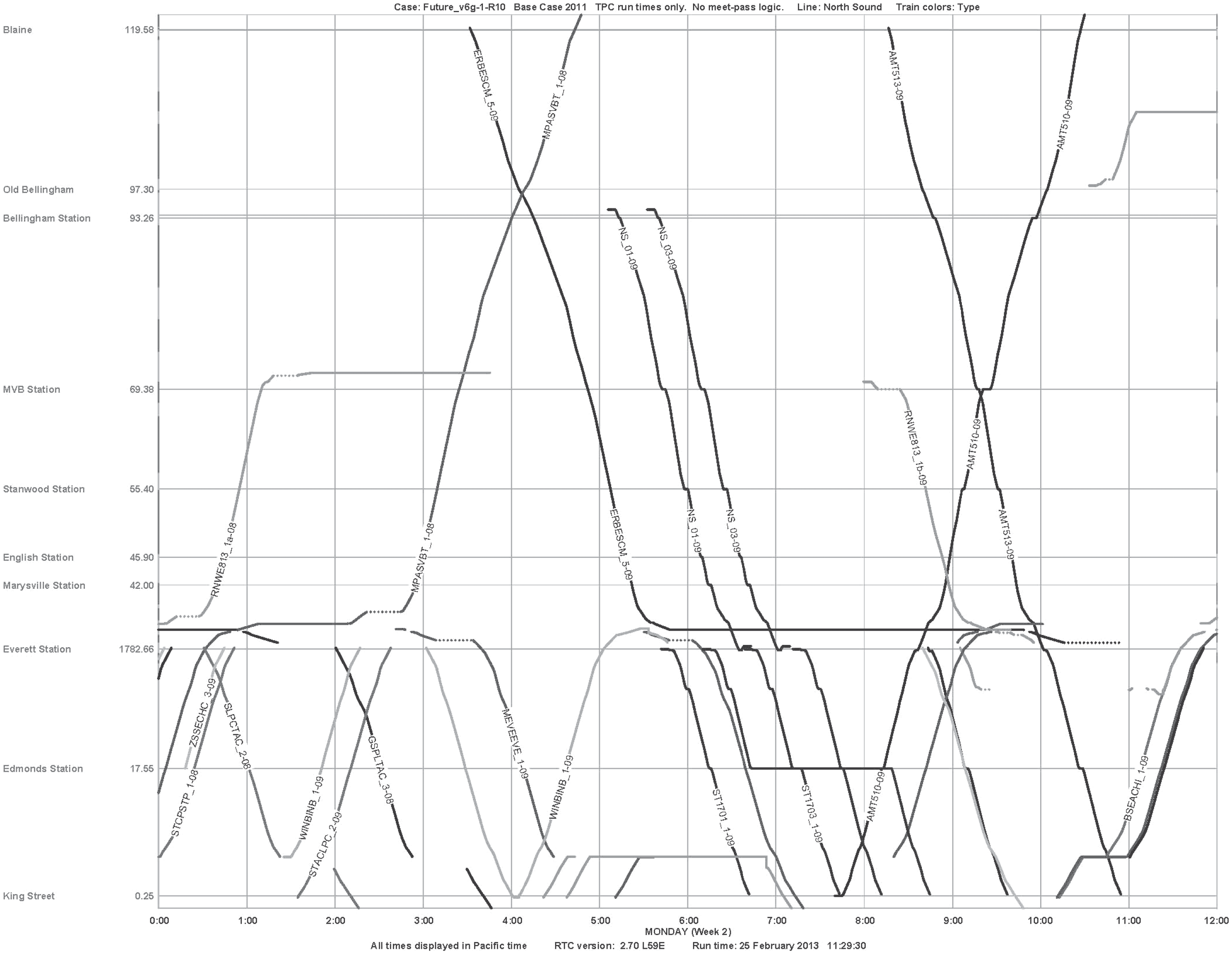
A TPC is also an essential component of all rail operations simulation models. Simulation models calculate the movements of all trains on a specific line segment in parallel over time, saving a snapshot of the operation at the end of each time interval and re-starting the calculation for a new time interval. Time intervals boundaries are set after either a fixed length of time or when an event occurs, such as a dispatcher decision to route a train into a siding. The TPC is used to calculate the movements of each train for each time interval given initial speed, terrain, train weight, locomotive power, and operating instructions applicable to each train at that time and location.

3.4.2.2 String Line Analysis

A string line chart is a representation of rail operations over a line segment on a time-distance plot. Figure 3-4 is a typical string line chart.

A string line chart is a time-distance plot showing all trains operating on a line segment over a given time period, most often 24 hours. Usually distance in miles is shown on the Y or vertical axis, which will also show station, passing siding or crossover locations. The X or horizontal axis shows time in hours and minutes. Train movements are shown as forward or backward sloping lines depending on the direction of travel. Steeper slopes indicate a faster train. A stationary train, usually at a passing siding or at a station stop is shown as a horizontal line.

String line charts are used in almost all capacity analyses. They illustrate present capacity problems by displaying what actually happens, especially delays at different points along the line segment. They are provided as one of the outputs from complex simulation analyses, along with delay statistics, journey time data and animations. They can also be produced manually. Furthermore, they are also a capacity analysis tool in themselves. String line charts display the results of "what if" exercises, such as adding additional trains, adding passing sidings or crossovers, adding double track sections, or changing schedules. String line analyses, typically of a representative 30-day period, provide realistic estimates of journey time and operating delays for each train operating on the line segment for each scenario and highlight problem locations for further study.



Source: North Sound Rail Operations Simulation, Whatcom Council of Governments, 2011.

Figure 3-4. Typical string line chart showing conflicts of opposing trains.

3.4.2.3 Grid Time Analysis

Another relatively simple scoping method is known as a grid time analysis, which is used to test the upper limit for the number of daily trains a corridor can handle, without consideration of individual train service commitments.

The theoretical capacity to handle traffic on single track is dictated by the time it takes a train to travel the distance between two sidings and clear the way for an opposing train. The time a train takes to traverse the single track section and be in the clear for the opposing movement is called the one-way grid time. The grid time varies as a function of the spacing between sidings and the average of train speeds in each direction. The single track segment on which the trains take the highest amount of time dictates how many trains can traverse a line in a day. This segment defines the capacity over the line as the number of trains that can be handled daily.

Figure 3-5 is an illustration of a representative grid time analysis calculation.

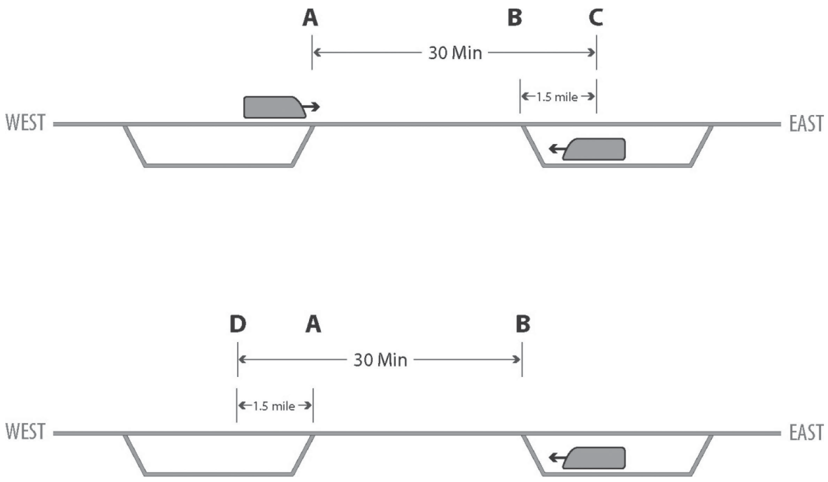


Figure 3-5. Representative grid time analysis calculation.

In the upper illustration, an eastbound train is progressing past one siding to another. The time it takes to run from being stopped at point A to point C is 30 minutes. C is 1.5 miles past point B, being a typical length of a longer freight train today. It is assumed that the eastbound train will come to a complete stop before it reaches the end of the eastern siding, until the track ahead is clear of any opposing trains. A westbound train is waiting in the eastern siding for the eastbound train to clear point B.

In the lower illustration, a stopped westbound train pulls out of the eastern siding just after the eastbound train has passed point B. It takes another 30 minutes for the westbound train to run past point D, 1.5 miles west of point A. It is assumed that the westbound train will come to a complete stop by the time it reaches the end of the western siding.

In all it takes the two opposing trains 60 minutes or one hour of grid time to cover the length of single track between points C and D. Thus the maximum theoretical capacity of this segment is two trains per hour or 48 trains per day.

The theoretical capacity calculation assumes the availability of an unlimited supply of trains at both ends of a line segment throughout the day. This is not realistic for actual operations, so a downward scaling factor is applied to derive the practical capacity of the line. The scaling factor reduces the theoretical number to reflect a typically uneven sequence of trains entering the track segment, as well as allowing for typical delays due to track maintenance work, slow orders, and unplanned service disruptions. As a general rule, the practical capacity of a line with one or more single track segments falls in the range of 50% to 75% of the theoretical capacity. A lower percentage could reflect assumptions about particular conditions due to the time of year, such as during the spring snow melt when ground may be soft over extended periods of time, requiring slower operations. The range can also reflect the bias of the analyst: a more conservative analyst, knowing fewer details about operations of a line, may assume a lower percentage to guard against potentially overstating practical capacity.

Over segments of double and triple tracks, calculating the practical capacity of a route is not as straightforward as on single track. Theoretically, the capacity is extremely high because trains can fleet behind one another, unimpeded by opposing traffic and limited only by the train speed and by the spacing between trains provided by the signal system. In practice, however, numerous other factors combine to reduce the effective capacity of multiple track segments. The most important ones are traffic mix (trains with different speeds, characteristics and customer requirements);, track outages for repairs and maintenance; spacing between block signals and interlockings; and queuing at entrances of terminals and junctions.

When dealing with multiple tracks, there is no cut and dried method of calculating this capacity and one can only address cases on an individual basis, through simulations or other methods, each with the cases' specific operating conditions. However, this does not preclude identifying trends and capacity ranges that these individual analyses have provided over time.

3.4.2.4 Other Scoping and Planning Approaches

Not all rail service capacity assessments are targeted to development of specific rail projects. Broad scale planning exercises may rely on the tools described below as a more cost-effective proxy for the detailed and time consuming modeling techniques which support specific contract and capital upgrade proposals for specific line segments. Some examples of these broader approaches include:

Parametric capacity estimate. Capacity is calculated from a "capacity formula" where the inputs are number of tracks, signal block lengths, train speeds, siding and crossover spacing, and mix of train speeds. Alternatively, tables or graphs derived from the formula may be used. The formula is derived from the capacity of a representative sample of line segments.

Generic linear programming and cost-benefit algorithms. These algorithms are attempts to optimize capacity by identifying the lowest-cost combination of actions to reach a specified capacity goal. This approach is promoted by many independent consultants and academic institutions as an attractive way of resolving capacity problems without using time consuming and costly simulation analysis. However, the approach treats service output as a dependent variable that is specified by the capacity-maximizing algorithm, and for this reason it is wholly inappropriate for situations with strict service requirements such as passenger rail.

National Rail Freight Infrastructure Capacity and Infrastructure Study method. This 2007 study used a simplified variant of the parametric relationship method. The study sponsor, the Association of American Railroads (AAR), in collaboration with American Association of State Highway and Transportation Officials (AASHTO), sought to depict upcoming rail network congestion nodes on a national scale. Capacity estimates were derived from analysis of national rail traffic and infrastructure data by route segment using only three key variables: number of tracks, signal system type, and train type. The specific variables were:

- Number of tracks: Between one and six.
- Signal systems:
  - No signals and Track Warrant Control. Track warrants are structured voice radio messages giving a train permission to occupy a defined track segment, usually between sidings.
  - Automatic Block System (ABS).
  - Centralized Traffic Control (CTC) or Traffic Control System (TCS).
- Train types:
  - Heavy bulk commodity and general merchandise freight.
  - Fast freight: intermodal and multi-level auto carrier trains.
  - Passenger service.

The analysis resulted in a table relating capacity to the three key variables as shown in Table 3-2.

These estimates are broad averages and do not include many factors known to affect capacity, such as siding spacing and length, curves and grades, and the power assigned to trains. These capacity definitions were useful in developing a national "rail congestion" map in that the required engineering data was consistent with that required of rail industry players in their annual regulatory filings.

Table 3-2. Estimated average capacities of typical freight railroad corridors.

		Practical Maximum Trains per Day	
Number of tracks	Type of Train Control	Multiple Train Types	Single Train Type
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
Note: Estimates for 5 and 6 tracks omitted.			

3.4.3 Operations Simulation Analysis Methods

Simulation analysis has become the principal method by which line capacity issues are resolved, both in North America and overseas. These models provide a step-by-step simulation of all trains operating on a specific line segment to create a complete and accurate picture of operations. The models incorporate a routine to simulate, or look up from schedule data, the arrival of trains at both ends of the segment, a TPC to simulate train movement over the line between signals, sidings, and crossovers along the segment, and a dispatching algorithm that mimics the behavior of a typical dispatcher making meet-and-pass and similar decisions. Model outputs include string line charts, journey time and delay statistics, and animations. The models are also capable of introducing random disruptions into the simulation, such as from unplanned maintenance of track and of equipment failures, and to test the robustness of the operation to recover from such delays.

Four simulation models have been identified.

- *NCFRP Web-based Freight-Passenger Rail Corridor Project Screening Tool.* This is a model developed under a National Cooperative Freight Research Program (NCFRP) contract. The research is described in *NCFRP Report 27: Web-Based Screening Tool for Shared-Use Rail Corridors.* It is a web-based tool designed for initial planning analysis and to be easily accessible to interested parties. Information on the web-based screening tool can be accessed at http://www.trb.org/main/blurbs/171116.aspx.
- *Berkeley Simulation Software's Rail Traffic Controller (RTC).* RTC is used by the Class I railroads, government agencies, commuter and passenger operators, and consultant groups throughout the railroad industry. The RTC system is particularly notable for its ability to simulate actual dispatch behavior on a North American freight railroad as it copes with high variability in the timing and volume of train movements.
- *SYSTRA's RAILSIM Program.* RAILSIM is primarily used by commuter and passenger agencies, Class I railroads, and consultant groups. Strengths of RAILSIM are its ability to simulate complex schedules of passenger operations and its associated features for planning equipment and staff resources needed for an intensive passenger service.
- *CANAC's RAILS2000 Program.* This tool has experienced a decrease in use over time and now has relatively limited exposure within the industry. It is used primarily within CANAC's consulting services.

Because of their complexity and importance, simulation models are discussed in detail in Section 3.5.

3.4.4 Modeling Objectives and Model Data Requirements

A key issue in capacity analysis, which affects how the models are used and the usefulness of results, is the level of detail in infrastructure and operations data needed by the models. All capacity models need these data at some level of detail to achieve their objectives. The accuracy of model results for a specific line segment depends directly on how closely the data represent actual infrastructure and operating conditions, including details of individual trains operating over the segment. An analysis relying on a generic parametric model using coefficients derived from a variety of actual operations cannot provide the level of detail and credibility that can be achieved by using a detailed simulation model. It follows that the appropriate use of the simpler models is to study broad transportation alternatives, such as between alternative routes, upgrade levels or between rail and non-rail alternatives. Once a broad alternative has been selected, then detailed modeling must be used to determine what capacity investments are required to meet planned rail service objectives. In most cases, such modeling is the only way to provide proper support for major infrastructure investments and to finalize contract agreements between users of a line segment.

Detailed analysis requires detailed data. If the rail line segment is operated by a public agency, such as a commuter rail authority or Amtrak, then detailed operation, track, and signal system data will normally be available to any responsible party interested in capacity analysis. However, if the line segment is operated by a private freight railroad, then much of the detail concerning rail operations may be proprietary and market sensitive. Data will only be released under strict confidentiality conditions, and the railroad will be sensitive to the interpretation of any results obtained.

The most common situation is where a public agency—for example, a state or regional passenger rail authority—is seeking to implement passenger rail service over one or more freight railroad line segments. There is tension inherent in this situation: the freight railroad needs assurance that a proposed passenger service will not interfere with freight operations, and the passenger authority needs to assure that state and federal funding is being spent responsibility and passenger rail service objectives will be achieved.

Recent practice has been for one party (usually the freight railroad) to manage the analysis, and for the other party (the passenger rail authority) to have access to capacity model methods, inputs and results. Trust and cooperation between the host freight railroad and the passenger authority are essential, and may involve considerable effort to overcome initial suspicions on both sides and to maintain trust over time. A fundamental step forward is for both parties to agree on the modeling input assumptions that drive the analysis.

Section 3.5 describes the mechanics of detailed modeling, including data requirements and the pros and cons of alternative simulation models.

3.5 Detailed Simulation Models

3.5.1 Technical Modeling Process and Data Needed

The detailed simulation models are used to determine whether a specific line segment has sufficient capacity for each rail traffic type moving over the segment to meet its service quality goals. Simulation analysis provides the most reliable and accurate way of making this determination. Five simulation modeling approaches have been identified, each with different strengths and weaknesses, as described in this section.

3.5.1.1 Input Data and Model Operation

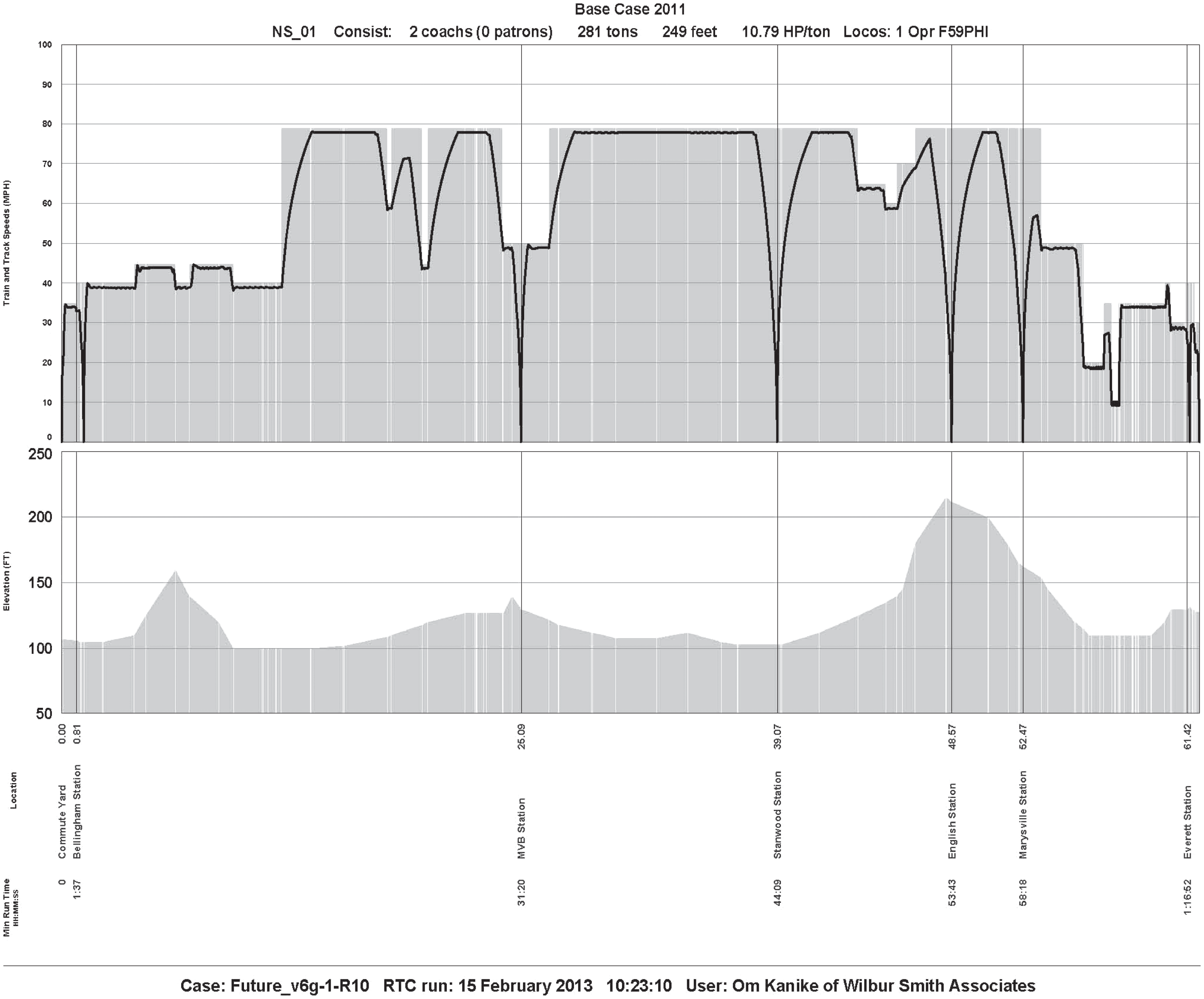
While different models may vary in level of detail and emphasis given to different aspects of a rail operation, the primary data input categories will be as follows:

- Details of the trains operating over the line segment, including weight, locomotive power and braking characteristics. The level of detail can vary between a generic freight or passenger train and the make-up of each individual train. These factors most clearly distinguish passenger from freight trains, and between different types of freight trains. As well as differences to power-to-weight ratios mentioned earlier, braking capabilities differ greatly between passenger and freight trains. Short passenger trains, typically less than 1,000 feet with automatic wheel slide protection systems (similar to ABS on an automobile), have higher braking rates and shorter stopping distances. In addition, because the train is short, the time taken to release the brakes by restoring air pressure in the brake system is short. With long freight trains (up to 10,000 feet), brakes must be applied slowly to avoid excessive longitudinal forces in the train, and the time taken to restore air pressure and release the brake is much longer than with passenger trains.
- Line segment infrastructure details, including passing siding locations and lengths, signal locations and signal block lengths, crossover locations, switch types, curvature and grade, and speed limits applicable to each traffic type. Signal system characteristics are critical to capacity. Signal block lengths and siding spacing govern the distance between trains, and they are a fundamental limit on capacity. Although most line segments being analyzed will be equipped with CTC, with remotely controlled switches and signals, some lower-traffic locations will only have ABS with manually operated switches at passing sidings. In this case, the time taken by train crews to operate switches must be factored into the simulation. PTC, when implemented, may impose conservative braking characteristics on trains to ensure they can always stop before a stop signal even under adverse braking conditions.
- Traffic and operations data. For passenger trains the data may include the planned schedule and statistics for average schedule deviations due to factors other than interference from other rail traffic, such as over-staying time at a station stop and operating delays outside the line segment being analyzed. For freight trains, many of which are likely to be unscheduled, arrival time at the line segment must be represented by a probability function.

The modeling process can start once the train, infrastructure, and operations data have been entered into a model’s database. The process involves first using passenger and freight operations data to initiate trains entering the line segment in chronological order. The model may use Monte Carlo randomization methods to represent the uncertainty in freight train operations. Then, train movements are simulated by the TPC function of the model applied to each train, and the dispatcher simulator function of the model is used to resolve operating conflicts as they arise. The model can also introduce operations disruptions, such as slow orders and delays due to external factors, using data representative of typical operations.

The result is a detailed description of the movement of each train through the line segment. It is usually necessary to run the simulation for several days to fully capture random effects, typically a week to a month (7 to 30 days). A highly detained simulation involving hundreds of train movements per day over several days or weeks can be run in a matter of a few hours, or less. A range of operating statistics may be derived from each model run; the statistics include trip times and trip time variability over the line segment and average delays to each type of train. Other outputs include string line charts, animations, locations where delays occur, and train speed graphs.

A train speed graph is shown in Figure 3-6.



Source: North Sound Rail Operations Simulation, Whatcom Council of Governments, 2011.

Figure 3-6. A typical train speed graph.

Normally the initial and final periods of the simulation are discarded as unrepresentative. These warm-up and cool-down periods can range from a few hours to a day each.

These data are compared with the requirements for each type of rail service to determine whether or not capacity is adequate.

3.5.1.2 Analyzing a Shared Passenger/Freight Rail Corridor

The analysis of a real passenger freight corridor normally involves defining a series of rail traffic scenarios and determining capacity adequacy for each. Observed service deficiencies are then isolated for each such scenario and additional model runs performed to test alternative investment and operations approaches. The outcome of this iterative process is to define the best combination of inputs for increasing capacity and enabling each user of the facility to meet service speed and integrity goals, and to determine a fair distribution of investment costs between the users.

It is also necessary to consider planned or likely changes in passenger and freight traffic over a term of up to 20 years. This is because track access agreements between freight railroad and a passenger rail operator should have a long life to avoid frequent renegotiations. FRA also requires 20-year service and infrastructure assessments as a condition of federal funding participation in such projects. Only by first taking a longer view can private and public sector stakeholders be assured that early phase commitments will not be wasted as a more mature service structure evolves.

While each corridor will need an analysis plan tailored to local circumstances, a typical sequence of capacity model runs for new or additional passenger rail service would be as follows:

1. *Base Case.* The base case simulation is of present passenger and freight rail traffic and other conditions on the corridor under study. Model results are compared with actual corridor performance over a minimum 7-day period, and are used to calibrate the model for this specific corridor. The calibrated model is then available for further capacity analyses of the corridor.
2. *Freight Traffic Growth Case, without Capacity Improvements.* This case includes estimates of freight traffic growth, usually for the 5-, 10- and 20-year time horizons, to indicate when additional capacity would be needed to maintain freight service quality. Generic freight volume growth estimates (such as the Freight Analysis Framework from FHWA) are used to develop longer term projections in the absence of specific market and lane data. This case can actually be a series of cases, depending on freight growth assumptions and the timing of same.
3. *Freight Traffic Growth Case, with Capacity Improvements.* This case will be guided by the results of Case 2 showing the locations and types of capacity problems, if any, that need to be corrected to maintain service quality. Like Case 2, it can be a series of cases, depending on the freight growth assumptions and timing of same.
4. *Initial New Passenger Service Case, without Capacity Improvements.* Additional passenger train trips are added to the base case and results reviewed for both passenger and freight traffic. If both still meet service requirements, then no immediate capacity improvements are required. If service requirements are not met, then analysis of capacity improvements is required, as in Case 6.
5. *Initial New Passenger Service Case with Capacity Improvements.* This case explores candidate capacity improvement options, guided by the results from Case 4 as to where and when capacity problems (e.g., delays) occur. The results will allow the analyst to select the most cost-beneficial improvements for passenger service.
6. *Ongoing Analysis Cases.* These cases combine new or additional passenger service with expected growth in freight traffic to determine what capacity improvements are needed to achieve desired service quality goals for all traffic types using the corridor. The cases will consist of various scenarios with differing assumptions of passenger and freight traffic on the corridor.

While capacity analysis is essential for planning improvements on a busy rail corridor, it does not provide a complete answer. Capacity analysis does not take into account all factors that must be taken into account in decision making. Most models do include impacts for entering and exiting freight terminals, where a lack of capacity can affect adjacent main line segments.

Furthermore, the incidence of service disruption due to track maintenance or slow orders, as well as unplanned events, can be underestimated. That noted, it is possible to simulate a number of conditions that may affect operations over a specific corridor, such as a track outage due to weather conditions, signal failures, train coupler failure, etc. The goal is to test the recoverability of the operation given a fixed rail infrastructure.

Also, capacity analysis in part is an art, where experience of past analyses and actual performance outcomes will influence the interpretation of results. Openness and good communications among all stakeholders is essential to acceptance of results and buy-in by all.

3.5.2 Descriptions of Individual Capacity Models

This section describes various capacity analysis tools that rely on the simulation of rail operations over a selected rail corridor.

3.5.2.1 NCFRP Web-based Freight-Passenger Rail Corridor Project Screening Tool

The National Cooperative Freight Research Program's (NCFRP) Web-based Freight-Passenger Rail Corridor Project Screening Tool is a preliminary screening tool to evaluate the effects of adding new passenger rail service to existing freight or shared-use rail lines. Also known as the Shared-use (SU) Tool, it is designed to meet the need of public agencies with limited resources in identifying rail corridors that merit further investigation as candidates for shared-use service. Representatives from Class I railroads, the Association of American Railroads, commuter rail operators, state Departments of Transportation and the Federal Railroad Administration have overseen the development of this tool.

The SU Tool uses a refined TPC, incorporating graduated tractive effort and dynamic braking curves to reflect train-handling practices. Resistive forces on the train are calculated on a car-by-car basis every 500 feet or less, accounting for changes in terrain and track curvature. The tool implements a deadlock-free dispatching algorithm to closely mimic actual train operations on complex, shared-use territories. Slow orders and track outages for maintenance and inspection may also be incorporated into the simulation.

The tool complies with the "Railroad Operations Analysis" described in the FRA's 2005 guidance manual for rail corridor planning (Reference: *Railroad Corridor Transportation Plans: A Guidance Manual*, Office of Railroad Development, RDV-10, Federal Railroad Administration, July 8, 2005, pp. 14-15). Operations over corridors are simulated with specific topographic detail, speed zones, and train schedules and their corresponding variances. As trains are simulated over alternative paths on multi-track corridors, operational string lines over a 24-hour period are developed for analysis purposes to test alternative design strategies. Results are identified with minute-by-minute train metrics on string line and block authority visualization. Train performance is measured in minutes of delay by individual train and by train type: passenger, freight, intermodal, and other types as defined by the user. The tool evaluates the capacity effects of track infrastructure improvements and scheduled track outages.

The SU Tool has a meet-pass logic that allows it to automatically resolve conflicts of opposing trains on the basis of priority, as well as allowing high priority trains to pass (overtake) slower trains. RTC, described herein, has a similar capability.

As with all simulation models, the reliability of output from the web-based model is a product of accurate track infrastructure data and train consist and train schedule information. Track survey data can be imported directly into the tool or entered using a graphic track visualization screen. Default equipment libraries help users develop train consists, and other input screens track train schedules and time table routes.

3.5.2.2 Berkeley Simulation Software's Rail Traffic Controller

A widely used model for shared-use passenger and freight operations is the Rail Traffic Controller program developed by Berkeley Simulation Software. It is a computer simulation model that mimics human dispatching decisions that would be made to send trains through a rail subdivision and/or network. In addition to evaluating train movements, the model has the ability to estimate the impact of changes to rail infrastructure and train movements. Both cost and performance are continuously recomputed for a given track configuration to minimize cost of delay for trains involved. RTC is commonly used to develop operating plans, diagnose bottlenecks, recommend schedule changes, evaluate various improvements to the rail infrastructure, and assess the impact of adding new trains to the corridor.

The model has been used for providing potential locations for main track improvements, sidings, turnout speeds, turnout locations, train control system improvements, and train operation changes. It is the most widely used capacity planning/simulation tool used in the railway industry in the United States. Its use of corridor animation has allowed technical and non-technical users to understand and comprehend the corridor operations and the needed infrastructure improvements. All seven Class I railroads in the U.S. plus Ferromex in Mexico and Amtrak have this software in-house and require their consultants to use it when dealing with their operations. Having the standardized model already in place, with the basic corridor information within the RTC database, reduces the effort and time needed in conducting detailed evaluations of a corridor's capacity.

RTC, as other sophisticated models, incorporates a Train Performance Calculator that determines the minimum run time of a train between two points, taking into account the alignment, gradient, allowable speed of the track, the horsepower and tractive effort of the locomotive, the tonnage, length and make-up of the train, and the specific physics of energy and resistances in having the train move across the corridor. It is the key component of the simulation system that replicates the actual movement of a specific train over a specific corridor. The resultant performance calculations are then incorporated by the Train Dispatch Simulator (TDS) that replicates and simulates the movement of all trains over a corridor. Whereas the TPC evaluates the performance of a specific train, TDS projects dispatch management decisions for all train movements and interactions over a corridor.

The simulation process to test the effect of adding trains over a corridor utilizes standard railroad capacity planning procedures. That is, RTC is run first with the base case or existing train pattern operating over the corridor. The base case includes all current freight traffic, mixed freight and passenger trains, and local freights. Subsequent simulation runs test the effects to the overall operations under increased traffic patterns (viz., planned freight traffic growth and introduction of passenger traffic). This testing allows for the determination of operational effects that occur to existing freight traffic, while prioritizing passenger trains. It also allows for quantifying average train velocities and delay statistics as line capacity under existing and proposed railway track conditions is consumed.

RTC's chief attractiveness for freight railroads is its meet-pass logic, reflecting priority-based opposing train conflict resolutions. This is indeed the way railroad dispatchers resolve opposing train conflicts, so railroad executives have faith that RTC can accurately simulate their operations. Also, its graphical display of results, where a viewer can watch a train's progress along a rail line, including delays, are useful in communicating the analysis and its implications to decision makers. Another advantage is that most Class I railroads have created an RTC database for most of their main lines. This reduces the cost and duration of capacity analyses on these lines: only data on proposed infrastructure and operations changes needs to be entered before running a simulation analysis. RTC base case assumptions and output may also be calibrated against existing operations as a means of improving the credibility of future case service/infrastructure scenarios.

All this capability comes at a cost. RTC analysis requires extensive data gathering and labor hours for the analysis. RTC licenses for using the program are also expensive to acquire.

3.5.2.3 SYSTRA Inc.'s RAILSIM

Another widely used simulation program available for use is SYSTRA's RAILSIM Simulation Software Suite which is used to model and analyze operations on the most complex rail networks, including transit (light rail and heavy rail rapid transit), freight rail, commuter rail, and mixed main line railroad traffic. Though not as popular as RTC within the North American rail industry, it is used by commuter and passenger agencies due to its ability to simulate train movements within controlled terminal areas.

The RAILSIM package includes simulation and design capabilities for many types of train control systems, including fixed block and moving block systems. RAILSIM support for communications-based train control modeling and analysis includes flexible menu-driven inputs for buffer distances, communication times and system latency, under speed settings for typical operation, and guaranteed brake rate settings. The RAILSIM database also supports site specific definition of re-localization beacons, the wayside-to-train communications devices that serve to reset any accrued error in the determination of the current position of each train on the track.

As with other complex models, RAILSIM uses a TPC as the basis for train operations over a defined corridor. Following the TPC development and network setup, complete simulations over the corridor can then be run testing the operations and quantifying the capacity under new signal and/or infrastructure design under various "what if" analyses.

While popular for transit planning and frequency commuter line analysis, its lack of meet-pass logic for resolving train conflicts based on priority limits its attractiveness for analyzing unscheduled freight operations.

3.5.2.4 CANAC Inc.'s RAILS2000

Another program available for use is The Railway Analysis and Interactive Line Simulator (RAILS2000) model from CANAC Inc. The program replicates the operations of a corridor and tests the effects of changes (infrastructure changes and/or traffic changes). The software is owned by CANAC Inc., currently a wholly owned subsidiary of SAVAGE Companies. The model, originally developed by Corporate Strategies Inc. (CSI) of Washington, DC, was acquired by CANAC in 1999.

RAILS2000 is an event-based simulation model and, as with other models, it contains a TPC that drives the movements of individual trains within the simulation. The software also contains a TDS which simulates the dispatching and control of trains over a defined route or network of lines. The TPC evaluates the performance of a single train over a given track, whereas the TDS is used for multiple trains over a network of tracks. The software is logic-based, with optimizing capabilities deliberately restricted to emulate real-world limitations of train dispatching. The model is capable of handling multi-track main line corridors and signals for both freight and transit operations.

The program provides a consistent, reproducible, and inexpensive procedure for evaluating alternative railroad line and terminal configurations and train operations. It is a powerful tool for quickly establishing train schedules (timetables), analyzing service reliability, examining capacity issues, evaluating impacts of construction and maintenance delays (including work on road crossings and bridges), identifying conflicts, and evaluating alternatives. Computerization of operations analysis allows rapid, economical evaluation of a large number of complex alternatives.

At one time, RAILS2000 was used extensively by CSX Transportation and Canadian National Railway, but was gradually replaced by RTC because as the Class I freight industry migrated to a common modeling platform. RTC also has superior simulation graphics that more easily enable translation of technical model outputs to lay audiences. Although now much less popular than the RTC or RAILSIM, RAILS2000 has been a proven tool used on select projects throughout North America.

3.5.2.5 Other Models

Other proprietary models from consultant and academic groups in the marketplace exist, though detailed information about how they work may not be readily available. Some less sophisticated models incorporate various linear programming techniques to allow varying levels of corridor analysis following field calibration. Such models require basic train running times between nodes to be directly input and used as the fundamental operational criteria for current and proposed operations. Their value is that a relatively quick, high level analysis can be performed but a more detailed, data intensive approach will still be required in advance of any specific project designs.

3.5.2.6 Summary of Simulation Models

Within the railroad industry, the main two simulation tools currently utilized are the RTC and RAILSIM packages. Both have proven their robustness and have incorporated physical principles of equipment and specific territory. At the same time they are comparatively easy to employ for technical and non-technical users. They have developed an extensive equipment database and sophisticated and proven train dispatch algorithms and train control systems. Animation has allowed the results to be explained and represented to non-technical users and thus enabled a better buy-in by stakeholders examining specific corridors. Whereas RTC has been embraced by the freight industry, RAILSIM is used primarily by the passenger/commuter rail industry. RAILS2000 model is also an excellent model with ease of use and accurate results, but it has been eclipsed by RTC as the model of choice by the freight rail industry due to its lack of operational animation.

A model with limited use in complex situations, the NCFRP web-based SU Tool is a screening tool capable of evaluating rail capacity on shared-use rail corridors. It offers some of the same basic fundamentals that the RTC or RAILSIM offer and with a quick turnaround response, but it does not obviate the need for analysis with more robust modeling tools. It can be used in the early stages of a project's development in support of a basic, exploratory "feasibility study."

The use of such tools as described above may be complex and time consuming. One advantage, however, is that use of a model already employed by one of the host carriers may save substantial time and resources where the corridor in question has already been encoded into the software platform. Much of the time and energy consumed in employing such tools relates to the initial setup and the high level of detail required in the physical plant description.

Use of a standardized modeling tool allows the analytical process to focus on evaluating the operations alternatives and developing sound recommendations. Once the fixed plant database is in place (and depending on the complexity of operations) varying scenarios can be quickly and easily tested for a specific corridor.

Animation and its internal logic are perhaps the greatest attributes that RTC brought before the rail industry. Its ability to animate train operations for viewing by management and non-technical stakeholders (rather than with string lines and mathematical reports) was key to its acceptance as the tool of choice by the freight railroads. Results presented with simple animation allow management and stakeholders to quickly understand the existing issues and recommendations quickly.

RAILSIM's ability to simulate high frequency train operations in a controlled environment has been key in its acceptance by several transit agencies.

In summary, a simulation model is simply a tool that allows the stakeholders to model a specific corridor and to develop mutually agreed upon infrastructure improvements for the chosen operation. The acceptance by the rail industry of the RTC and RAILSIM models has permitted the current developers to continually reinvest in development opportunities to maintain technological relevance when dealing with current and future train operations. Whereas the use of other models is continually evolving, no other models as yet bring to the table the same level of technical sophistication and stakeholder acceptance. The Class I railroads and many transit agencies have embraced RTC and RAILSIM as essential tools for planning and extracting maximum productivity from their expensive and increasingly crowded track networks.

CHAPTER 4

Best Practices

4.1 Introduction

Presented herein are three case studies that illustrate various capacity assessment methodologies to determine if adequate line capacity exists given specific assumptions about the train mix, volume, and operating patterns.

The first case study, a conceptual ***grid time analysis*** of the LOSSAN Corridor in Southern California, served as a means to help public agencies along the corridor understand the range of capacity enhancements required over time to ensure fluid passenger and freight operations.

The second study relates the results of an ***RTC operations simulation*** for the start-up and build-out of the New Haven-Hartford-Springfield (NHHS) commuter rail service. That service will share the Amtrak Springfield Line with Amtrak and freight train traffic starting in 2016.

The third case study compares findings of an ***RTC simulation***, a ***grid time analysis*** and an application of the ***NCFRP web-based SU Tool*** brought to bear on a start-up of proposed regional passenger rail operations along the North Puget Sound (hereafter, North Sound) between Bellingham and Everett in Washington State.

As study team members for this guidebook had worked on the LOSSAN, NHHS, and North Sound analyses, these cases were selected to illustrate the various capacity assessment methodologies.

4.2 LOSSAN Corridor Capacity Investment Planning

4.2.1 Introduction

The 351-mile-long LOSSAN Rail Corridor between San Luis Obispo, Santa Barbara, Los Angeles and San Diego is the second busiest passenger rail corridor in the U.S., second only to the Boston-to-Washington Northeast Corridor. More than 7.2 million passenger riders make trips on LOSSAN Corridor trains annually. (Reference: *LOSSAN Corridor Strategic Implementation Plan*, San Diego Association of Governments, April 2012.) Looking toward a future of higher gasoline prices and more congestion on parallel road systems, the demand for the corridor's rail service is likely to grow.

The 2010 *LOSSAN Corridor Strategic Assessment*, sponsored by the Orange County Transportation Authority and Caltrans, was in part an attempt to identify the rail line capacity constraints and the scope of potential solutions needed to maintain adequate capacity for passenger and freight trains in the corridor for the foreseeable future. The methodology utilized was a conceptual grid time analysis.

4.2.2 Existing Corridor Services

There are four different corridor passenger rail services. These are:

- The *Pacific Surfliner*, operated by Amtrak with financial support from Caltrans Division of Rail, between San Diego and San Luis Obispo via Los Angeles Union Station (LAUS).
- The *Metrolink* commuter rail service, operated by the Southern California Regional Rail Authority (SCRRA) between Oceanside and Montalvo (north of Oxnard) via LAUS.
- *COASTER* commuter rail, operated by North County Transit District (NCTD) between San Diego and Oceanside.
- Amtrak Long-Distance Network Services: the *Coast Starlight* operating between Seattle, northern California and Los Angeles; and the *Southwest Chief* operating between Chicago and Los Angeles (for a relatively short segment between Fullerton and LAUS).

There are three freight rail operators on the LOSSAN Corridor, sharing track with passenger trains. UP serves customers between San Luis Obispo and Los Angeles, and between South Anaheim and Santa Ana. BNSF runs trains between Los Angeles, Fullerton, and San Diego. A short line or small railroad, the Pacific Sun Railroad, serves local customers in the Oceanside area.

On a typical weekday, there are as many as 100 trains per day on the busiest portion of the corridor, between Redondo Junction near Downtown Los Angeles and Fullerton.

4.2.3 Planning for the Future

The growth of corridor ridership has been dramatic. In 1979, the Amtrak *San Diegans* carried 1.2 million passengers. Ten years later, ridership totaled 1.8 million. Metrolink commuter rail service started in 1992, followed by COASTER in 1995. In 2000, the *San Diegans* were renamed *Pacific Surfliners* to more accurately capture the range of its service, which by then extended to San Luis Obispo. All three services have expanded to meet the ever growing demand, which is now six times what it was 30 years ago.

Continued ridership and service growth, however, face challenges. Chiefly among these is that higher numbers of trains are reaching the capacity limits of the physical plant.

There have been many studies of the LOSSAN Corridor and its capacity needs. The original planning work began in the 1980s. In the time since, passenger rail operators separately have developed service expansion plans, but these studies have been service-specific. The LOSSAN Rail Corridor Agency, the Joint Powers Authority charged with coordinating planning efforts for the corridor, identified various long term investment options to support more passenger rail service. However, the improvements were not tied to specific increases in train traffic over time.

The *LOSSAN Corridor Strategic Assessment* aimed to make that link of improvements to train volumes. The first step was to assess the state of the corridor. Current passenger and freight operations were profiled. Second, funded or programmed capital investments in the corridor's physical plant were identified. Lastly, operating conditions on the corridor were assessed, with capacity bottlenecks identified.

Figure 4-1 shows corridor weekday train volumes at the time of study initiation in 2008.

4.2.4 Grid Time Analysis

The study required a basic understanding of where line capacity problems exist and where more trains might be added, given both existing conditions and planned or programmed, near term line capacity improvements. The tool to enable this understanding was the capacity "yard

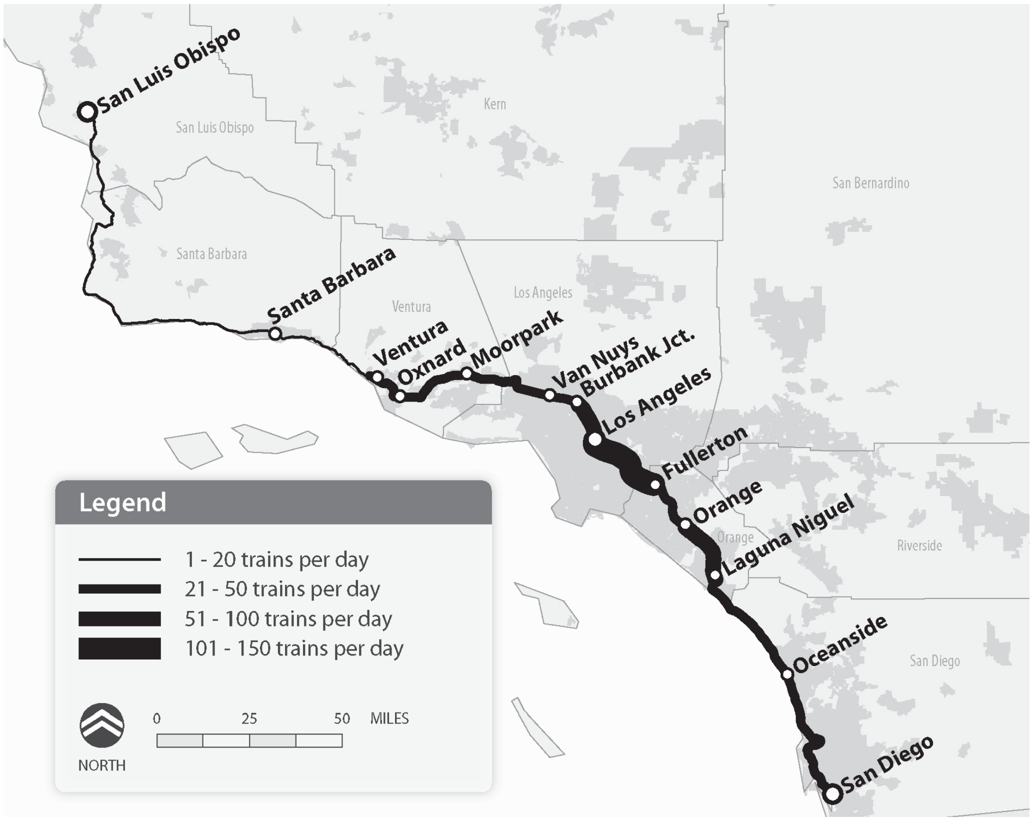


Figure 4-1. Line densities on LOSSAN corridor segments in 2008.

sticks" appearing in Table 4-1. The methodology employed relates to the grid time analysis described in Chapter 3.

The practical capacity limits of two track configurations are calculated Table 4-1. Here, practical capacity is defined as the number of trains that can run on a track segment efficiently given its configuration and appropriate allowances for both regular maintenance-of-way and small, incidental occurrences that work to delay trains. In other words, practical capacity is the point at which the addition of new trains begins to degrade operating performance on a specific corridor segment. For example, the practical capacity of a single track segment with frequent sidings is calculated as follows:

- Seven or eight miles between sidings equates to about 15 minutes of one-way grid time between sidings, given an average freight speed of 30 miles per hour.

Table 4-1. Practical rail line capacities.

Track Configuration	Minutes between Sidings	Minutes of Headway	Practical Capacity in Trains per Day
Single Track	15		50
	20		35
	30		25
Double Track		10	150
		20	75

- With 15 minutes between sidings, maximum capacity equals four trains per hour between sidings.
- Maximum daily capacity or theoretical capacity equals four trains per hour multiplied by 24 hours or 96 trains per day.
- Practical daily capacity would be half that figure, or about 50 trains per day. Conceptually, any trains above this number could negatively impact performance. This formula provides for maintenance-of-way, random delaying occurrences, and the mix of train types that traverse the corridor.

In this context, the halving of theoretical capacity to bracket practical capacity is based on practical experience with schedule and train performance variability for the kinds of traffic on a line. It includes assumptions of long, heavy and slow freight trains that do not operate on schedules, along with fast and light schedule passenger trains. With a highly disciplined operation, practical capacity can begin to approach theoretical capacity. An example is a big city transit operation versus a Class I medium density line. The former gets more out of the capacity that is available.

The maximum capacity of a double track segment is calculated differently:

- Assumed braking distance for large freight trains (operating on all corridor segments) is two miles.
- Assuming a simplified signal system, another two miles is required to stop a train.
- Assuming 25–30 mph freight train speeds and a four-mile braking distance, minimum headways would be around eight to 10 minutes between trains.
- With 10 minutes between trains, maximum capacity equals six trains per hour.
- Maximum daily capacity or theoretical capacity equals six trains per hour multiplied by 24 hours, or 144 trains per day per track or 288 per double track.
- Practical daily capacity would be half that figure, or about 150 trains per day, sufficient to allow for maintenance-of-way, random delaying occurrences, and traffic mix.
- It should be noted, that except for the short segment between Fullerton and Redondo Junction, south of LAUS, the predominant use of the corridor is passenger trains, with relatively similar operating characteristics and maximum speeds, but with widely differing stopping patterns (intercity versus commuter).

The advantage of such a conceptual approach in estimating practical line capacity is that it is straightforward and fairly simple to do. One has to know train counts and track configurations. But the conclusions on capacity rest on a number of assumptions about all train movements on a specific track segment. This is not always the case. Train type, speed, and length vary and, as a result, a specific segment of track may have more or less of a practical capacity limit than the table above indicates. Nevertheless, the approach helps to point out where opportunities and trouble spots might occur.

The advantage of operations simulation versus a conceptual grid time analysis like the LOSSAN study is it can deal easily with a multitude of variations. It is most usefully employed when projects are closer to being realized. The reason is, operations simulation is time consuming and expensive to undertake. This is to say, the dollars are better spent when the desired outcomes are better defined.

4.2.5 Future Train Volumes and Required Improvements

Table 4-2 compares the practical capacity of LOSSAN Corridor segments with the estimated future traffic volumes. In four cases, the estimated 2020–25 train volumes will be below the practical capacity for the line segments. However, for the remainder of segments, future volumes

Table 4-2. Practical capacity versus baseline and future volumes.

LOSSAN Segment	Practical Capacity	2008 Volume (Baseline)	2020-2025 Volume
San Luis Obispo – Santa Barbara	35	14	20
Santa Barbara – Ventura	25	20	34
Ventura – Moorpark	35	28	72
Moorpark – Van Nuys	50	42	72
Van Nuys – Burbank Junction	150	44	74
Burbank Junction – Los Angeles	150	85	134
Los Angeles – Fullerton	150	102	232
Fullerton – Orange	150	45	104
Orange – Laguna Niguel	150	65	152
Laguna Niguel – Oceanside	50	44	56
Oceanside – San Diego	50	48	98

will be greater than the estimated practical capacities of the segments, indicating that capacity enhancements for these line segments will be needed at some point. Train volumes for the intervening years were calculated (these were not shown in the table for the sake of simplicity) so implementation of improvements could be identified in five-year increments (2010–15, 2015–2020, and 2020–25). A few examples are listed herein from north to south.

- *Santa Barbara-Ventura:* Sidings improvement will be required by 2011–15. Practical capacity today is about 25 trains per day. Specific improvements could include Seacliff Siding north and Rincon Siding. With the implementation of Santa Barbara commuter service in the near term, a north platform would be needed at Oxnard by 2011–15 as well.
- *Ventura-Van Nuys:* By 2020–25, more sidings and/or double track will be required to ensure capacity for at least 72 trains per day.
- *Los Angeles-Fullerton:* Triple track as soon as possible. While the segment may not have reached its practical capacity limit, there is little to no room today for more peak period service. Quadruple track will be required by 2020–25.
- *Laguna Niguel-Oceanside:* Siding improvements and some double tracking will be required by 2020–25.
- *Oceanside-San Diego:* Some siding improvements will be required by 2011–15. More sidings, double track and tunnels will be required by 2020–25.

4.2.6 LOSSAN Grid Time Analysis Summary

The LOSSAN study fell short of recommending specific locations and specific types of improvements. That sort of specificity would be the product of a more detailed examination, using rail operations simulation, when actual future train volumes and schedules are better defined. With this analysis, the study aimed to illustrate for LOSSAN policy makers where capacity constraints will likely exist given certain assumptions of daily train volumes and the types of solutions that could be deployed.

The 2010 study addressed more issues than infrastructure needs. These included an endorsement of a hierarchy of services, ranging from express and limited stop intercity services, and interregional commuter services involving equipment belonging to both Metrolink and COASTER, improved train connectivity at stations, and common fare instruments. These improvements were seen as means to make the corridor more convenient to use and thus spur ridership. However, it was the linking of infrastructure improvements to train volumes over time that was at the heart of the LOSSAN strategic vision—an outcome realized through the use of the conceptual grid time analysis described above.

Over the intervening years, conditions on the corridor have changed in numerous ways. Freight train growth, for one thing, has been slower than anticipated, an outcome of the recent economic recession and curbing of rail-borne international container volume going to and from the Ports of Los Angeles and Long Beach. Commuter train operations and growth assumptions have changed as well. Since the grid time analysis, the LOSSAN agency has continued to study the timing and location of improvements on the corridor through operations simulation using RTC with current assumptions for passenger and freight train operations.

4.3 New Haven-Hartford-Springfield Corridor Planning

4.3.1 Introduction

Since 2001, the Connecticut Department of Transportation has been working toward the implementation of a new commuter rail service on the 61-mile Amtrak Springfield Line between New Haven, Hartford and Springfield, MA. Preliminary work on what was to be called the New Haven-Hartford-Springfield (NHHS) Corridor was completed in the first half of the decade. Then in 2008, work began on an Environmental Analysis, which was completed and accepted by the Federal Railroad Administration in 2012. A map of the line appears as Figure 4-2.

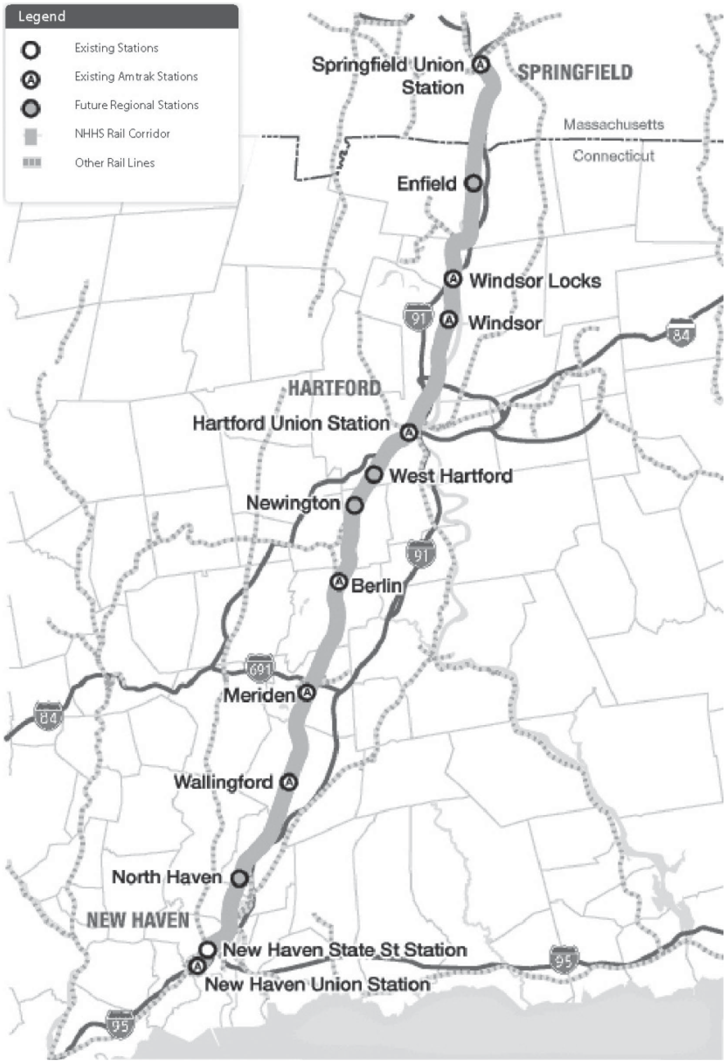


Figure 4-2. New Haven-Hartford-Springfield (NHHS) line.

A key element of all work phases since the beginning of the project was the use of rail operations simulation to identify line capacity enhancements required to ensure fluid passenger and freight rail operations on the line, which is also a federally designated high speed rail corridor. The simulation task was performed by means of the Rail Traffic Controller software, which is a standard tool for rail operations analysis and train performance evaluation. (Reference: *2016 Start-Up HSIPR Corridor Service, Version 2d*, produced by CDM Smith, 2012.)

The proposed New Haven-Hartford-Springfield High Speed Rail Corridor is planned to be implemented in phases. This phased implementation approach will require adaptation of operating plans and schedules to utilize as much of the added capacity as possible to provide improved passenger rail services without reducing the performance of the freight railroads.

4.3.2 Existing Corridor Operations

Existing train operating information was provided by the operators on the route. These were: Amtrak Northeast Corridor passenger trains, Pan Am Railways (PANAM), CSX Transportation, Providence and Worchester Railroad (P&W), and the Connecticut Southern Railroad (CSO) freight trains. Conversations with all carriers occurred in the late summer and early fall of 2008 and an update, performed in mid-2011, identified an overall decrease in scheduled freight service.

The existing passenger schedules were based on Amtrak's summer/fall 2011 schedule and included the Amtrak trains operating on the Springfield Line, and Amtrak Northeast Corridor (NEC) trains and ConnDOT sponsored Shore Line East (SLE) commuter trains operating between New Haven and Mill River, the NEC junction for the Springfield Line.

4.3.3 Simulation Parameters

4.3.3.1 Modeled Operating Cases

A comparison of the modeled cases is shown in Table 4-3. Each of the listed cases was coded into the RTC simulation software, and a set of ten weekly schedules was simulated. Random

Table 4-3. Modeled operating cases.

Simulation Case	Description	Infrastructure	Improvements	Schedule	Train Ranking/Priority
Case 1	No Build 2011	Existing		2011 Amtrak 2011 Freight	Higher Priority Passenger Trains
Case 2	No Build 2030	Existing		2011 Amtrak 2011 Freight Grown to 2030 Levels at 1.75% per Year.	Higher Priority Passenger Trains
Case 3	2016 V2d (2030 Build)	Improved	Double Track between Cedar Hill Yard and Hartford Station and between Hartford Yard and Hayden Interlocking, Additional Siding and Rehabilitation Running Track in Hartford Yard, Upgrade Switches Hartford Yard, Hayden Interlocking.	Amtrak 2016 V2d Service Plan Including Expanded Intercity and New Commuter Service. 2011 Freight Grown to 2030 Levels at 1.75% per Year.	Higher Priority Passenger Trains

variations to scheduled dwell times and initial departure times were applied to simulate the effect of minor random day-to-day impacts on train operations. The results were averaged over the runs and are presented below. Simulation results were used to evaluate the performance of the proposed service plan in combination with the improvement of the existing rail infrastructure, compared to the existing infrastructure and service plan.

4.3.3.2 Train Priority and Ranking

One of the key features of RTC is its meet-pass conflict resolution logic. RTC resolves "meets" or conflicts of opposing trains on the basis of priority, just as a human dispatcher would. For example, if a passenger train has a higher priority than a freight train, then when a passenger train and a freight train are approaching each other on single track, the passenger train would "hold" (remain on) the main line while the freight train would "take" (enter) a siding in order to let the passenger train pass. Also, if a train is running late, its priority increases. The opposite is true if a train is running early on its schedule.

There are three priority values to be set in RTC: minimum, initial, and maximum. The initial priority is a value assigned to a train when it goes on line; minimum and maximum are the lowest and highest boundaries.

RTC also offers a second layer of dispatching criteria based on train ranks. This parameter is used to handle special trains such as high and higher speed rail. There are seven ranks available: ranks 1 to 3 designate train types as elite, while 4 to 7 as regular. RTC will strive to keep higher ranked trains on schedule; lower ranked trains can be forced to take large delay in order to keep elite trains on schedule.

4.3.3.3 Randomization

All simulations were modeled to recognize that there is a level of randomness that occurs in train operations. The RTC software can recognize this with the application of randomization factors applied to each case. For the simulations the initial departures and dwell times were allowed to vary on a random basis within the following parameters: passenger trains were modeled with up to 2 minutes late initial departure and up to 15 seconds extended dwell time. Freight trains were modeled with up to 15 minutes early/late initial departure and up to 5 minutes extended dwell time.

4.3.3.4 Simulation Run Settings

Each simulation was run for a 7-day period plus half a day for warm-up and cool-down. Ten runs were performed for each case, and each run had a different random seed, viz., train schedules and delays were different during each run. The results of the 10 runs were averaged and reported as the results for each particular operating case modeled.

4.3.3.5 Train Performance Calculator

The train performance calculator (TPC) parameter depicts the ideal run of a train. TPC run times assume no conflicts with other trains, all switches aligned, and all green signals along the route. RTC trains were calibrated to replicate performance reported on TPC charts provided by Amtrak. Also speed restrictions on the corridor were coded according to Amtrak's train performance chart, which showed a maximum design speed of 110 mph with 80 mph speed limits at level crossings. The speed restrictions north of Hartford Station were assumed to remain identical to the current speed limits.

4.3.3.6 Pad

According to FRA's *Railroad Corridor Transportation Plans* guidance manual, whenever passenger schedules are produced by various TPC runs, a pad (make-up/recovery time) must be

Table 4-4. On-time performance (OTP) threshold values.

Passenger Services		
Train Type	**Train Runtime in Simulation Corridor (Minutes)**	**OTP Threshold (Minutes)**
New Haven – Springfield	90	6
NEC and SLE	15	2
Freight Services		
Train Type	**Train Runtime in Simulation Corridor (Minutes)**	**OTP Threshold (Minutes)**
CSO	420	60
CSXT Springfield	30	5

added to the TPC schedule to account for a number of factors. For a double track network the schedule pad is calculated by increasing the train runtime by a minimum of 7% to take into account such factors as human operation instead of perfect TPC operation, temporary slow orders, congestion or off-schedule trains, adverse weather conditions, and signal imposed delay, etc.

4.3.3.7 On-Time Performance

The On-Time Performance (OTP) parameter represents train schedule adherence and is expressed as the percentage of trains arriving between their scheduled arrival time and a specific OTP threshold value. OTP threshold values used in the simulations are shown in Table 4-4. For passenger trains values are based on the minimum pad (7%) for the longest passenger running time, specifically, six minutes pad for a scheduled run time of one hour and 30 minutes. With respect to freight trains, considering their length/weight and consequent slower acceleration/deceleration capability, 15% of the longest service runtime train was used. Exceptions are NEC and SLE passenger trains, which traverse the network for approximately 15 minutes, thus the lower threshold. The same reasoning was applied to freight trains with short running time such as the CSXT trains between West Springfield Yard and Springfield Station.

4.3.3.8 Train Frequencies

Freight service frequencies and schedules were identical to the existing 2011 schedules for all cases. For the simulations in 2030, it was assumed that freight train lengths and weights will increase by 1.75% annually over the next 19 years (a 39% increase over 2011) for both the No Build and the 2016 V2d cases. The service frequencies are shown in Table 4-5.

Table 4-5. Comparison of frequency of train service in trains per week.

Case	Passenger	CSO	CSXT	PANAM	P&W	All Trains NHV-HFD-SPG
2011 No Build	92*	18	15	2	18	145
2030 No Build	92*	18	15	2	18	145
2016 V2d	245*	18	15	2	18	298
*Note: includes passenger trains running the full 61-mile corridor and those only traversing a small sub-segment near New Haven station.						

4.3.4 Simulation Results

Due to the increase in freight train length and weight, the performance parameters do show a slight degradation of operating performance when evaluating 2030 No Build versus the 2011 No Build Case.

The delay statistics for 2016 V2d (2030 Build) simulations are unchanged or improve relative to the No Build cases except for the Delay Percentage for freight. On-time performance improves relative to the 2030 No Build case for both freight and passenger, even though volumes of the line more than double. Overall delay and on-time metrics improve. Table 4-6 shows a comparison of performance parameters.

In addition, Figure 4-3 shows the location and the amount of delays occurring in the network. The 2030 Build case clearly shows significant reduction in the delays in the improved (double track) section between the Mill River junction and Hartford, compared to the No Build cases.

Figure 4-4 shows the cumulative percent delay for both passenger and freight trains. For example, 95% of passenger trains have cumulative true delay (delay in run time) of less than 5 minutes. It can be observed that the 2030 Build case passenger and freight cumulative delays are comparable to the 2011 No Build case, without any optimization to the 2030 Build case train schedules.

4.3.5 NHHS Operations Simulation Summary

To conclude, the increased passenger service, as proposed in the 2016 V2d corridor service in combination with the assumed growth in freight train length and weight due to future demand in rail shipments, can be handled on the proposed infrastructure with sufficient operational

Table 4-6. Comparison of performance parameters.

Delay Percentage (1) (4)			
Case	**Passenger**	**Freight**	**Overall**
Delay Percentage (1) (4)			
2011 No Build	1.4	18.1	7.2
2030 No Build	1.6	18.4	7.7
2030 Build (2016 V2d)	1.3	18.8	5.0
Minutes of Delay per 100 Train Miles (2)			
2011 No Build	1.7	54.1	11.3
2030 No Build	2.0	58.2	12.3
2030 Build (2016 V2d)	1.7	53.3	6.2
On-Time Performance (3)			
2011 No Build	97.9%	100.00%	98.7%
2030 No Build	97.2%	99.2%	97.9%
2030 Build (2016 V2d)	99.2%	99.6%	98.9%

1. Delay percentage is measured as the ratio between the amount of delay at the terminal station versus the total amount of scheduled train run time
2. Ratio of total amount of delay of all trains and the amount of train miles traveled in the simulation corridor.
3. Trains are assumed to perform on-time when the arrival time at the terminal is less than 6 minutes later than the schedule arrival time for passenger trains and less than 1 hour for freight trains.
4. Delay is defined as the total difference between the planned arrival time and the recorded arrival time at the terminal station. The results are averages of 10 weekly schedules simulated using randomization.

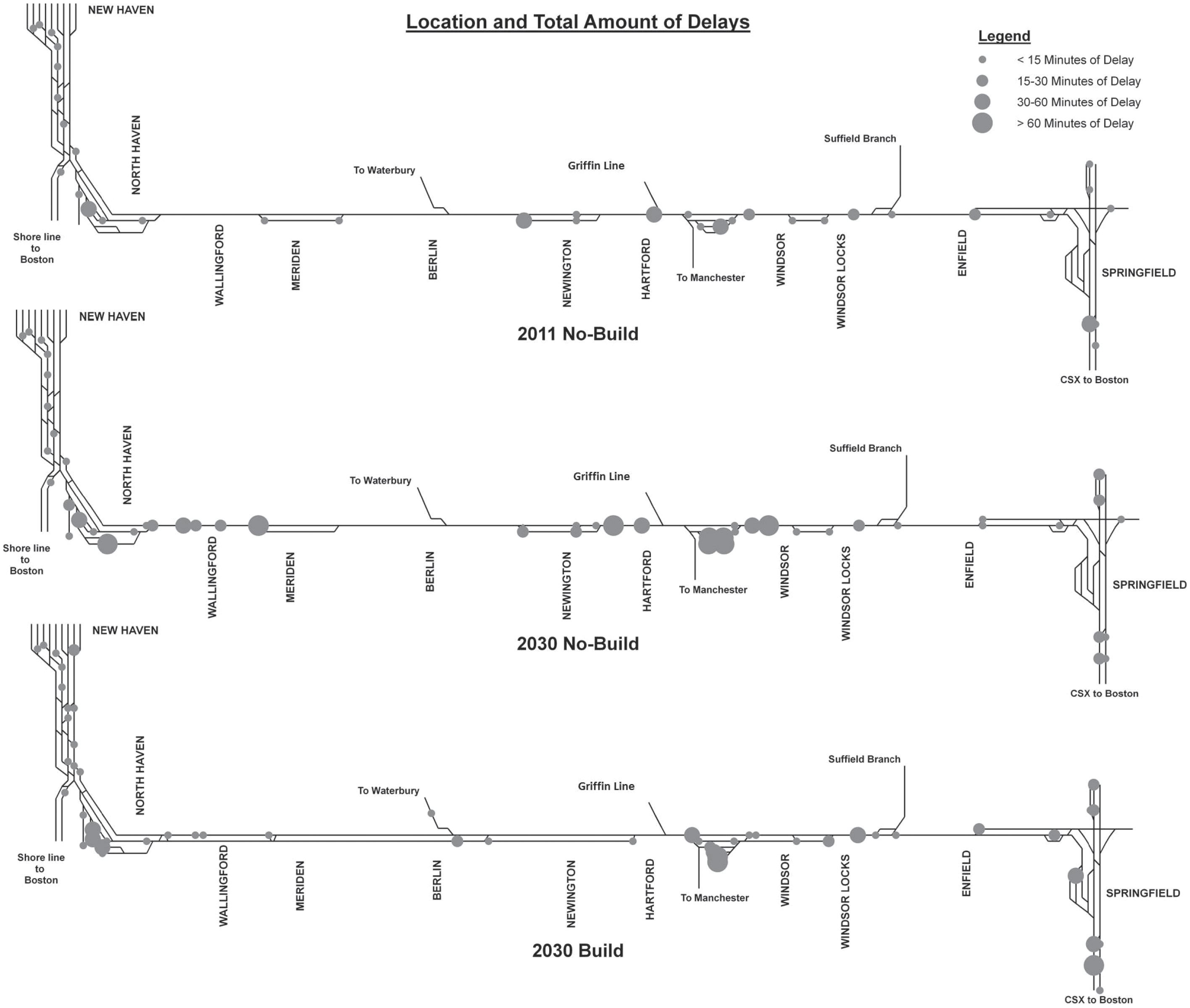


Figure 4-3. Operating delay analysis.

quality. Optimization of the freight service can potentially provide further reductions in delay for both passenger and freight service.

4.4 North Sound Rail Assessment Comparisons

4.4.1 Introduction

In 2010 *North Sound Regional Rail Operations Simulation*, sponsored by the Whatcom Council of Governments, was initiated to answer the following question: Are the capital improvements previously identified for the implementation of new *Cascades* service sufficient to enable the implementation of reliable commute-oriented regional rail passenger services between Bellingham and Everett, WA, on the BNSF Railway?

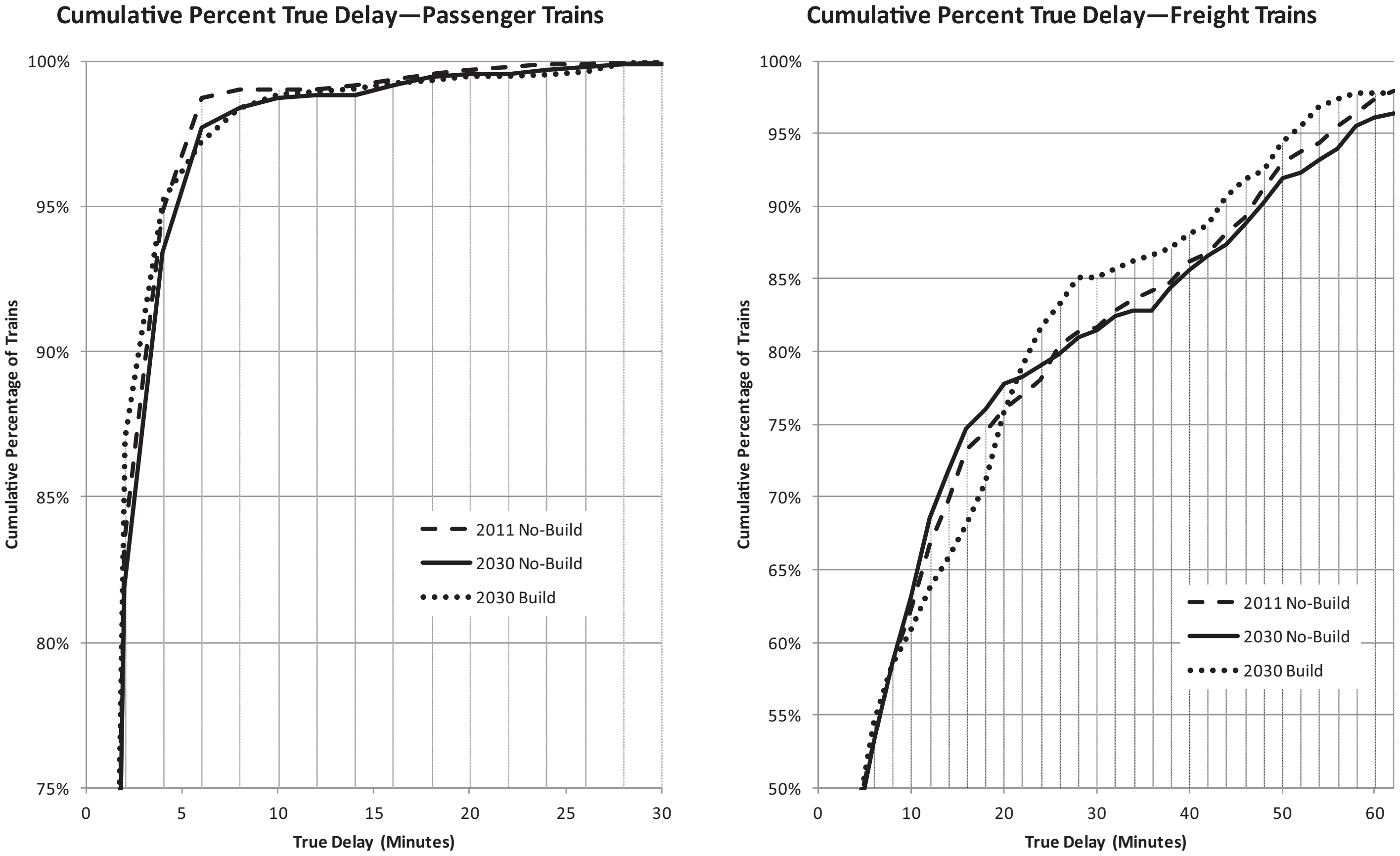


Figure 4-4. Cumulative percent true delay—passenger and freight trains.

This question was first explored in a 2008 analysis. The 2010 study was an update. Both studies followed the same approach: use RTC to test if existing and proposed anticipated passenger plus existing freight trains can share the line without serious deterioration in service quality.

This case study first details the results of that operations simulation answering the question posed above. Subsequently, the same basic question is investigated using two other methodologies—a grid time analysis and an analysis employing the NCFRP web-based operations simulation tool—and the results of all three are compared. The case study concludes with observations of using three different tools for the same job.

4.4.2 North Sound Rail Operations Simulation

4.4.2.1 Introduction

The work scope for the 2008 and subsequent 2010 studies included a computer-based simulation of railroad operations with and without the proposed regional rail trains. The study area for the 2010 study was the same as for the 2008 study: Wenatchee to Everett, Seattle to Everett, and Everett to Bellingham and Blaine as shown in Figure 4-5.

BNSF provided records of actual train movements for a month-long period that were used by the study team to create train files representative of current traffic patterns, including time and day of operation, train length and tonnage, and crew change locations. (Train files are used to

Figure 4-5. North sound regional rail operations simulation study area.

perform the simulation.) The 2010 study took into account the then current Sounder, Amtrak *Empire Builder* and *Cascade* trains, plus a third *Cascade* round trip between Seattle and Vancouver, British Columbia. This train was assigned a mid-day schedule as envisioned by the Washington State Department of Transportation.

The Rail Traffic Controller program was used for this analysis. RTC is also used as an analysis tool by BNSF. All simulations were performed with RTC Version 2.70 L59E.

The regional rail service plan assumed in the simulation would have two morning trains departing Bellingham and continuing to Everett, with intermediate stops at Mt. Vernon-Burlington, Stanwood, English, and Marysville. At Everett, the trains would connect with Sounder commuter service between Everett, Mukilteo, Edmonds, and Seattle King Street. Two corresponding afternoon trains would leave Everett after arrival of connecting Sounder trains, and return to Bellingham. In order to include the collateral effects of freight service outside the immediate Bellingham-Everett service area, the simulation area included trackage of the Bellingham Subdivision from the Canadian border at Blaine south to Everett, and trackage of the Scenic Subdivision from Wenatchee west to Everett and Seattle.

The regional rail schedules assumed appear in Table 4-7.

Table 4-7. Regional rail schedules.

NORTHBOUND – PM				SOUTBOUND - AM		
Station	**NS 01**	**NS 03**		**Station**	**NS 02**	**NS 04**
Everett	17:45	18:45		Bellingham	5:10	5:40
Marysville	18:06	19:06		Mt. Vernon	5:41	6:11
English	18:12	19:12		Stanwood	5:56	6:26
Stanwood	18:22	19:22		English	6:06	6:36
Mt. Vernon	18:37	19:37		Marysville	6:12	6:42
Bellingham	19:05	20:05		Everett	6:30	7:00

Note:

(1) Intermediate dwells 30 seconds.

(2) Departure times shown for all stations, with exception of terminals (arrival time).

4.4.2.2 Network Simulations

The rail network for the simulations was drawn using current BNSF track charts and time tables (variously dated between 2007 and 2010), provided by BNSF simulation modelers. Centralized Traffic Control signalization (whereby a dispatcher in a remote location directs the progress of trains over a section of track by wayside signals) was added to the simulation cases except in yard areas.

Assumptions regarding the track and capacity improvements for each simulation case were taken from the 2008 study; these were based on diagrams of conceptual improvement plans prepared for WSDOT by Transit Safety Management and HDR Engineering. The improvements represent a package of track improvements that WSDOT and BNSF had accepted as requirements for extension of the second Amtrak round trip to Vancouver, the addition of a third Amtrak round trip, as well as for increasing Sounder service to four round trips between Seattle and Everett. Some of the improvements assumed in the 2008 study had since been realized. Others are scheduled to be completed with American Recovery and Reinvestment Act (ARRA, 2009) funding or other funds in the near future. Thus, assumed for the base case (Simulation 1) were:

- Double track through Interbay Yard
- Double track from Milepost (MP) 7.3 to MP 7.8, with universal crossover at MP 9.0
- Incorporation of Mukilteo Sounder station
- Extension of Lowell siding west to MP 1783.0
- Extension of English siding southerly to MP 43.9
- Extension of Stanwood northerly to MP 57.6
- Extension of Mt. Vernon siding southerly to MP 65.5
- Burlington yard revisions and new main line (no siding at this location)
- Revision of Custer and Intalco sidings to provide extended yard track (no siding at this location)
- Extension of Swift siding between MP 114.9 and MP 118.1 with 5 mph freight speed limit at north end

Improvements in the vicinity of Delta Yard, identified and modeled during the previous study, were not included in the 2010 effort. Specifically:

- Ease of main line curve at north end of the yard
- New main line around the yard
- Revision of yard tracks/leads

However, by means of distance equations, study modelers coded longer receiving and departure tracks at Delta Yard to avoid long freight trains blocking yard approaches during crew change layovers or switching operations.

Train files, as noted, were based on BNSF records of actual movements during the peak week of October 2010. Based on train type, thresholds for early or late departure were included, and the RTC random feature was used to simulate different departure times for each day of operation. RTC was also set to permit variations in dwell time. The simulations were run for a seven-day statistical period, with 24-hour warm-up and cool-down periods.

These periods are a programming feature that is to assure steady state of operations for the simulation. While a simulation may start at a specific time, e.g. 8 AM on a Monday, in reality trains are moving on the line before the start time and dealing with conflicts from opposing trains. A warm-up period accounts for train operations before the start time of a simulation and thus helps to ensure a steady state of operations by the time the simulation actually begins. The function of a cool-down period is the same, only pertaining to the end of a simulation.

Statistical performances were calculated by averaging ten simulation runs for each simulation case.

The study team provided BNSF with draft final RTC simulation and summary files. After addressing all comments by BNSF staff, cases were re-run, obtaining the results summarized later in this section.

Four cases were simulated:

- ***Simulation 1*** represents existing track configuration, plus near term track improvements, and existing trains, including the fourth Sounder round trip between Seattle and Everett, two *Cascade* round trips between Seattle and Vancouver, the *Empire Builder*, and BNSF trains.
- ***Simulation 2*** has the same track configuration and freight trains as Simulation 1. However, with respect to passenger trains, it adds the two Bellingham-Everett weekday regional rail trains and a third *Cascade* Seattle-Vancouver round trip on a mid-day schedule.
- ***Simulation 3*** adds a set (Set 1) of capacity improvements, which include double tracking two sections between Everett and Seattle (MP 27.0 to MP 27.8 and MP 15.8 to MP 17.8), and implementing two universal crossovers (at MP 27.8 and MP 17.8).
- ***Simulation 4*** adds a further set (Set 2) of track improvements by extending the siding at South Bellingham, joining Samish and Bow sidings, and implementing a universal crossover at MP 81.0.

Table 4-8 shows the list of track improvements and trains operating between Everett and Bellingham.

4.4.2.3 Analysis of Simulated Performance

Shown in Table 4-9, the statistical performance measures, by which the simulation cases can be compared, are defined herein.

Average Train Speed: Average passenger train speed increases with the introduction of the new regional rail service; that is, due to more trains running on the Bellingham Subdivision, which has higher speed limits than most sections in the Scenic Subdivision (especially along the mountainous line between Everett and Wenatchee), speeds on average increase. Capacity improvements

Table 4-8. Assumed track improvements for north sound regional rail simulations.

Improvement	Simulation 1	Simulation 2	Simulation 3	Simulation 4
Freight Service	Current Service	Current Service	Current Service	Current Service
Cascade Service and Amtrak Empire Builder	2 Vancou’r RT 1 Em. Bldr. RT	3 Vancou’r RT 1 Em. Bldr.	3 Vancou’r RT 1 Em. Bldr. RT	3 Vancou’r RT 1 Em. Bldr. RT
Commuter and Regional Rail Service	4 Sounder RT	4 Sounder RT 2 Regional RT	4 Sounder RT 2 Regional RT	4 Sounder RT 2 Regional RT
Construct regional rail layover tracks at Bellingham (MP 94.4) and Everett (MP 1782.7)	No	Yes	Yes	Yes
Double track, MP 27.0 to MP 27.8 with universal crossover at 27.8	No	No	Yes	Yes
Double track MP 15.8 to MP 17.8 with universal crossover at MP 17.8	No	No	Yes	Yes
Extend South Bellingham northerly to MP 97.0	No	No	No	Yes
Join Samish and Bow with universal crossover at MP 81.0	No	No	No	Yes

Table 4-9. Simulated performance for 7-day period.

Measure	Simulation 1	Simulation 2	Simulation 3	Simulation 4
	Base Case	Base Case + New Service	Base Case + New Service + Improvements Set 1	Base Case + New Service + Improvements Sets 1 and 2
Passenger Train Count	82	116	116	116
Expedited Train Count	72	72	72	72
Freight Train Count	240	240	240	240
Total Train Count	**394**	**428**	**428**	**428**
Passenger Train Miles	14,096	16,696	16,726	16,774
Expedited Train Miles	117,775	117,801	117,711	117,748
Freight Train Miles	195,890	195,793	195,327	195,699
Total Train Miles	**327,761**	**330,290**	**329,764**	**330,222**
Average Passenger Speed	35.6 mph	36.5 mph	36.6 mph	36.6 mph
Average Expedited Speed	22.8 mph	22.7 mph	22.7 mph	22.8 mph
Average Freight Speed	14.9 mph	14.6 mph	14.7 mph	14.9 mph
Overall Average Speed	**19.2 mph**	**19.7 mph**	**19.8 mph**	**19.9 mph**
Passenger Delay Percent	3.8%	4.7%	4.4%	4.2%
Expedited Delay Percent	18.6%	18.9%	18.9%	18.2%
Freight Delay Percent	33.6%	36.8%	35.6%	33.4%
Overall Delay Percent	**24.7%**	**25.6%**	**24.9%**	**23.6%**
Passenger Delay per 100 TM	5.4 minutes	6.4 minutes	6.0 minutes	5.7 minutes
Expedited Delay per 100 TM	35.9 minutes	36.7 minutes	36.6 minutes	35.4 minutes
Freight Delay per 100 TM	74.0 minutes	81.1 minutes	78.6 minutes	73.8 minutes
Overall Delay per 100 TM	**48.6 minutes**	**49.1 minutes**	**47.8 minutes**	**45.2 minutes**

do not significantly influence passenger trains' average speed, which stays consistent at about 36 miles per hour.

The average speed of expedited freight trains (those with highest operating priority) slightly decreases with the added passenger trains operating over the network. However, when both sets of capacity improvements are implemented, average speed returns to the level seen in the base case. The same pattern and results apply to general merchandise freight trains.

Overall, the average speed parameter increases throughout each simulation case.

Delay Percent: This is delay time as a percent of pure run time. Compared to Simulation 1 values, this parameter increases across all train types when new passenger services are introduced in Simulation 2. The highest increase is experienced by general merchandise freight. Track enhancements under Simulation 3 and 4 do appear to mitigate delay percent, but at different degrees: passenger trains' delay decreases from 4.7% down to 4.2% which is still higher than in the base case. On the other hand both expedited and general merchandise freight ultimately experience better than base case performances; the same result is also reflected in the overall parameter.

Delay per 100 Train Miles: This measure of system performance shows a trend similar to Delay Percent with respect to train types. Again, passenger trains experience higher minutes of delay once new services commence; and even if track improvements mitigate delays, performances do not improve or equate to original conditions. On the other hand, freight trains show better than base case performances under future build scenarios. In terms of overall delay per 100 train miles for freight and passenger trains combined, the results are better than the base case.

4.4.2.4 North Sound Operations Simulation Summary

In line with previous simulation effort, this study shows that the addition of Bellingham-Everett regional rail service, plus the operation of one additional *Cascade* round trip Seattle-Vancouver, will not degrade current freight performance, but instead will improve it, assuming concurrent track capacity improvements. This round of simulations confirms the validity of the improvement package, whether or not the Bellingham-Everett regional rail service is established. The results do indicate minor increases in delay to passenger trains in Simulation 4 versus the base case Simulation 1. Mitigation of such delay may require operational changes or track capacity enhancements.

As with the 2008 study, the 2010 round of simulations did not test any potential increased levels of freight service in combination with the added passenger trains. An increase in freight service levels could include coal and grain traffic for export from ports along the route.

Importantly, BNSF advised that its review and comment on the RTC simulation did not constitute BNSF agreement to plans to implement a regional rail service between Bellingham and Everett. BNSF explained that its traffic patterns change over time, so baseline conditions will change. If the regional rail service were to materialize, BNSF said it will perform an independent operations simulation of the line to confirm system performance.

4.4.3 North Sound Grid Time Analysis

4.4.3.1 Introduction

There are various levels of analyses that can be applied to determine whether the capacity of a line is adequate. A relatively simple grid time analysis can be used as a first cut to determine whether there may be a potential capacity problem in a corridor that warrants further investigation. In this example, the BNSF rail corridor between Blaine and Everett was tested and evaluated as a conceptual level grid time analysis screening, albeit more detailed in terms of inputs than the LOSSAN grid time analysis as described in Section 4.2.

The reader should note two context elements for the grid analysis described below:

- Grid time analysis would most naturally be the first and simplest scoping-level evaluation of service capacity for a rail corridor. For purposes of illustration the guidebook team chose an alignment that had earlier been modeled in RTC so that readers would be able to compare the products of each approach.
- For purposes of simplicity the team is reporting the results of the grid time analysis for only a portion of the RTC-modeled service territory described above, namely the track segment between Everett and Blaine.

In a simple grid analysis the capacity of a single track line to handle traffic is dictated by the time it takes a train to travel the distance between two adjacent passing tracks and clear the way for an opposing train (one-way grid time). The sum of the forward and reverse move grid times (turnaround grid time) for a balanced operation is the total time taken by a pair of opposing trains to cross a single track section. The single track section with the highest grid times is the most restrictive for the movement of the trains over the route between two major points such as between terminals and defines the maximum capacity for that segment.

Ordinarily, such a "quick" analysis incorporates conservative assumptions and is easy to apply as a screening device. Normally if such application does not suggest any capacity problem on a line, then a railroad can be confident that capacity is sufficient and may not need to investigate further. However, if the grid time analysis shows that there is a potential capacity problem on a corridor, it is then recommended that a series of corridor simulations be conducted on a rigorous basis to test and evaluate the operations and capacity issues over the corridor. Based on the results of these simulations, adequacy of line capacity is then confirmed. In this grid time analysis, the theoretical capacity of portions of the route was calculated over each of the corridor single track segments ("grids").

The theoretical capacity calculation assumes the availability of an unlimited supply of trains at both ends of the line throughout the day. To correct for this oversimplification, a downward scaling factor is applied to derive the practical capacity of the line. The theoretical number is reduced to reflect conditions that all railroads encounter (i.e., track maintenance work, slow orders, unplanned disruptions, etc.) that reduce the effective capacity of the route. For this analysis, given the similarity of traffic on the line, the practical capacity of a line with one or more single track segments is assumed to be 75% of the theoretical capacity railroad design engineers seek to achieve.

The grid time for a train is defined as the time taken from a stopped position at the switch at the start of the single track segment to train length distance (6,000-foot in this example) past the switch at the end of the single track segment (start of next siding or double/multi-track section). The train is also brought to a stop at the start of the next single track segment (end of siding or double/multi-track section). The train length distance allowance is applied to factor the train length, ensuring that the longest train has cleared the switch for the opposing train. By starting from stop, the additional time required for acceleration is accounted for. With the stop at the end of the passing track, the appropriate time loss for deceleration is applied as well.

4.4.3.2 Description of the Blaine–Everett Rail Corridor

The Blaine–Everett rail corridor over the BNSF Railway is a low density freight operation that has in the order of 3 to 14 daily freight train movements per day plus 4 daily Amtrak passenger trains (two *Cascades* trains in each direction per day). In addition, daily light engine movements along with the occasional work train run across the corridor. The 88-mile line between Blaine and Everett is comprised of a single track with 8 sidings of over 6,000 feet for trains to meet one another. Current freight trains that operate over this segment include loaded coal trains in the northbound direction, empty coal trains in the southbound direction, and daily manifest trains in both directions. Table 4-10 shows the siding names and lengths, locations, grid lengths, and average train velocity over each segment (from RTC simulations).

Table 4-10. Grid breakdown of the Blaine–Everett rail corridor.

GRID BREAKDOWN
Blaine - Everett Rail Corridor

Siding length (feet)	Siding Name	Milepost (miles)	Single Track Grid Lengths between Sidings* (miles)	Average Train Velocity (mph)
4,602	Blaine	119.58 118.61		
Between sidings:			**1.81**	40
8,588	Swift	116.8 115.1		
Between sidings:			**1.91**	40
10,150	Intalco/Custer	113.19 110.94		
Between sidings:			**2.79**	40
8,478	Ferndale	108.15 **106.37**		
*	Bellingham	98.07 97.11		
*	MP 96.73	96.73 96.36		
Between sidings:			**12.91**	30
6,347	Bellingham Station (South Bellingham)	**93.46** 92.20		
*	Samish	83.53 82.76		
Between sidings:			**11.30**	35
8,884	Bow	80.90 **79.06**		
4,635	Burlington Yard	71.91 70.36		
Between sidings:			**11.68**	35
6,075	Mt Vernon	**67.38** 65.50		
Between sidings:			**8.97**	50
6,381	Stanwood Station	56.53 55.18		
			8.94	50
10,680	English Station	46.24 **43.9**		
*	Marysville	39.19 38.69		
Between sidings:			**6.88**	50
	Delta Junction	**37.02**		
	Everett Station	32.00		

* Note: Grid length (in miles) taken only between sidings capable of holding a train of 6,000 ft in length. The one exception is Blaine, as all trains must stop there for customs inspection.

The single track grid lengths range from approximately two miles in distance to as much as 13 miles. The longer the distance of each grid segment, the less capacity that the system is capable of handling.

4.4.3.3 First Pass—Grid Analysis for Freight Operations Only

As a first pass, the grid analysis was performed over the corridor under the assumption of all trains having equal priority and all being freight trains. A standard freight train of 6,000-feet was used in this example as the basis of the conservative movement calculations. The train would start and stop at each siding, with the average speed as obtained from the aforementioned North Sound RTC simulation for the individual grids. An acceleration and deceleration time of 10 minutes was added to each grid movement. At the northern three sidings, and due to their proximity with the border crossing, it was assumed that the effects of the border crossing delays would add 45 minutes of delay to each train in each segment, thus restricting the free flow of trains.

As can be seen in Table 4-11, the grid analysis yields a relatively free flowing operation given a freight only environment, except for the problems related at the northern end due to border crossing delays. With current freight operations in the order of 14 daily movements and with a grid analysis that shows capacity between 26 to 50 trains per day capability for most of the route, there seems to be sufficient capacity. However, as this corridor is shared with passenger trains, the grid analysis is further refined to account for the prioritization in effect with such movements. As a general rule, the dispatcher must ensure that sufficient track capacity be available for high priority passenger train service. Accordingly, for each passenger train, the grid analysis must incorporate a total of three available grids to ensure that the train does not stop or get delayed due to freight interference. The individual grid is analyzed along with the grid ahead and grid behind, for a total of thee-grid calculation for each passenger train.

4.4.3.4 Addition of Existing Passenger Trains to the Mix

As can be seen in Table 4-12, the practical capacity of each segment has been reduced to account for the prioritization of the existing Amtrak *Cascade* passenger trains. Other than the northern three sidings being affected by the border delay issues, the current 14 daily freight trains are within operational capacity limits of the existing infrastructure with a range of 21 to 46 trains per day for most of the route.

4.4.3.5 Addition of Future Passenger Trains to the Mix

As Amtrak increases service by two daily *Cascade* movements per day (one additional daily train per direction) and the North Sound Regional Rail Service introduces four weekday movements (two weekday trains per direction), a further grid analysis was done to test the effects to capacity over the corridor, as seen in Table 4-13.

With the introduction of a third Amtrak *Cascade* daily train and with the North Sound Regional Rail Service introducing two morning and two evening trains between Bellingham and Everett, the available capacity over the corridor becomes much more restricted. The grid analysis at this stage indicated that three segments south of Bellingham are at or close to their practical capacity limits, requiring further analysis (through simulations) to quantify the effects and develop appropriate remedies. The three questionable areas included the grids between:

- Ferndale and Bellingham where the calculated practical freight train capacity was 18 trains per day but actual daily freight traffic was 14 trains;
- Samish and Bow where the calculated practical freight train capacity was 16 trains per day but actual daily freight traffic was 14 trains; and,
- Bow and Mt. Vernon where the calculated practical freight train capacity was 17 trains per day but actual daily freight traffic was 14 trains.

Table 4-11. First pass grid analysis for freight operations only between Blaine and Everett.

GRID BREAKDOWN Blaine - Everett Rail Corridor					
Siding Name	**Single Track Grid Lengths between Sidings (Miles)**	**Total Time for Each Train to Cross Grid Including Border Delays (Minutes)**	**Theoretical Maximum Number of Freight Trains per 24-hour Period**	**Practical Maximum Number of Freight Trains per 24-hour Period (75% of Theoretical)**	**Actual Freight Trains per Day (Peak Days)**
Blaine					
	1.81	61.6	23.4	17.5	14
Swift					
	1.91	61.8	23.3	17.5	14
Intalco/Custer					
	2.79	63.1	22.8	17.1	14
Ferndale					
Bellingham					
MP 96.73					
	12.91	41.0	35.1	26.3	14
Bellingham Station					
Samish					
	11.30	33.8	42.6	31.9	14
Bow					
Burlington Yard					
	11.68	34.5	41.8	31.3	14
Mt. Vernon					
	8.97	23.9	60.3	45.2	14
Stanwood Station					
	8.94	23.8	60.4	45.3	14
English Station					
Marysville					
	6.88	21.4	67.4	50.5	14
Delta Junction					
Everett Station					

Table 4-12. Impact of existing passenger trains.

Siding Name	Single Track Grid Lengths Between Sidings (Miles)	Total Time Freight Slots Unavailable Due to Psgr. Train Priority (Minutes)	Available Minutes in Day for Freight (Minutes)	Theoretical Maximum Number of Freight Trains per 24-hour Period	Practical Maximum Number of Freight Trains per 24-hour Period (75% of Theoretical)	Actual Freight Trains per Day (Peak Days)
Blaine						
	1.81	83.7	1,356.3	21.5	16.1	14
Swift						
	1.91	100.5	1,339.5	21.7	16.3	14
Intalco/Custer						
	2.79	161.3	1,278.7	20.3	15.2	14
Ferndale						
Bellingham						
MP 96.73						
	12.91	276.8	1,163.2	28.4	21.3	14
Bellingham Station						
Samish						
	11.3	303.9	1,136.1	33.6	25.2	14
Bow						
Burlington Yard						
	11.68	276.9	1,163.1	33.7	25.3	14
Mt. Vernon						
	8.97	194.5	1,245.5	52.1	39.1	14
Stanwood Station						
	8.94	171.5	1,268.5	53.2	39.9	14
English Station						
Marysville						
	6.88	128.4	1,311.6	61.4	46.0	14
Delta Junction						
Everett Station						

Table 4-13. Impact of new passenger trains.

Siding Name	Single Track Grid Lengths between Sidings (miles)	Theoretical Maximum Number of Freight Trains per 24-hour Period	Practical Maximum Number of Freight Trains per 24-hour period (75% of theoretical)	Actual Freight Trains per Day (Peak Days)
Blaine				
	1.81	20.8	15.6	14
Swift				
	1.91	20.9	15.7	14
Intalco/Custer				
	2.79	19.0	14.2	14
Ferndale				
Bellingham				
MP 96.73				
	12.91	25.0	18.7	14
Bellingham Station				
Samish				
	11.3	22.0	16.5	14
Bow				
Burlington Yard				
	11.68	22.8	17.1	14
Mt. Vernon				
	8.97	38.0	28.5	14
Stanwood Station				
	8.94	39.5	29.7	14
English Station				
Marysville				
	6.88	47.1	35.3	14
Delta Junction				
Everett Station				

In general, whenever the calculated capacity and the actual capacity numbers are relatively close to one another, a potential area of conflict is identified. In this case, it is simply a “flag” that is raised when there is an introduction of the new passenger services. A physical capacity constraint of some sort is likely to occur that will require some sort of physical capacity enhancement. By focusing the next level of analysis over the identified three segments, it is likely that the reduction of grid lengths may be the most appropriate recommendation (i.e., connecting sidings such as between Samish and Bow and between Bellingham with MP 97).

4.4.3.6 Impact of Additional Improvements

As a final test of the impact of adding capacity improvements over the corridor, four sidings were connected making two longer sidings: Bellingham/MP 96.73 siding; and Samish/Bow siding. These siding combinations have the effect of minimizing single track grid lengths between

MP 106.37 (south switch of Ferndale siding) and MP 83.53 (north switch of new Samish/Bow siding). As can be seen in Table 4-14, potential freight train volumes increase dramatically on the remaining single track grid lengths in this mid-route area over previous volumes.

It should be noted that this grid analysis assumed a lesser improvement than the RTC simulation regarding joining sidings at Bellingham. In RTC, the South Bellingham (or Bellingham Station) siding was joined with the Bellingham siding at MP 97.0. In the grid analysis, sufficient capacity could be provided by joining MP 96.73 siding with Bellingham siding; this is a sub-segment of the South Bellingham (Bellingham Station)/Bellingham siding improvement concept tested by RTC in Simulation 4.

4.4.3.7 North Sound Grid Time Analysis Summary

The results of the grid analysis raised a cautionary flag following the potential introduction of a new passenger and commuter rail service over this corridor. Even though the existing operations showed adequate capacity, this capacity was "lost" when a new passenger/commuter service

Table 4-14. Impact of joining Samish and Bow sidings; extending Bellingham siding to MP 97.

Siding Name	Revised Grid Lengths (miles)	Theoretical Maximum Number of Freight Trains per 24-hour Period	Practical Maximum Number of Freight Trains per 24-hour Period (75% of theoretical)	Actual Freight Trains per Day (peak days)
Blaine				
	1.81	20.8	15.6	14
Swift				
	1.91	20.9	15.7	14
Intalco/Custer				
	2.79	19.0	14.2	14
Ferndale				
	8.30	37.1	27.9	14
Bellingham / MP 96.73				
	2.90	52.9	39.7	14
Bellingham Station				
	8.67	29.8	22.4	14
Samish / Bow				
Burlington Yard				
	11.68	23.5	17.1	14
Mt. Vernon				
	8.97	38.0	28.5	14
Stanwood Station				
	8.94	39.5	29.7	14
English Station				
Marysville				
	6.88	47.1	35.3	14
Delta Junction				
Everett Station				

was contemplated. However, the analysis did identify the area most in need of further study and set a path for subsequent evaluation with more sophisticated analytical tools.

4.4.4 North Sound Web-based Shared-use Tool Analysis

4.4.4.1 Introduction

As a third test, the Web-based Freight-Passenger Rail Corridor Project Screening Tool, also known as the Shared-use (SU) Tool, developed for the National Cooperative Freight Research Program (NCFRP) Project 30, was used to determine if the capacity improvements planned for the *Cascades* would enable the implementation of two round trip, peak period North Sound regional rail trains on weekdays.

The SU Tool was developed in response to a broad interest from public planning agencies in having access to a scoping-level instrument that would narrow down the range of potential corridor service opportunities and isolate locations that are worthy of further study. It includes a number of features, such as train performance logic, that are more sophisticated than the simple grid analysis described above. The SU Tool may thus be viewed as an intermediate level approach, falling between simple grid time analysis and the very precise (and data intensive) service capacity output features of RTC.

The SU Tool requires MS Silverlight (a free web browser add-in). If this not already installed, the user will be prompted to download it. The SU Tool works on a browser that supports the Silverlight add-in. Per the SU Tool website, these browsers include Internet Explorer version 6 or later, Safari, Google Chrome, and Firefox web browsers.

The SU Tool webpage is self-explanatory and a user manual is provided on the website to guide through the steps involved in creating a simulation model. The SU Tool organizes data pertaining to a simulation analysis (which may contain multiple scenarios) into a container system. The three principal data containers in SU are Folders, Rail Systems, and Operating Plans.

- Folders contain all of the data required for an analysis. A Folder contains one or more Rail Systems, which in turn contains one or more Operating Plans. Trains are contained in the Folder, and any train in the Folder may be referenced by any Operating Plan in any Rail System.
- The Rail Systems container consists of track and related information (grades, curves and speed zones), all other infrastructure features, station lists, timetable routes, and traffic control blocks. Rail Systems include one or more Operating Plans.
- An Operating Plan contains a list of selected trains from the Folder. Each train has a designated timetable route and operating schedule. An Operating Plan also contains a set of central dispatcher parameters and other operating plan elements.

The SU Tool provides two ways of coding the Rail System (network). There is a visual interface for beginners, which can be used to code railroad infrastructure (segments, switches, speed limits, curvature, elevation, and stations). For more experienced users, a table-based interface is available to import data pertaining to infrastructure in a Comma Separated Values (CSV) file format. The table-based interface can be used to export the network files which are created using visual interface and recreate a new alternative with minimal effort, instead of building from scratch.

For the North Sound simulation, an attempt was made to use the data interface to export the network from RTC simulation directly into the SU Tool using custom programming. Due the conversion issues, modelers were forced to resort to the visual interface. However, this effort provided a valuable lesson in understanding how the network is coded, and also significantly helped in coding the alternatives.

The visual interface consists of click and drag methods to code the network; the details of coding are explained in the SU Tool user manual. Once a segment is coded, the attributes (e.g., train speed limit) of the segments can be modified by clicking the segment and choosing edit speed limit pop-up. The passenger and freight speed limits can be entered manually. The network was developed in incremental steps to check for any errors at each stage. Once the network is coded, a route file was created. Each route includes a "begin" and an "end" station, along with the intermediate stop locations.

SU Tool provides visual tools to create trains. A train consist was created for each train using the number of locomotives and cars along with empties and loaded cars data provided by BNSF. Using the trains created, modelers developed a train timetable based on the route data from the network. The timetable includes arrival, departure, and dwell time at each location on the route.

Likewise, an operating plan was developed using the train data. There are additional parameters in the operating plan container, such as set central dispatcher parameters and other operating plan elements. For simplicity, these parameters were left to default values.

As with the grid time analysis, the basic train operating patterns for the SU Tool analysis were the same as defined for the foregoing RTC simulation description. Also, the goal of the analysis was the same. That is, do the improvements envisioned for more Amtrak *Cascade* trains provide sufficient capacity on the rail network between Blaine and Everett to host new North Sound regional rail trains and still maintain fluid, reliable freight and passenger operations?

4.4.4.2 Network Simulations

As a part of SU Tool analysis three cases were simulated:

- Simulation 1 (base case) represents existing track configuration between Everett passenger station to Bellingham and Blaine along with existing trains including two *Cascade* round trips between Seattle and Vancouver and BNSF trains. The analysis period was reduced to one day to reduce the simulation effort. The peak day was chosen such that it has maximum trains in a given week.
- Simulation 2 has the same track configuration and freight trains as Simulation 1. However, with respect to passenger trains, it adds the two Bellingham-Everett weekday regional rail trains and a third *Cascade* Seattle-Vancouver round trip on a mid-day schedule.
- Simulation 3 adds track improvements by extending the siding at South Bellingham north to Bellingham siding, joining Samish and Bow sidings, and implementing a universal crossover at MP 81.0. The trains were carried over from Simulation 2.

4.4.4.3 Simulation Results

The SU Tool provides a summary of the train operational effects as changes in average speed and delay by individual train and by train type: freight and passenger. The SU Tool simulation results by train type are summarized in Table 4-15. A speed profile for the North Sound service appears as Figure 4-6.

Table 4-15. Simulation results from SU tool.

	Average Speed (in mph)		Average Delay (in minutes)	
Case	Passenger	Freight	Passenger	Freight
Simulation 1 (Base Case): No Build (Existing Trains)	50.7	29.0	2.0	160.6
Simulation 2: No Build (Future Trains)	48.3	28.5	15.0	145.9
Simulation 3: Build (Future Trains)	47.2	30.5	6.8	52.4
Note: Simulation 2 runs are unstable when simulated with different random numbers.				

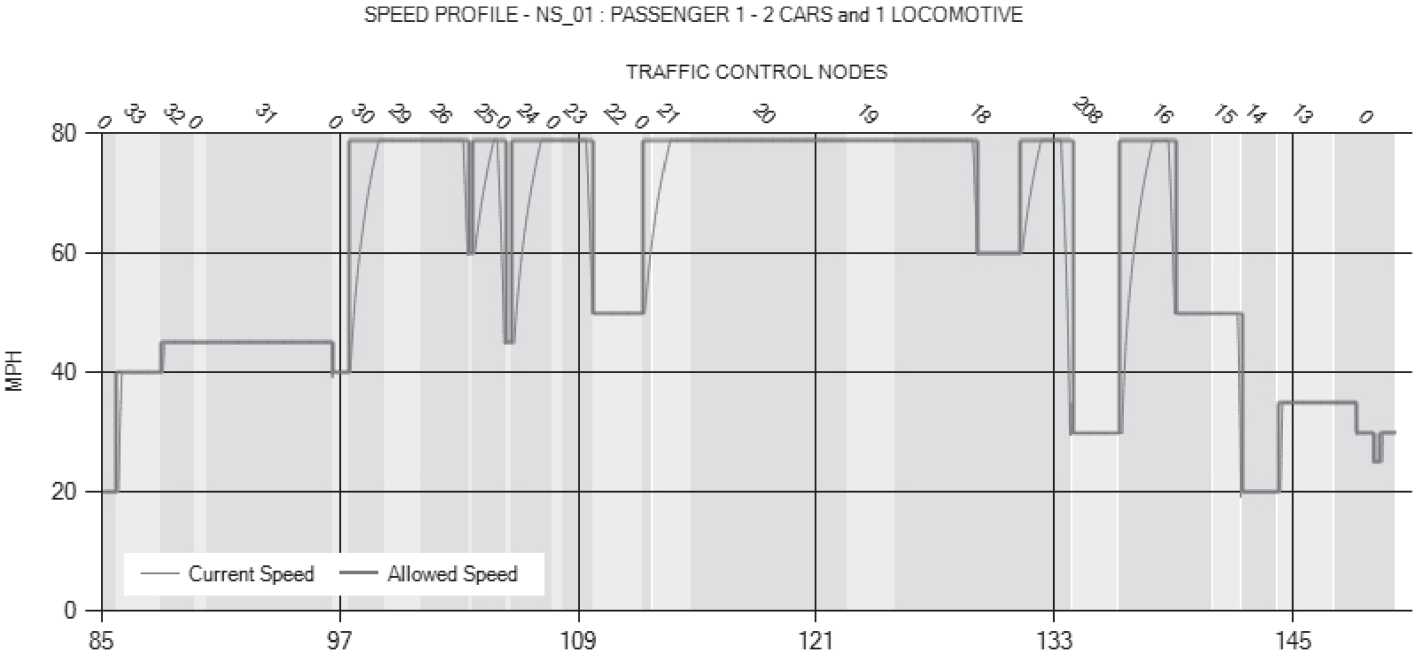


Figure 4-6. Train performance calculation generated by SU tool.

As shown in the table, Simulation 3 results (average speed and average delay) for freight trains were better than the Simulation 1 (base case) results. Improvement in the freight trains performance can be attributed to the infrastructure improvements in the Simulation 3 network. Also, the reduction in the average speeds and increase in average delays for passenger trains in Simulation 3, when compared with the Simulation 1, can be attributed to the Bellingham-Everett weekday regional rail trains, which have more stops compared to the *Cascade* trains (Seattle to Vancouver passenger). The Simulations 1 and 3 runs behaved fairly consistent with different random numbers.

The Simulation 2 results may not be reflected accurately as additional runs with different random numbers revealed instability, with significant delays and reduction in speeds for both passenger and freight trains.

4.4.4.4 North Sound SU Analysis Summary

The results from the SU Tool analysis indicate that the addition of the two North Sound regional rail round trips and an additional *Cascade* round trip would have no negative impact on BNSF freight service, given the enhanced network assumed for Simulation 3. However, passenger train speeds and delays would worsen.

4.4.5 Comparison of RTC, Grid Analysis and SU Tool Results

The North Sound RTC simulation, grid time analysis and SU Tool analysis provide results that are in some ways quite similar. The RTC simulation showed that, with the new passenger trains (*Cascades* and North Sound regional rail trains), passenger train performance would deteriorate somewhat, but freight train performance would be enhanced. This is the same finding generated by the SU Tool application. While the results like average speed per passenger and freight trains are different, the findings overall are consistent.

The grid time analysis found that sufficient capacity exists today for the new passenger trains. But mid-route between Blaine and Everett, conditions get tight. Such a finding does indeed raise

Table 4-16. Summary of analysis methodologies for North Sound case study.

Approach	Labor Hours	Data Needs	Comment
Grid Time Analysis	40	Track charts, employee time table, and train counts for Everett to Blaine	Quick for spotting potential trouble areas. Difficult to apply to complex networks.
Web-based Shared-use Tool	120	Track charts, train operating patterns, and equipment detail for Bellingham Subdivision	Good scoping-level tool. Lacks tools to visualize train simulation. Not user friendly to test network robustness, i.e., running multiple scenarios. Model utility in complex network situations not tested in this case. Data saved on web servers. Free tool.
Rail Traffic Controller	400	Track charts, employee time table, train operating patterns, and equipment detail for Scenic and Bellingham Subdivisions	Proven operations simulation methodology. Good tools for visualization of train simulation. Easily calibrated to reflect actual dispatcher practices. Runs on a local computer. RTC licenses must be purchased.

a flag over potential service issues, which both the RTC and the SU Tool confirmed: passenger train performance suffers.

It is worth noting that grid time analysis can be used to quickly identify potential solutions for capacity constraints and test them—albeit not as definitively as either of the two simulation methodologies.

Table 4-16 provides estimates of the time requirements for the three different analysis methodologies that were applied in the North Sound case study. Both the grid time and SU Tool analyses were for just the Everett-Blaine segment. The estimate for the RTC analysis reflects the simulation of the Scenic and Bellingham Subdivisions in addition to the Everett-Blaine segment, and thus is much higher. The estimates for labor hours are surrogates for estimated costs.

The larger point of the comparison is that each analytical method has its place. Grid time analysis should be considered an up-front tool, used to understand whether or not a capacity constraint exists. Operations simulation, on the other hand, should be used to investigate the issue further, and to shape and define potential solutions.

CHAPTER 5

Taking Shared-Use to the Next Level: Chicago–Saint Louis High Speed Rail

5.1 Introduction

This guidebook concludes with a discussion of recent and ongoing planning for the Chicago-Saint Louis high speed rail implementation on the UP and CN line. This line will host high speed trains in the near term, along with increasing amounts of freight and conventional passenger services. It is included in the guidebook because its planning effort has embodied many of the themes for successful shared-use corridor planning that were uncovered in the stakeholder outreach effort discussed in Chapter 2. Namely:

- The necessity of building trust between the host freight railroad and the public agency sponsor;
- The importance of taking a longer term view to account for changing rail operating patterns;
- The need to look for factors affecting corridor operations that may reside well outside of the corridor itself; and,
- A highly detailed, rigorous operations simulation testing the robustness to proposed track configurations given differing assumptions for train mix and operating patterns.

Relative to the case studies already presented, the Chicago-Saint Louis rail planning effort represents the next level of shared-use corridor planning employing capacity analysis.

5.2 Background

Passenger rail service between Chicago and Saint Louis has a long and colorful history, being the product of a state initiative in the early 1850s. Illinois' first major carrier, the Illinois Central Railroad (IC), was chartered in 1851 and by 1856 was operating over 750 miles of track. It was the nation's largest rail carrier in that year and linked Chicago to points south while encouraging settlement of downstate areas, including East Saint Louis. (Reference: Chicago Historical Society). Abraham Lincoln was IC's most famous lawyer, and his early exposure to rail no doubt influenced his championing of the nation's first transcontinental rail link even in the midst of the Civil War.

In modern times Chicago-Saint Louis service survived the massive, nationwide service reductions that accompanied Amtrak's creation in 1971 and the exit of most private carriers from the business of moving people. Amtrak service between the two cities has continued, unabated even as much of the underlying trackage has changed hands (three times) and even survived a bankruptcy challenge. Today most of the corridor is owned and operated by Union Pacific Railroad. In 2006 the passenger service frequency was increased from three to five round trips per day.

Modern day interest in improving rail service between Chicago and Saint Louis extends back to 1979 with a formal assessment of true, electrified high speed rail service on a dedicated alignment.

The outcome of that study was a judgment that such an infrastructure approach was too expensive and that efforts should instead focus on upgraded speeds and frequencies using existing, shared alignments with freight carriers. The 1994 IDOT *Chicago-St. Louis High Speed Rail Financial and Implementation Plan* put forward a corollary architecture for improved service involving diesel-powered trains operating at 110–125 mph.

The USDOT formally designated the 284-mile Chicago-Saint Louis corridor as part of the "Chicago Hub" high speed rail corridor in 1992. The "Chicago Hub" plan served as the foundation for what was to become, in 1996, the Midwest Regional Rail Initiative (MWRRI). The MWRRI constitutes the overall planning framework for intercity passenger service improvements across nine Midwest states and 3,000 miles of higher speed rail service.

The current Chicago-Saint Louis high speed rail improvement project is a combination of track section upgrades:

- A 37-mile, single track segment from Joliet to Dwight is being upgraded by virtue of monies released from cancelled ARRA-funded rail improvement projects in Ohio and Florida. Siding and double track improvements will alleviate the most severe capacity constraints on the entire Chicago-Saint Louis route and are proceeding on the basis of "categorical exclusions" insofar as the EIS process is concerned.
- Track between Dwight and Saint Louis is undergoing major upgrades as described in a 2004 favorable FRA/FHWA Record of Decision (ROD). This ROD was based on an EIS study conducted by Illinois Department of Transportation (IDOT) to assess service and infrastructure upgrades south of Dwight to permit three daily round trip trains to operate reliably at 110 mph speeds. A pair of slower, conventional speed trains and the long-distance *Texas Eagle* will continue to ply the same route. The possession of a completed, formal ROD served the state particularly well in the competition for ARRA funds; environmental clearances and other approvals were in hand as needed to launch "shovel ready" elements of the project.

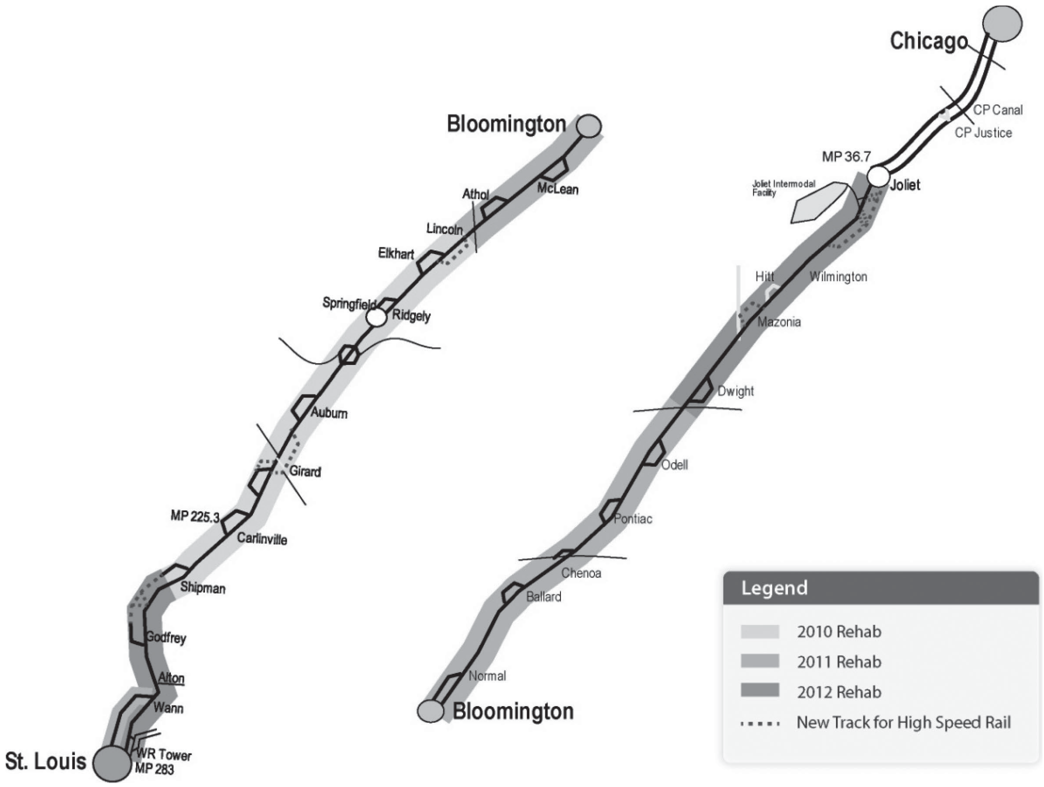
Improvements between Joliet and Chicago proper will come as part of a later phase of work. A recent federal announcement specified the former Rock Island/Metra alignment as the preferred routing for improved intercity services between Joliet and downtown Chicago. Current service is provided over UP between Dwight and Joliet and then Canadian National Railway (former Illinois Central) tracks northward into Chicago proper. The change in route will also shift the Chicago terminus from Union Station to Chicago LaSalle Street when trains move to the new alignment. A graphical representation of the corridor appears as Figure 5-1.

The funding for the line improvements has included significant contributions from the Illinois Department of Transportation and the federal government.

5.3 Freight Carrier Perspective

Union Pacific views the Joliet-Saint Louis corridor as a key traffic lane for intermodal freight service, anchored by the expansive Center Point intermodal facility in Joliet. Center Point will have a throughput capacity of 700,000 trailers and containers per year. UP's perspective on the corridor includes a need to protect all existing rail freight service capacity on the alignment while insisting on levels of investment that are capable of delivering the high-quality service levels expected by passenger service sponsors.

The capacity assessment and contracts for construction of new facilities were developed pursuant to "arm's length" negotiations between the parties as mandated by FRA for projects funded under the American Recovery and Reinvestment Act.



Source: Union Pacific Railroad/Illinois Department of Transportation

Figure 5-1. Chicago–Saint Louis high speed rail corridor.

5.4 A Timely Example

The study team believes the Chicago-Saint Louis project provides valuable insights for those considering major passenger rail corridor upgrades, on shared track, in other corridors. When completed it will be the only example of a freight carrier-dispatched and owned alignment with a high number freight trains as well as 110 passenger mph trains. Other project elements to be noted include:

- Implementation of advanced train control and other safety appliances (such as four-quadrant gates) simultaneous with the rollout of upgraded passenger service.
- “Nesting” of a funded, medium-term improvement plan within the context of an as yet unfunded 20-year service vision. Upgrades underway to permit increased speeds for existing trains are carefully configured to minimize re-work when the full double track configuration is finally put into place.
- Unique provisions for accrual of public capital renewal funds and for allocation of costs associated uniquely with the higher-standard FRA Class VI infrastructure. These are described in Section 5.10.

5.5 Project Vision—Illinois DOT

Improvements to Illinois passenger rail service have enjoyed strong, bipartisan support at the state level for over two decades. A high profile 2009 meeting between Senator Dick Durbin and then-UP Chairman Jim Young set the stage for the most recent efforts, signaling the strongest possible commitment to delivering a quality product that delivers benefits to all stakeholders.

The official Illinois vision statement for the project is as follows:

> *"More than 90 percent of the over 35 million corridor trips have origins or destinations in Chicago or St. Louis. A more balanced transportation system in the corridor would provide travelers with greater mobility options. To achieve this, either a new transportation mode must be introduced, or improvements to an existing, less frequently used intercity passenger rail mode must be made. Reduced travel time, increased service reliability, and enhanced safety would attract travelers from automobile and air travel to a new or improved rail mode of transportation."* (Reference: Illinois DOT High Speed Rail website, www.idothsr.org.)

5.6 Project Environment

The Chicago-Saint Louis project was spearheaded by the State of Illinois, consistent with federal guidance under the Passenger Rail Investment and Improvement Act (PRIIA) of 2008 that assigns the primary leadership role in development of new intercity services to the states. While a small portion of the corridor at the Saint Louis end of the line is in Missouri, the current project is for most purposes an Illinois project.

Illinois elected to first pursue improvements on that portion of the corridor where placement of the long term alignment is clear and engineering issues are straightforward. Upgrades to the Dwight-East Saint Louis portion of the corridor had received federal green light in a favorable 2004 Record of Decision in response to an IDOT Environmental Impact Study of service upgrades. Detailed prior planning south of Dwight positioned the state very well to take advantage of high speed intercity passenger rail (HSIPR)-dedicated stimulus funding consistent with the "shovel ready" objectives of the stimulus program.

In January 2010 the Federal Railroad Administration announced $1.1 billion in funding for the Dwight to Saint Louis corridor improvements; upgrades to this portion of the alignment are planned to be substantially completed in 2015. Photos of improvements are shown in Figure 5-2 and Figure 5-3.

5.7 Corridor Analysis and Development of the Upgrade Program

The architecture of the current (Phase One) upgrade program was first developed pursuant to a detailed operations assessment and modeling exercise in 2002. The 2002 technical assessment informed the 2003 EIS submission which led to the Record of Decision noted above. Line

Photo by Parsons Brinckerhoff

Figure 5-2. Improvements at Odell siding.

Photo by Parsons Brinckerhoff

Figure 5-3. Station improvements at Normal.

capacity modeling, using the Rail Traffic Controller (RTC) operations simulation program, was performed after loading the infrastructure data and train service specifications that are standard for use of the RTC program. The current funded plan includes installation of a total of 31 miles of double track over four line segments, 15 rebuilt sidings, one new siding, fencing, signaling upgrades and grade crossing rebuilds. Siding reconstruction includes widening the space between track centers to 20 feet, allowing trains on adjoining lines to proceed at full track speed during periods of track renewal. A substantial share of the Phase One capital investment is occurring to support the long term Phase Two build-out.

A general upgrade of existing track facilities—cross ties, rail, and higher-standard rail appliances—is also required to support the 110 mph passenger operation. When Phase One is complete there will be no change in the number of trains that ply the route today (five round trips). However, trip time reductions will occur as a result of the increased maximum speed to 110 mph from 79 mph.

The Phase Two operations and infrastructure assessment took place in 2009. A dedicated team of railway operations, simulation, and engineering experts set out to update the 2002 RTC analysis. The goal was to determine the required investments needed to support nine total daily passenger round trips between Joliet and Saint Louis, including the long-distance *Texas Eagle.* Phase Two will add four daily express round trips and will also increase the maximum speed to 125 mph. The long-distance *Texas Eagle* is unlikely to see maximum speeds increased from today's 79 mph under either Phase One or Phase Two.

The timing of the project was excellent for the project sponsors in that expert resources were readily available to support technical planning and construction activities. The North American rail industry has a long history of boom and bust construction cycles depending on economic and modal competitive conditions. Most of the Saint Louis-Chicago project work was initiated after the conclusion of a two-decade period of industry expansion where even basic track materials were often priced at a premium and in short supply.

A UP modeling expert was dedicated, at IDOT expense, to work solely on the Saint Louis service alignment along with two external consultants approved jointly by UP and IDOT. Dedication of the UP expert to this project ensured significant focus on the project needs and scheduling control by IDOT for attendance at meetings, etc., on short notice. Total cost of the modeling exercise is estimated at around $450,000, a considerable sum to be sure but not out of scale with the expected $3 billion total project investment.

A structured communications protocol along with a web-based project status site kept all participants in the loop as the analysis progressed. Conference calls took place weekly, with face-to-face meetings (in Chicago) on a quarterly basis. It should be noted that this communications approach supported both the Phase Two analysis and the ramp-up of Phase One construction activity as the project moved forward. By early 2010 the Phase Two capacity assessment and simulation work was largely complete. Construction agreements for Phase One work were signed by IDOT and UP in July 2010 and March 2011.

Restrictions on out-of-state travel for IDOT employees limited their ability to meet with UP officials in Omaha. A single, full day meeting in late 2009 included IDOT and FRA officials. Simulations were shown that reflected the nine daily round trip passenger frequencies along with the 16 daily UP freight trains projected to use the alignment. Detailed performance metrics for the passenger operation were also provided.

Once there was agreement on the service definitions the capacity assessment, testing of configurations and simulation proceeded smoothly. Analysis start-up challenges included reaching agreement on the level of resources required for the analysis, selection of third-party consultants, and meeting the timing requirements of the ARRA funds used for the project.

5.8 Translation of the Corridor Analysis into the Engineering and Investment Program

In July 2010 and March 2011 IDOT and Union Pacific entered into construction agreements to perform the corridor upgrades between Joliet and East St. Louis, IL. Specifications and costs of the upgrade program were developed by UP in consultation with IDOT and consistent with the 2002-2003 capacity assessment. Union Pacific secured dedicated outside legal counsel to help manage the many dozens of agreements required to execute the project. UP has noted that the dedicated legal staff was essential in meeting the aggressive timing requirements of ARRA.

5.9 Service Outcomes Agreement

A particular challenge for all sponsors of new intercity passenger rail services has been the development of specific “Service Outcomes Agreements” (SOAs) that spell out the obligations of host carriers and service operators following the completion of line upgrades, along with specific remedies to employ if and when service targets are not met. These SOAs are a common requirement for approval of federal funding support as overseen by the FRA, and are designed to ensure public value and benefit from public investment in private rail facilities.

The UP/IDOT-Amtrak-FRA SOA was negotiated over a period of approximately nine months and was formally signed in December 2010. SOAs have proven challenging to negotiate in that host carriers are required, for the first time, to provide specific service guarantees for passenger operations as a condition of new public investment in their facilities. While a detailed description of the negotiations process is beyond the scope of this study, it may be noted that the areas of greatest challenge have proven to be:

- *Measurement of service performance.* Traditional Amtrak "conductor delay reports" document delays in service from the perspective of an on-board train observer. Such reports are unable to capture the contribution of various network service elements in creating a service shortfall. A specific delay may be caused by a mechanical failure of another train (freight or passenger), freight or passenger terminal operations, and/or dispatch decisions of the host carrier.
- *Root cause analysis procedures.* A formal structure to codify and assign root causes for systematic service shortfalls is needed to properly assign responsibility and ensure optimal targeting of new capital investments.
- *Prescription of remedies.* Patterns of service shortfalls require a response from the service provider, the host carrier, or some combination thereof.

5.10 Track Maintenance Agreement

A track maintenance agreement specifying terms for funding and maintaining the shared track was signed in March 2012. While agreements of this type are common in the rail industry, the Chicago-Saint Louis alignment is unique in that it will be the first such facility maintained to FRA Class VI standards while simultaneously handling large volumes of freight. Some unique features of the agreement include:

- Mechanisms for accrual of capital renewal funds to provide stable financial flows in support of major, cyclical investments that are inherent in the operation of main line rail infrastructure. A relatively stable annual public contribution is to be escrowed in anticipation of major capital renewal program requirements beginning in years 12 to 15 after completion of the initial upgrade.
- Allocation and tracking of capital and maintenance obligations associated with FRA Class VI infrastructure standards on an alignment with significant freight volumes. IDOT will be responsible for those engineering expenses specifically associated with the higher standards. The "baseline" UP cost responsibility is defined according to historic experience of the carrier in moving analogous volumes of freight along with the existing Amtrak passenger trains over a traditional FRA Class IV main track infrastructure.

5.11 Next Steps

In late fall 2010 IDOT began work on a corridor-wide Phase Two, Tier I EIS to describe the next phase of service improvements and associated infrastructure upgrades. This new phase will incorporate full double tracking of the corridor, generally incorporating the improvements defined in the Phase Two capacity analysis described above. It also defines the specific preferred alignments for service north of Joliet and consolidation/realignment of service through the Springfield metro area. Finally, improvements will be described for the approach into St. Louis through Metro East region, including bridge improvements over the Mississippi River.

The IDOT Phase Two, Tier I EIS was approved by the FRA in December 2012. The Record of Decision generally approves the infrastructure plan as supported by the simulation and capacity work described above. Also included in the ROD are freight service consolidation and alignment improvements in Springfield as well as the selection of the Rock Island/Metra corridor as the primary intercity service route north of Joliet. Table 5-1 shows the times for high speed rail service appearing in the 2004 Record of Decision. This schedule of five round trips (three operating at high speed) will be in effect at the completion of the Phase One improvements (2015), and will be the basis from which Phase Two improvements will be implemented.

Table 5-1. Phase one schedule for the Chicago-St. Louis high speed rail service.

		301	303	21	305	307
Station	**Mile**	**HS Standard**	**Lincoln Service**	**Texas Eagle**	**HS Standard**	**HS Standard**
Chicago	0	07:00	09:25	13:45	17:15	19:00
Summit	12	07:23	09:48	---	17:37	19:22
Joliet	37	07:45	10:15	14:40	18:00	19:45
Dwight	74	08:12	10:49	---	18:27	20:12
Pontiac	92	08:28	11:06	15:27	18:43	20:28
Normal-Bloomington	124	08:53	11:39	16:04	19:08	20:53
Lincoln	156	09:19	12:10	16:37	19:34	21:19
Springfield	185	09:44	12:50	17:14	19:59	21:44
Carlinville	224	10:14	13:28	17:49	20:29	22:14
Alton	257	10:42	13:59	18:22	20:57	22:42
St. Louis	284	11:10	15:00	19:21	21:25	23:10

Note: Train Number 301 was labeled HS Express in the 2004 Record of Decision. It is amended above as it reflects stops at all intermediate stations.

Source: 2004 Record of Decision.

In Phase Two nine round trips, including the five above and four additional round trips, will travel each direction daily. Limited stop high speed express trips would take 3 hours and 50 minutes from Chicago to St. Louis, while additional, all-stops high speed trains would add 20 minutes to this schedule in consideration of six additional stops en route. Maximum speeds would also be increased to 125 mph from the 110 mph maximum prescribed in the current phase of work.

Tier II EIS studies began in 2013 for Phase Two improvements, including more detailed operations analyses. The timing of the Phase Two upgrades is linked to funding availability, and is unclear at the time of this writing. Table 5-2 identifies the schedules for passenger trains on the Chicago-St. Louis corridor when Phase Two operations are implemented.

Table 5-2. Chicago-St. Louis high speed rail train service schedule, double track phase—southbound.

	501	571	573	503	505	21	507	575	577
Station	HS Express	HS Standard	HS Express	HS Express	HS Standard	Texas Eagle	HS Express	HS Express	HS Standard
Chicago	05:40	07:00	08:40	10:30	12:00	13:45	14:05	17:30	19:00
Summit	---	07:22	---		12:22	---			19:22
Joliet	06:25	07:45	09:25	11:15	12:45	14:40	14:50	18:15	19:45
Dwight	---	08:12	---		13:12	---			20:12
Pontiac	---	08:28	---		13:28	15:27			20:28
Normal-Bloomington	07:22	08:53	10:22	12:12	13:53	16:04	15:47	19:12	20:53
Lincoln	---	09:19	---		14:19	16:37			21:19
Springfield	08:09	09:44	11:09	12:59	14:44	17:14	16:34	19:59	21:44
Carlinville	---	10:14	---		15:14	17:49			22:14
Alton	09:02	---	12:02	---	15:42	18:22	---	20:52	---
E. St. Louis	---	11:00	---	14:10	---	---	17:45	---	23:00
St. Louis	09:30	11:10	12:30	14:20	16:10	19:21	17:55	21:20	23:10

Source: 2009 IDOT Service Development Plan for the Chicago-St. Louis HSR operation, Phase Two.

Finally, it should be noted that a limited portion of 110 mph Amtrak service began in November 2012 over a 14-mile segment between Dwight and Pontiac. IDOT and Union Pacific are carefully monitoring train and signal performance as well as engineering maintenance issues associated with 110 mph operations as providing context for the large scale rollout of higher speeds in the next few years.

5.12 Conclusion

A great deal has been learned in developing Chicago-Saint Louis about the institutional and legal challenges of essentially re-building a privately held main track alignment with over $1 billion in public investment. Much is still unknown, however, about the long term costs and operating implications of operating significant numbers of both main line freight and higher speed passenger trains over common FRA Class VI infrastructure with a maximum allowable speed of 110 mph for passenger trains.

While freight trains operate regularly over portions of the Northeast Corridor, the overall volumes are small in relation to the passenger activity. Conversely, large numbers of passenger trains operate in high-density freight alignments at “conventional” speeds of 79 mph or less, particularly for commuter service operations.

It is always possible to engineer a physical plant capable of handling all classes of trains, if cost is no object. What will be interesting to learn from Chicago-Saint Louis is the long term cost and operations practicality of all the projected services, passenger and freight, operating on a common physical plant. Chicago-Saint Louis may become the *de-facto* testing ground for the economic limits of shared track access.

APPENDIX A

Discussion of Train Prioritization and Effect on Line Capacity

A.1 Introduction

Railroads are unique in the transportation industry in that they operate a substantial portion of their networks with vehicles simultaneously moving in both directions on a single line. To use a highway analogy, this would be like cars moving in opposite directions on a single lane road, with the need to determine how they pass each other when moving in opposite directions and how a faster car can pass a slower car moving in the same direction.

A.2 Single Track Operations

Railroads solved these problems by constructing passing sidings at strategic locations, generally between 5 and 15 miles apart. When trains moving in opposite directions encounter one another, one of the trains is routed into a passing siding to let the opposing train pass. See Figure A-1, Case 1. The train dispatcher coordinates the movement of trains and uses the signaling system, or in some cases voice communication by radio, to instruct the trains where to go, with the goal of efficiently moving traffic over the network.

In such a single track operation, whenever two trains meet one another, one or both will be delayed. One train is routed into a siding, where it will stop and wait for the opposing train. The train moving in the opposite direction may see some delay if the train it is to meet has not pulled completely into the siding when it is approaching the meet location. Generally, the dispatcher will try to minimize the delay by routing the first train to arrive at a meet location into the siding so that the opposing train can pass by without delay, but the timing may not always be perfect.

One train can overtake another on a single track, but this will cause significant delay to the remaining traffic, slowing overall movement on the route. Consider a typical single track line with passing sidings located 10 miles apart. As seen in Figure A-1, Case 2, trains moving in the same direction will normally space themselves about two sidings, or 20 miles, apart, as they approach a train moving in the opposite direction.

If a dispatcher wants to overtake one train with another, the first train will have to be held at a siding until the following train catches up to it from two sidings back. The higher priority train will then have to get two sidings ahead before the lower priority train can proceed again. All during this time, there can be no movement by trains in the opposite direction, since the two trains running in the same direction will occupy a siding location where opposing trains would normally meet.

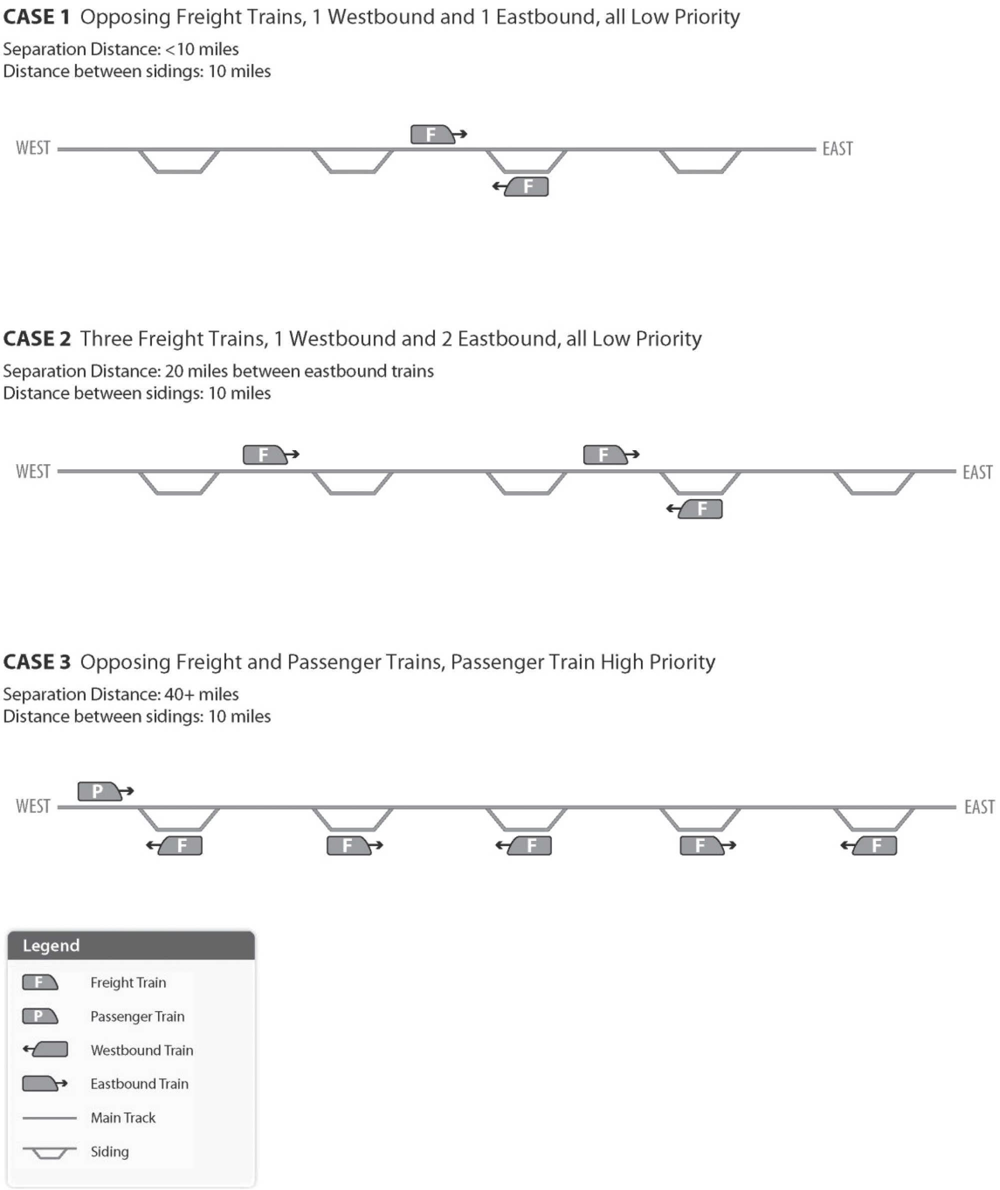


Figure A-1. Three illustrative cases of rail line capacity consumption.

A.3 Double Track Operations

A double track rail line is similar to a two-lane highway. Trains moving on double track lines generally stay to the right, and they typically follow one another at a common speed since it is difficult to overtake a slower train by running on the "left hand" track. In contrast to single track operations, trains meeting one another on double track can pass freely without delay to either train. Passing sidings, like those used on single track lines, are generally not needed or provided.

Railroads provide crossovers at regular intervals on double track to allow trains to move from one track to the other. Like sidings on single track, crossovers are typically spaced about five to 15 miles apart. These crossovers are provided primarily to allow trains to move around a section of track that has been closed for maintenance, or to access industries whose sidings and spurs are located on the opposite side of the tracks. Crossovers are sometimes used to allow trains to

Table A-1. Overtake distance required.

Catch up to slower train	5 miles
Overtake slower train	3 miles
Run ahead to clear signals	5 miles
Total	13 miles

overtake one another. Crossover speed limits depend on the switch angle, and crossover moves often take place at reduced speed.

In describing how one train can overtake another on a double track line, it may be easiest to compare the operation to a two-lane highway. If a car wanted to pass a slower vehicle on a two-lane road, there would have to be a break in the opposing traffic of about a mile before the car could safely pull out into the opposing lane and complete the overtake. It would take perhaps a quarter or a half of a mile to complete the maneuver and pull safely back into the proper lane.

It takes significantly more space and time to execute the same maneuver on a railway. The break in opposing traffic has to be in the order of 50 miles to avoid delaying the opposing trains, and the distance to complete the overtake would be in excess of 20 miles. It is possible for one train to pass another in less distance, but this requires that the train being overtaken stop to facilitate the move. Further, any opposing trains must stop to allow one of the trains to run on their track.

As an example, consider two trains moving in the same direction, with a slower train, with a capability of achieving 40 mph, running in front of a faster train, with a capability of 60 mph. Normally, the second train will follow the first by about five to seven miles because of the way the signaling system separates the trains.

If the train dispatcher wanted to allow the faster train to overtake the slower train, and if the opposing track were clear, the slower train would first be routed onto the opposing track at one of the crossover locations, then the faster train would overtake it on the regular line. The slower train is normally routed through the crossover to the opposite track because any speed restriction it has to obey while passing through the crossover will affect it less. To accomplish the overtake, the faster train first has to catch up to the slower train and pass it completely, then run far enough ahead that the slower train can move in behind it without being further slowed by the signaling system. These distances are shown in Table A-1.

Since the difference in speed between the two trains is 20 mph, the complete overtake would require about 40 minutes to accomplish. Since the slow train is progressing at 40 mph during this time, the total distance it occupies the opposite track would be a minimum of about 30 miles. This assumes a crossover is located at the right place to allow the train to move back to its regular track. If a crossover is not handy, the train will have to continue to the next crossover to switch back over.

A.4 Train Priorities

Class I railroads typically use a system of stated priorities to help ensure that trains move through the rail system in an orderly fashion with usually six or so tiers of priority. In general, passenger trains and certain intermodal trains receive relatively high priority; coal and grain trains (which are typically less time sensitive) are assigned a lower priority. In reality, however, all traffic other than that assigned the very highest priorities tends to operate on a first-come, first-served basis.

The practice of minimizing preferential treatment for certain trains helps to create fluidity throughout the rail system, thereby benefiting trains of all types. When there is moderate or heavy traffic on a route, railroads can generally make the best use of the physical plant by moving trains in order of departure at similar rates of speed. When some trains are expedited, other trains sharing the network will be negatively affected, and system velocity will decrease. Dispatchers simply do not have flexibility to expedite more than a handful of trains over others without creating disruptions on the system.

There are a limited number of situations in which it makes sense to take some trains out of order by moving them ahead of others. Passenger trains must move quickly, and intermodal trains generally require an accelerated schedule that is competitive with other modes of transportation. Moreover, such trains can be expedited more readily because they have high power-to-weight (horsepower per trailing ton, or hp/ton) ratios and are, therefore, capable of passing other trains quickly.

However, the faster that the passenger trains travel, the greater the separation distances needed between them and other trains over the corridor. The capacity footprint of the moving trains results in significant capacity consumption that restricts the flow of other users trying to share the same right-of-way. This verity illustrates a fundamental principle of rail service capacity: *The greater is the speed differential between trains, the more quickly is the capacity consumed for that section of track.* The most “efficient” use of a fixed physical rail alignment is for all trains to travel at a common speed.

Freight trains, which normally are separated by two siding lengths (or 20 miles) between each other, require double that distance when dealing with prioritized and higher speed passenger trains. As seen in Figure A-1, Case 3, the capacity “wake” ahead of a passenger train (on a single track railroad with passing sidings) can be in the order of 40 miles, thus requiring all freight movements in the vicinity to be positioned so as not to interfere in any way. Valuable rail capacity is thus consumed whenever such speed differential operations exist combined with high priorities.

APPENDIX B

Discussion of Positive Train Control and Effect on Line Capacity

B.1 Introduction

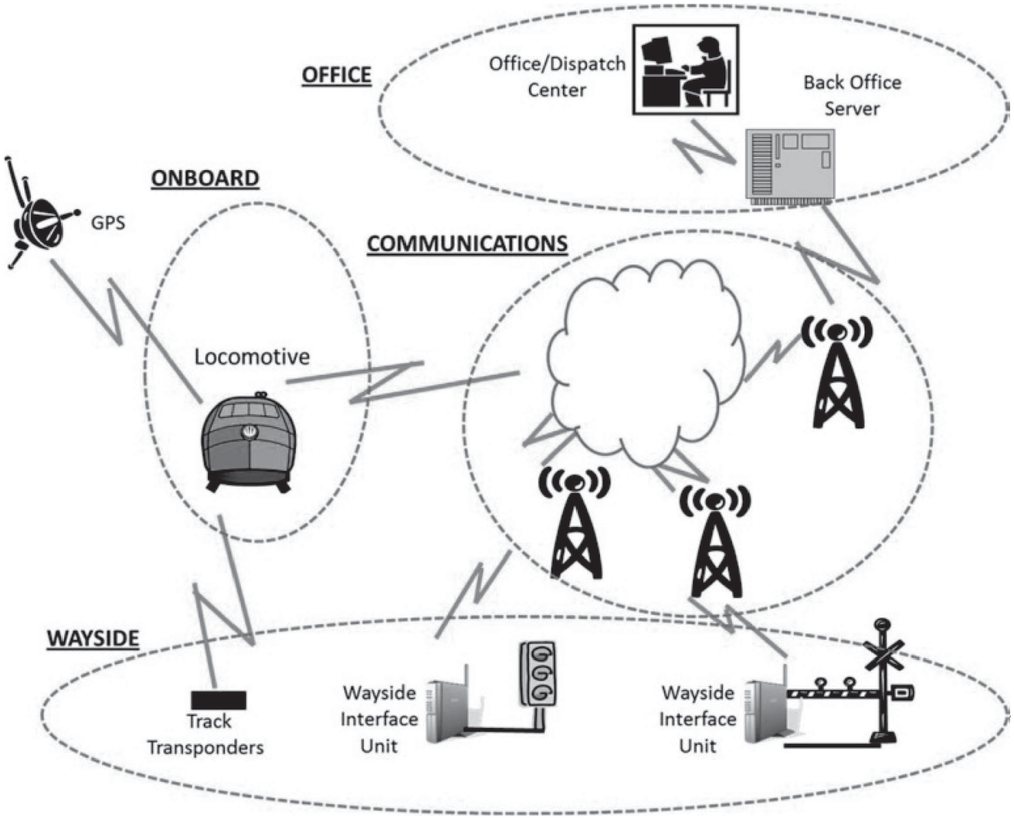
A high profile collision between a Los Angeles Metrolink commuter train and a Union Pacific freight train in September 2008 killed 25 people. This incident galvanized political interest in establishing firm deadlines for long-discussed improvements in train control and safety technologies on the nation's rail system. Interest in the new technologies was focused on lines where passenger trains and/or hazardous materials move on a regular basis.

In October 2008 Congress passed the Rail Safety Improvement Act (RSIA), legislation that includes a requirement that much of America's main line rail network be equipped with advanced signaling and train control technology by December 31, 2015. This package of technologies, known popularly as Positive Train Control (PTC), had been under consideration by carriers and other rail stakeholders for more than two decades but appeared no closer to implementation until the time of the Metrolink disaster. Absent a regulatory mandate the industry had failed, on its own, to develop common design approaches and standards that would support common use across the North American rail network. Other elements of RSIA include revisions to hours of service, employee training, safety reporting, and whistleblower protection regulations. It is the implementation of PTC, however, that is seen to have the greatest potential impact on railway capacity over the short to medium term. The Federal Railroad Administration is responsible for promulgation and enforcement of rules applicable to the new systems.

B.2 PTC Explained

PTC systems are formally defined as "a system designed to prevent collisions between trains, over-speed derailments (derailments caused when a train exceeds speed limits); incursions into established work zone limits (i.e., for roadway workers maintaining track); and the movements of a train through an improperly positioned switch." (Reference: *Overview Highlights and Summary of the Rail Safety Improvement Act of 2008*, Federal Railroad Administration, March 10, 2009.)

The technologies required to support these capabilities are still in various phases of testing and development despite the looming 2015 deadline. Systems can operate through a combination of satellite, ground transponder, and internet communications channels. Securing robust and redundant data transfer capabilities for the huge volumes of information generated by the new PTC architecture is, in and of itself, a major challenge. Figure B-1 is a generic diagram illustrating how a PTC system would work.



Source: "Positive Train Control Implementation Status, Issues, and Impacts", Federal Railroad Administration, August 2012.

Figure B-1. Generic diagram of a PTC system.

B.3 Anticipated Effects of PTC on Line Capacity

As PTC systems are just evolving, it is premature to quantify the impact of PTC on rail capacity for a typical corridor. However, some general comments of likely effects may be made:

- The earliest impacts following PTC installation will be to reduce flexibility and overall corridor capacity. This is because PTC architecture is being employed as an "overlay" to existing, traditional train block and signaling systems. In any given circumstance the more conservative (restrictive) rule will apply for train operations.
- Development of PTC data channels will deliver unprecedented volumes of highly granular, near real-time operations data to railway operations and control centers. Extracting management value from those data streams will require new tools and processes but should, over time, position carriers to refine their operations plans and protocols and improve the predictability and regularity of line operations.
- Significant elements of the PTC overlay systems architecture can later serve to support more sophisticated, stand-alone train control systems that move beyond the legacy signaling and control environment. In this new environment the "protection" would be dynamic, that is, it would move along with the train itself. Wayside signals would disappear, and spacing between trains would be the product of both train speeds and the unique deceleration capabilities of each unique train consist. Service capacity benefits may be significant for these new stand-alone systems. The time required for developing and then vetting, through regulation, this entry into the "new world" of rail operations is, however, a matter of considerable controversy.

APPENDIX C

Glossary of Railroad Terminology Appearing in This Guidebook

C.1 Introduction

The foregoing guidebook contains numerous technical terms which may be unknown to the general reader. This glossary is meant to equip the reader with the brief definitions of these terms. Following the glossary is a listing of abbreviations and short names which appear in the guidebook.

C.2 Glossary

Alignment. A general term for the route taken by a rail line between two points. For example, "the alignment of XYZ railroad between A and B contains numerous curves." In a more technical sense, alignment means lateral deviations of track centerline from a true tangent or curve. FRA track safety standards 49 CFR Part 213 specify acceptable alignment deviations for each FRA Track Class.

Allowable speed. Maximum speed allowed for a specific train type in a specified location.

Amtrak. The marketing name for the National Passenger Railroad Corporation that operates virtually all regularly scheduled intercity passenger rail service in the United States.

American Recovery and Reinvestment Act (ARRA). Commonly referred to as the Stimulus or The Recovery Act, it was an economic stimulus package enacted by the 111th United States Congress in February 2009 and signed into law on February 17, 2009, by President Barack Obama.

Association of American Railroads (AAR). An industry association representing the interests of Class I railroads. In addition AAR subsidiaries and associated organizations are responsible for a range of activities mostly supporting freight railroading, such as industry rolling stock standards, inter-railroad freight car tracking and repair billing, and cooperative research and development.

American Association of State Highway and Transportation Officials (AASHTO). A standards setting body which publishes specifications, test protocols and guidelines used in highway design and construction throughout the United States. It represents air, rail, water, and public transportation as well.

Aspect. See Railroad Signal and Train Control Systems.

Automatic Block System (ABS). See Railroad Signal and Train Control Systems.

Automatic Train Control (ATC). See Railroad Signal and Train Control Systems.

Automatic Cab Signals (ACS). See Railroad Signal and Train Control Systems.

Automatic Train Stop (ATS). See Railroad Signal and Train Control Systems

Base Case. See Capacity and Capacity Analysis.

Block. See Railroad Signal and Train Control Systems.

Block Authority. See Railroad Signal and Train Control Systems.

Bulk Trains. See Train and Traffic Type.

Capacity and Capacity Analysis. ***Capacity*** or ***Line Capacity*** is the ability of a railroad line segment to carry a given mix and volume of railroad traffic while meeting generally accepted service quality standards. ***Capacity Analysis*** is the process of estimating capacity for a specific railroad line segment. Other capacity and capacity-analysis terms are:

- ***Base Case.*** An analysis of rail service performance on an existing rail corridor for the existing rail traffic volume and mix. Base case analysis normally precedes analyses of the effects of changes in traffic level and infrastructure.
- ***Grid Time Analysis.*** A capacity analysis method that uses travel time between passing sidings to estimate capacity in trains/day.
- ***Latent Capacity.*** Available but unused capacity.
- ***Line Capacity.*** See Capacity.
- ***NCFRP Web-based Freight-Passenger Rail Corridor Project Screening Tool (SU Tool).*** An operations simulation program developed by the National Cooperative Freight Research Program. It is expected to be available to the public on the FRA's website in early 2014.
- ***Operations Simulation.*** A widely use, computer-based method of calculating train movements over a defined territory; it is employed for capacity analysis, operations planning, and rail investment planning. Simulation usually involves step-by-step calculation of the progress of all trains over the territory based on train weight, locomotive power and braking performance, dispatcher decisions, grades, curves, signaling systems, switch types, and other factors.
- ***Parametric Modeling.*** An approach to estimating capacity that relies on a simple formula with coefficients derived from regression analysis of a limited number of capacity parameters, such as siding spacing, number of running tracks and rail traffic mix, and actual observed capacity on a large number of rail line segments.
- ***Practical Capacity.*** The estimated capacity of a rail line segment after adding an allowance for delays, uneven train sequencing, and unplanned events to theoretical capacity.
- ***Rail Traffic Controller (RTC).*** A proprietary simulation-based capacity modeling computer package widely used by Class I freight railroads, Amtrak, and many consultants.
- ***RAILSIM.*** A proprietary simulation-based capacity modeling computer package widely used by commuter railroads and rail transit systems.
- ***RAILS2000.*** A proprietary simulation-based capacity modeling computer package
- ***Simulation Modeling.*** See Operations Simulation.
- ***SU Tool.*** Web-based Freight-Passenger Rail Corridor Project Screening Tool developed by the National Cooperative Freight Research Program (NCFRP).
- ***String Line Analysis.*** A graphical method of capacity analysis that represents train movements over a line segment on a time-distance chart.
- ***Theoretical Capacity.*** The estimated capacity of a rail line segment before allowing for typical train delays and uneven train sequencing.
- ***Train Dispatch Simulator.*** Element in simulation modeling that mimics the behavior of a real dispatcher in routing multiple trains over rail lines.
- ***Train Performance Calculator (TPC).*** Computer software that performs a step-by-step calculation of the movement of a train over a specific line segment, taking into account locomotive power, train weight, braking characteristics, and speed limits but not interference from other trains. TPC's are used to estimate pure (unhindered) running time along with other subsystems in several capacity analysis methodologies.

Capitol Corridor. California passenger rail corridor running between San Jose, Oakland, Sacramento and Auburn.

Carload Freight. See Train and Traffic Type.

Categorical Exclusion. A category of actions in the area of environmental impact assessment that an agency has determined does not individually or cumulatively have a significant effect on the quality of the human environment (40 C.F.R. §1508.4). In the context of rail projects, such an exclusion enables a project to proceed without detailed analysis of environmental impacts.

Centralized Traffic Control (CTC). See Railroad Signal and Train Control Systems.

Class I Railroad. A large freight railroad having revenue exceeding an inflation-adjusted annual threshold defined by the Surface Transportation Board (STB). In 2011 the threshold was $433.2 million. Class I railroads are subject to detailed financial and operating reporting requirements. Currently (2012) seven U.S. railroads meet Class I criteria. Class I railroads are large railroads having thousands of route miles of operations.

Commuter Train. See Train and Traffic Type.

Conflicts. A conflict arises when two opposing trains try to pass over the same section of track at the same time. Normally, the signal and train control system will prevent an actual collision. The dispatcher must determine which train has priority, and give that train authority to proceed while holding the lower-priority train until the line is clear.

Control Point. See Railroad Signal and Train Control Systems.

Computer-Aided Dispatching (CAD) (As distinct from Computer Aided Design used by all engineering disciplines). A system that provides a simulation of expected train movements on a railroad line segment to assist the dispatcher in determining meet and pass locations.

Cool-down Period. The final period of a simulation, which can last a few hours to a full day, and which is normally disregarded as unrepresentative of train operations.

Corridor. A general term used by transportation planners and analysts to describe transportation facilities between two points, thus Rail Corridor, Highway Corridor or Utility Corridor. The term is often used in reference to a geographical location or specific rail service, e.g., Northeast Corridor, Capitol Corridor (CA), and LOSSAN Corridor (CA).

Crew Change Location. See Crew District.

Crew District. ***A Crew District*** comprises the rail territory over which train crews employed at a specific location will normally operate trains. A ***Crew Change Location*** is the point at the boundary between crew districts where crews of a long distance train are changed. Capacity analyses have to allow time for the change to take place and a new crew to perform required safety tests.

Crossover. Track installation (including pairs or large numbers of switches) allowing trains to move from one track to another on double track.

Curvature. The sharpness of a railroad curve, and the inverse of curve radius. Curvature is usually measured by railroad track engineers in degrees. A 1° curve has a radius of about 1 mile.

Department of Transportation (DOT). A federal or state agency responsible for all modes of transportation.

Distributed Power. The railroad practice of the placing of additional locomotives at intermediate points in the middle or end of the train; these locomotives are remotely controlled from the leading locomotive, to allow longer trains.

Dispatcher, Dispatching and Dispatcher's Desk. A ***Dispatcher*** is a railroad employee responsible for managing train movements over a specific railroad territory. ***Dispatching*** is the function performed by the dispatcher, and the ***Dispatcher's Desk*** is the dispatcher's workstation with radio and other communications, switch and signal controls, and displays showing track layout, train locations, and signal and switch positions

Double Track. Two main running tracks. Traditionally each track is reserved for one direction of travel. Current practice is to signal and use both tracks for bi-directional running to maximize capacity.

Environmental Impact Statement (EIS). A document describing the environmental impacts of the proposed action, e.g., any adverse environmental impacts that cannot be avoided should the proposal be implemented and reasonable alternatives to the proposed action, among other things.

Expedited Train. See Train and Traffic Type.

Federal Railroad Administration (FRA). The federal agency with oversight responsibility for the safety of the national railway system. It also has funding authority for certain railroad projects supported with federal funds, including Amtrak funding.

Federally Designated High-Speed Corridor. A designation by the FRA of corridors that have complied with certain planning requirements for high speed rail service. However, the term is outdated. The FRA now refers to express corridors, regional corridors and emerging corridors.

Federal Highway Administration (FHWA). The FHWA is the federal agency responsible for the development and maintenance of the national highway system. Emphasis is on funding projects and setting standards.

Freight Analysis Framework (FAF). A process used by FHWA to derive estimates of future U.S. freight transportation volumes.

Fluidity. A term used by U.S. railroads to quantify the efficiency of freight operations. The usual fluidity parameter is the average speed of freight trains between freight terminals.

Freight Terminal. A complex of rail yards usually near or in a major city.

Freight Yard. See Yard.

General Merchandise Train. See Train and Traffic Type.

Grade Crossing. A location where a highway or city/local street crosses rail line at-grade.

Gradient. A geographic situation in which a rail line increases or decreases elevation, usually expressed in percentages. A 1% grade is 1 foot in 100 feet.

Grid Analysis. See Capacity and Capacity Analysis.

Host Railroad. An owner of a rail line segment over which one or more other railroads have rights to operate a defined service. Most often used to describe a freight railroad that hosts Amtrak or a commuter service.

Horsepower per Ton (hp/ton). See Power-to-Weight Ratio.

Hours of Service. Railroad employees in safety sensitive positions including train crews are subject to FRA-mandated Hours of Service regulations governing lengths of a work shift and mandatory rest periods between shifts.

In Slot. An opening circumstance in which a train takes its planned place in a sequence of trains operating over a specific rail line segment.

Interlocking. See Railroad Signal and Train Control Systems.

Joint Powers Authority (JPA). An institutional arrangement for multiple local government entities to combine to finance and manage a passenger rail service, or for another qualifying purpose.

JPAs are common in California. In other states, similar institutions can be implemented through interlocal agreements.

Intermodal Train. See Train and Traffic Type.

Latent Capacity. See Capacity and Capacity Analysis.

Light Engine Movement. A light engine movement means that a locomotive or locomotives not coupled to a train are moving over a rail line, usually to reach their next train assignment or a servicing location.

Line Capacity. See Capacity and Capacity Analysis.

Line Side Signals. See Railroad Signal and Train Control Systems.

Line Speed. Maximum speed at a specified location. Some train types may be required to operate at below line speed.

Local Freight Train. See Train and Traffic Type.

LOSSAN. Name applied to a 351-mile corridor running from San Luis Obispo in the north to San Diego in the south, along California's Pacific Coast.

Main Line. A rail line segment connecting two points on a railroad network used by long distance trains.

Manifest Train. See Train and Traffic Type.

Meet. Trains travelling in opposing directions passing each other at a passing siding

Midwest Regional Rail Initiative (MWRRI). A collection of rail corridors totaling 3,000 route miles and nine Midwestern states that would host new or enhanced passenger rail services. Chicago would serve as the unifying hub of the system. The concept was earlier described as the "Chicago Hub Network."

Monte Carlo Randomization Methods. An analysis method that involves repeated calculations of a specific analysis where some inputs are selected from a probability distribution rather than having a single value. The results of the calculation are usually expressed as statistics of selected outputs. Monte Carlo methods are used in capacity analysis to account for the effects of unscheduled train operations and typical service disruption.

Moving Blocks. See Railroad Signal and Train Control Systems.

National Environmental Policy Act (NEPA). A federal Act that requires environmental reviews of most federally funded passenger rail and other major investment.

Northeast Corridor (NEC). A major passenger rail corridor between Boston and Washington, DC, via New York City, Philadelphia, and Baltimore. The entire corridor is electrified. Its use is shared by Amtrak, various commuter rail operators, and freight railroads. Amtrak owns most of the corridor.

On-Time Performance (OTP). A widely used measure of passenger rail service quality, usually expressed as arrival delay statistics, e.g., percentage of trains arriving within X minutes of scheduled time. Freight railroads also track on-time performance, most commonly with expedited intermodal or premium service trains.

Operations Simulation. See Capacity and Capacity Analysis.

Overtake. See Pass.

Pad or Schedule Pad. Difference between the scheduled time for a specific rail journey and the minimum travel time (pure running time) to adjust for statistically normal delays.

Parametric Modeling. See Capacity and Capacity Analysis.

Pass. When a train overtakes another train traveling in the same direction at a passing siding.

Passenger Rail Investment and Improvement Act (PRIIA). A federal act, signed into law in 2008, that governs passenger rail policy and funding from 2008 to 2013.

Passenger Terminal. A major passenger station usually with dead-end or stub-ended tracks.

Passenger Train. See Train and Traffic Type.

Positive Train Control (PTC). See Railroad Signal and Train Control System.

Power-to-Weight Ratio. Refers to the ratio of locomotive horsepower and total train weight ***(horsepower/ton)***, and is the key parameter in calculating train acceleration and achievable speed. See also ***Tractive Effort*** and ***Tractive Effort Curve***.

Practical Capacity. See Capacity and Capacity Analysis.

RAILSIM. See Capacity and Capacity Analysis.

Rail Safety Improvement Act (RSIA). The 2008 federal rail legislation that, among other provisions, requires the installation of PTC on lines carrying regularly scheduled passenger service and selected hazardous materials.

Railroad Signal and Train Control Systems. General term applying to methods used by railroads to ensure safe and efficient train operations. Individual signal and train control systems and elements in common use and referenced in this report are:

- ***Aspect.*** The aspect is the color or pattern of a wayside light signal providing a specific message to a train operator. Commonly, a green light means "all clear," an amber light means "approach" (warning that the next signal may be a stop signal), and a red light means "stop." The railroad's Rule Book will define signal aspect meanings, which can differ between railroads and sometimes between railroad regions.
- ***Automatic Block System (ABS).*** A system of dividing a rail line into discrete blocks, typically 2 to 10 miles in length, entry to which is controlled by color-light signals (block signals) that automatically indicate whether the block is occupied by a train. A red signal indicates that the block is occupied and another train should not enter.
- ***Automatic Train Control (ATC).*** A system that continuously monitors train speed using electric or electronic control technology and automatically applies train brakes when the engineer fails to respond to signal indications to stop or reduce speed.
- ***Automatic Cab Signals (ACS***). A system that displays a duplicate of wayside signal indications in the engineer's cab, using electric or electronic communication technology.
- ***Automatic Train Stop (ATS).*** A system that applies train brakes when the engineer fails to respond to a more restrictive signal indication. Unlike ATC there in no continuous monitoring of train speed.
- ***Block or Signal Block.*** A length of track between block or interlocking signals. Normally only one train is permitted to occupy a block.
- ***Block Authority.*** Permission given to a train to enter and occupy a signal block. This permission is transmitted to the train's engineer by a voice radio message, a train order, a wayside signal indication, or is automatically transmitted to the engineer's cab by a PTC system or automatic cab signals.
- ***Centralized Traffic Control (CTC).*** A system where switches and associated signals are controlled by a dispatcher in a remote control center.
- ***Control Point.*** Location of remotely controlled switches and signals in a CTC system.
- ***Interlocking.*** An installation, originally mechanical but now electrical or electronic, at a siding or junction that ensures safe coordination between signals and switch positions.

- ***Line Side Signal.*** A color-light signal positioned alongside the track that provides movement authorities to train operators. Line side signal is an alternative term for wayside signal.
- ***Moving Blocks.*** An advanced train control approach where spacing between trains is defined by safe braking distance plus a safety margin for the specific train and train speed at the time. Fixed signal blocks are not used.
- ***Positive Train Control (PTC).*** A train control system that will automatically enforce authorities, speed limits, and work zone restrictions if the engineer fails to operate the train correctly. A detailed description is provided in Appendix B.
- ***Shunt.*** An electrical connection between rails through the wheel and axle set of a train, completing a track circuit and activating automatic block signals and other train control systems.
- ***Signal Block.*** See Block above.
- ***Track Circuit.*** Electrical circuit used to detect the presence of a train in a signal block.
- ***Track Warrant.*** A formal order issued to a train engineer on an unsignaled line segment authorizing a train movement between defined locations. Track warrants are usually recorded on a control center database that prevents a dispatcher from issuing confliction warrants.
- ***Train Control System (TCS).*** An alternative term for CTC used by some railroads.
- ***Wayside Signal.*** See Line Side Signal above.

Rail Traffic Controller (RTC). See Capacity and Capacity Analysis.

Reverse Running. An operating practice on double track where each track is signaled for one direction of running. Reverse running is when train direction is opposed to the normal direction, usually at lower speed and under manual rather than signal control.

Restricted Speed. Defined in railroad rule books as a speed from which a train can stop in half the visible distance and not to exceed 15 or 20 mph, depending on local requirements. Restricted speed operations are normally permitted on unsignaled yard tracks and after stopping at a block signal.

Record of Decision (ROD). The formal acceptance by the responsible authority of an Environmental Impact Statement (EIS) after completion of all legal requirements.

Root Cause. A term used to describe the depth in the causal chain where an intervention could reasonably be implemented to change performance and prevent an undesirable outcome.

Schedule. A list of train departure and arrival times used by a railroad both for internal operations management and to communicate with passengers and freight service customers.

Scheduled Service. A rail passenger or freight service that operates on a fixed, pre-announced schedule, as distinct from trains that operate on an as-needed basis. As-needed freight operations are a common practice in the U.S.

Sealed Corridor. A passenger rail corridor where the risk of a collision with a highway vehicle is minimized by closing as many grade crossings as possible, and installing high-performance crossing safety systems on all remaining crossings. This safety approach was initially applied to a rail corridor in North Carolina, and later applied elsewhere.

Service Outcomes Agreement (SOA). An agreement between host and tenant railroads specifying service quality parameters, such as journey time and on-time performance, that the host railroad guarantees it will provide a tenant railroad. Usually, the host is a freight railroad and the tenant a passenger service.

Shared-Use. This term refers to the use of rail corridor by multiple train or service types, most commonly passenger and freight trains. Related terms are as listed below:

- ***Shared Corridor.*** A rail corridor shared by two or more types of rail service, usually passenger and freight. This term is rarely used in reference to a corridor shared only by different types of freight service.

- ***Shared Track.*** Where passenger and freight trains operate on the same track.
- ***Shared Right-of-Way (ROW).*** A rail corridor where passenger and freight service operate over separate parallel tracks in a transportation corridor but do not normally interconnect. This frequently applies to shared ROW where the primary rail corridor is for FRA-regulated, "generally-connected" (conventional) passenger or freight trains and the parallel use is by lighter (non-FRA-compliant) rail transit, such as light rail or heavy rail metro/rapid-transit.

Shunt (as in track circuit). See Railroad Signal and Train Control Systems.

Siding. A track parallel to a main running track with switches at each end used to allow passing and overtaking movements.

Signal Block. See Railroad Signal and Train Control Systems.

Simulation Modeling. See Capacity and Capacity Analysis.

Single Track. A line segment with one main running track. Sidings are needed to allow passing and overtaking train movements.

Slow Order. A formal requirement, usually issued by the engineer responsible for track construction and maintenance on that segment, that limits train speed at a specific location. Slow orders may be permanent, for example, for a sharp curve; or temporary, for example, pending repair of a track defect.

Spur. A track branching off a main track to provide access to a yard, terminal or line side industrial plant.

State of Good Repair. The state of a rail line segment or corridor when all track defects have been corrected and life-expired structures and other installations have been replaced or rebuilt.

State Sponsored Service. An intercity passenger rail service that receives financial support from a state government authority or from a coalition of states.

String Line. See Capacity and Capacity Analysis.

Super-elevation. The banking of railroad track in a curve. Super-elevation is usually expressed as the height of the outer rail over the inner rail in inches and is incorporated into the track structure as a function of curvature and train speed.

Switch. A switch is a track installation where a single track divides into two tracks. Switch blades (tapered lengths of rail) can be moved laterally so that a rail vehicle moving over the switch can be directed to either track. Switch (blade) position can be controlled locally by a manual lever, or by an electrically powered switch motor from a remote location.

Terminal. See Passenger Terminal and Freight Terminal.

Theoretical Capacity. See Capacity and Capacity Analysis.

Track Circuit. See Railroad Signal and Train Control Systems.

Track Warrants. See Railroad Signal and Train Control Systems.

Tractive Effort. The horizontal force a railroad locomotive can exert on a train at its coupler. Tractive effort of a diesel-electric locomotive depends on horsepower, train speed, and its electrical control characteristics.

Tractive Effort Curve. The variation of tractive effort with speed. See Tractive Effort.

Train Control System (TCS). See Railroad Signal and Train Control Systems.

Train Consist. The rolling stock making up a train, e.g., numbers and types of locomotives and freight cars or passenger cars.

Train Crew. On-board railroad employees responsible for train operations, usually comprising engineer, conductor, and sometimes one or more trainmen (a.k.a., assistant conductors) to assist with passenger train doors, ticket checks, and switching operations. The conductor is the leader of the train crew.

Train Dispatch Simulator (TDS). See Capacity and Capacity Analysis.

Train Mix. The mix of train types operating on a line segment.

Train Performance Calculator (TPC). See Capacity and Capacity Analysis.

Train Sequencing. The order in which trains follow one another through a line segment. Usually determined by a dispatcher to maximize capacity while meeting service quality requirements.

Train and Traffic Type. A general term that distinguishes trains and rail traffic by type of rail service provided or type of commodity carried. Because of differing maximum speeds, train lengths, and power-to-weight ratios, train type is an important input to rail capacity calculations. The principal types are:

- ***Bulk Train.*** A train carrying a single bulk commodity, similar to a unit train as defined below.
- ***Carload Freight.*** Rail freight operation that moves single carloads of freight from origin to destination via classification yards and local and long distance general freight trains.
- ***Commuter Train.*** A passenger train providing shorter distance service (generally under 100 miles), usually in a large metropolitan area. Commuter trains typically make frequent stops (e.g., every 5 or 6 miles).
- ***Expedited Train.*** Any train operated on a faster, more tightly defined schedule. An expedited train will have a higher priority for meets and passes.
- ***General Merchandise Train.*** A train carrying a mix of freight types between classification yards.
- ***Intercity Passenger Train:*** A passenger train (typically Amtrak) providing medium to longer distance service (generally over 100 miles) between metropolitan areas. Intercity passenger trains typically make stops between 25 and 100+ miles apart, depending on population density.
- ***Intermodal Train:*** This train carries intermodal shipping containers or highway trailers. Because such freight is often time-critical, intermodal trains typically have higher power-to-weight ratios and maximum speeds.
- ***Local Freight Train:*** A train moving loaded or empty cars to or from a classification of switching yard to individual industry tracks.
- ***Unit Train:*** Unit trains carry a single commodity from origin to destination without intermediate switching, and usually return empty to the point of origin. Power-to-weight ratios and speeds are typically low. A majority of unit trains carry coal between mines and power plants. Other unit train or bulk commodities are grains and metal ores.
- ***Manifest Train:*** A scheduled general merchandise train.

Universal Crossover. A crossover comprises a pair of switches on a double track line to allow a train to move off one track and onto the adjacent track. A universal crossover is a pair of crossovers that allows trains moving in either direction to cross to the adjacent track without making a back-up move.

Warm-up Period. The initial period of a simulation, which can last a few hours to a full day, and which is normally disregarded as unrepresentative of train operations.

Wayside Signals. See Railroad Signal and Train Control Systems.

Yard. An array of tracks, usually unsignaled, where passenger and freight trains and cars are sorted, serviced and stored. On most railroads, specific operating rules apply to yard operations, including ***Restricted Speed*** requirements. Classification yards or switching yards are where general merchandise trains are assembled from cars gathered from local shippers, or broken down for local delivery. Storage yards are where railcars are stored. Intermodal yards lift trailers or containers onto or off of railcars.

Yard Lead. A track leading into and out of a yard, where trains can wait until track is available to exit the yard onto the main line or for continuing yard activities.

C.3 Abbreviations

Listed below are abbreviations appearing in the guidebook. Definitions are cited in the preceding section. Freight railroad and other abbreviations and short names used in this guidebook appear below as well.

AAR. Association of American Railroads.

ABS. Automatic Block System.

ACS. Automatic Cab Signals.

ARRA. American Recovery and Reinvestment Act.

AASHTO. American Association of State Highway and Transportation Officials.

ATC. Automatic Train Control.

ATS. Automatic Train Stop.

CAD. Computer-Aided Dispatching (vs. more commonly, "Computer-Aided Design").

CCJPA. Capitol Corridor Joint Powers Authority.

CSV. Comma Separated Values.

CTC. Centralized Traffic Control.

DOT. Department of Transportation.

EIS. Environmental Impact Statement.

FAF. Freight Analysis Framework.

FHWA. Federal Highway Administration.

FRA. Federal Railroad Administration.

HSIPR. High Speed Intercity Passenger Rail.

JPA. Joint Powers Authority.

LOSSAN. LOSSAN Rail Corridor.

MP. Milepost.

MWRRI. Midwest Regional Rail Initiative.

NCFRP. National Cooperative Freight Research Program.

NEPA. National Environmental Policy Act.

NEC. Northeast Corridor.

OTP. On-Time Performance.

PRIIA. Passenger Rail Investment and Improvement Act.

PTC. Positive Train Control.

RAILS2000. The Railway Analysis and Interactive Line Simulator.

ROD. Record of Decision

RSIA. Railroad Safety Improvement Act.

RTC. Rail Traffic Controller.

SOA. Service Outcome Agreement.

SU. Shared-use, as in SU Tool.

TCS. Train Control System.

TDS. Train Dispatch Simulator.

TPC. Train Performance Calculator.

TPS. Train Performance Simulator.

Freight Railroad Abbreviations

BNSF. BNSF Railway.

CN. Canadian National Railway.

CP. Canadian Pacific Railway.

CSO. Connecticut Southern Railroad.

CSXT. CSX Transportation.

IC. Illinois Central Railroad, now part of CN.

NS. Norfolk Southern Railway.

PANAM. Pan Am Railways.

P&W. Providence and Worchester Railroad.

UP. Union Pacific Railroad.

Other Abbreviations or Short Names

ACE. Altamont Commuter Express commuter rail service in Northern California.

BART. Bay Area Rapid Transit.

Caltrain. Commuter rail service on San Francisco Peninsula and in Santa Clara County.

Caltrans. California Department of Transportation.

COASTER. Commuter rail service in San Diego County.

ConnDOT. Connecticut Department of Transportation.

CSI. Corporate Strategies Inc.

IDOT. Illinois Department of Transportation.

LAUS. Los Angeles Union Station.

MARC. Maryland Area Regional Commuter rail service.

Metra. Chicago area commuter rail service.

Metrolink. Los Angeles area commuter rail service.

NCDOT. North Carolina Department of Transportation.

NCTD. North County Transit District running COASTER trains.

NHHS. New Haven-Hartford-Springfield.

NJ Transit. New Jersey Transit offering commuter rail services.

OCTA. Orange County Transportation Authority, member of SCRRA.

ODOT. Oregon Department of Transportation.

PennDOT. Pennsylvania Department of Transportation.

SCRRA. Southern California Regional Rail Authority running Metrolink trains.

SEPTA. Southeast Pennsylvania Transportation Authority.

SLE. Shore Line East commuter service in southern Connecticut.

Sounder. Commuter service along the Puget Sound in Washington State.

Sound Transit. Seattle area transit agency running Sounder trains.

USDOT. United States Department of Transportation.

VRE. Virginia Railway Express.

WSDOT. Washington State Department of Transportation.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation