Web-Based Screening Tool for Shared-Use Rail Corridors

DETAILS

80 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-28381-6 | DOI 10.17226/22329

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 27

Web-Based Screening Tool for Shared-Use Rail Corridors

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Subscriber Categories
Passenger Transportation • Planning and Forecasting • Railroads

Research sponsored by the Research and Innovative Technology Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2014
www.TRB.org

NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

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The NCFRP will produce a series of research reports and other products such as guidebooks for practitioners. Primary emphasis will be placed on disseminating NCFRP results to the intended end-users of the research: freight shippers and carriers, service providers, suppliers, and public officials.

NCFRP REPORT 27

Project NCFRP-30
ISSN 1947-5659
ISBN 978-0-309-28381-6
Library of Congress Control Number 2014930058

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

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Business Office
500 Fifth Street, NW
Washington, DC 20001

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FOREWORD

By William C. Rogers
Staff Officer
Transportation Research Board

NCFRP Report 27: Web-Based Screening Tool for Shared-Use Rail Corridors describes the research that was conducted to develop a practical tool to perform preliminary feasibility screening of proposed shared-use passenger and freight rail corridor projects as defined in the Federal Railroad Administration (FRA) publication, *Rail Corridor Transportation Plans, A Guidance Manual.* Given the limited resources available to states for passenger rail service plans and projects, it is important that public agencies have a screening tool that will identify projects that warrant further detailed investigation utilizing more rigorous analytic tools. The web-based screening tool can be accessed at http://www.fra.dot.gov/Page/P0702

The United States faces increased congestion on its highways and capacity constraints on its national rail system. In response to increased public demand for energy-efficient transportation alternatives, Congress enacted the Passenger Rail Investment and Improvement Act of 2008 (Act). Subpart j of the Act directs the administrator of FRA to (1) develop partnerships between the freight and passenger railroad industries and (2) provide assistance in assessing railroad operations, capacity, and capital requirements on shared-use corridors where publicly funded passenger rail trains are operated over privately owned freight rail lines. Nearly all Amtrak service operates over privately owned freight rail lines as will most of the new and enhanced intercity and commuter rail service now under consideration. In fact, the shared-use corridor concept is critical to the further development of all forms of passenger rail service.

Under NCFRP Project 30, DecisionTek, with the assistance of Transportation Economics & Management Systems, was asked to develop a web-based tool (to be hosted on the FRA website), a systems administrator's guide, and a user's manual to enable states and passenger rail operators to perform preliminary feasibility screening of proposed shared-use passenger and freight rail corridor projects. To accomplish the research objectives, the research team (1) inventoried, described, and assessed the functionality of existing train operations simulation and capacity tools; (2) for the identified tools, described the data needed to populate them; (3) conducted a gap analysis of the availability of public and private data for the identified tools and described alternatives for obtaining or inferring publicly unavailable data; (4) developed a web-based screening tool for shared-use passenger and freight rail corridor projects; (5) conducted three panel-approved case studies to evaluate the functionality and accuracy of the tool; and (6) developed the web-based tool, systems administrator's guide, and user's manual to be hosted on the FRA website.

CONTENTS

Note: Many of the photographs, figures, and tables in this report 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.

SUMMARY

Web-Based Screening Tool for Shared-Use Rail Corridors

This research was motivated by the Passenger Rail Investment and Improvement Act of 2008, which instructs the Federal Railroad Administration (FRA) to seek partnerships between freight and passenger railroads with a view to developing new passenger rail services that would support a growing economy and help relieve highway congestion.

Objective

The objective of the research was to develop a Web-based tool to enable states and passenger rail operators to perform preliminary feasibility screening of proposed shared-use passenger and freight rail corridor projects. The goal of the tool was to assist in preliminary analysis as defined in FRA's *Rail Corridor Transportation Plans: A Guidance Manual* (*1*).

Research Approach

The research reviewed rail corridor analysis methodologies for approaches that were suitable for a preliminary analysis tool. The research examined data requirements and analyzed the potential gaps in data availability and strategies for bridging them. Following the gap analysis, the researchers prepared five candidate case studies, from which three were selected by the project panel. The team developed a tool design and implemented it along with a users manual. The three case studies were conducted using the tool.

Summary of Findings

Findings are summarized according to the major research headings of methodology, gap analysis, and case study.

Methodology Findings

- Parametric tools, while requiring minimal data, are not sufficiently robust for corridor screening assessment.
- Optimization-based tools are overly complex for corridor screening. Issues relating to algorithm performance and efficiency, combined with the need to customize programming for each corridor, render tools of this type unsuitable.
- The main advantage of topological approaches is their ability to identify directly the bottleneck section(s) of a rail line, pointing directly to the locations where infrastructure additions may be the most needed.

- Probability-based delay equations tend to be too simplified to produce a credible corridor-specific screening assessment.
- The approach of adding a siding wherever a conflict occurs is a reasonable first-cut assessment of infrastructure needs on light-density corridors.
- The proposed conflict identification methodology is both quantitative and rigorous and is applicable to all corridors regardless of density. The methodology does not require an experienced rail analyst, and it qualifies as an effective element in a corridor screening tool.
- Simulation is the key validator of a screening assessment. The data requirements for a simulation are the same as those of the conflict identification methodology. Given robust train movement and dispatching algorithms, simulation provides essential information regarding operational feasibility and, therefore is a critical component of the screening assessment. This capability is provided as a core feature of the Shared Use (SU) tool and has been demonstrated in the case studies.

Gap Analysis Findings

- Table 3-2 summarizes the availability of infrastructure data and their sources.
- Table 3-4 summarizes the availability of traffic data and sources.
- Unit cost data is available from other studies, but will require adjustments for inflation and regional conditions.

Case Study Findings

- Three case studies were conducted based on the panel's selection from five candidate corridors. The three case studies were: Kansas City to St. Louis; Baltimore to Wilmington; and Chicago to Milwaukee.
- Case Study 1: St. Louis to Kansas City
  - The conflict identifier (CI) successfully identified the same required infrastructure as did the detailed comparison analysis. This demonstrates the tool's ability to perform as intended on a heavily used, shared freight corridor with difficult terrain and challenging operational constraints.
  - Simulations after improvement demonstrated that the proposed solution was feasible for expanded shared-use operations and warranted further study.
- Case Study 2: Baltimore to Wilmington
  - This case study was undertaken as a "double-blind" exercise without a validation benchmark. For the "do minimum" case, the CI showed that existing operations can be handled over the existing infrastructure with minimal conflicts.
  - Simulation demonstrated that removing intercity passenger traffic freed sufficient capacity for round-the-clock freight operations. Findings warranted further study.
- Case Study 3: Chicago to Milwaukee
  - The CI showed the same required infrastructure as the detailed comparison analysis.
  - Simulation demonstrated the feasibility of projected shared-use operations. Findings warranted further study.

Highlights of the Shared Use (SU) Approach

The Web-based screening tool named Shared Use (SU) is implemented to facilitate analysis workflows and in accordance with a design suited for implementation as a Web browser-based tool.

SU Workflows

SU is designed for preliminary screening of proposed projects that introduce new passenger service to existing freight or shared-use corridors. The tool is intended to be used very early in the planning process, where it offers a rigorous, systematic approach for establishing a framework or starting point from which more detailed discussions and analyses can follow. The methodology is consistent with the requirements of the FRA *Guidance Manual* (*1*) and the analysis is limited by the level of data that is either publicly available or that can be obtained by state DOTs for screening capacity needs.

A key consideration in the design of the tool was structuring it to accommodate a typical analyst's workflows. Figure S-1 illustrates the SU tool workflow. These are described in the body of the report in Section 3.5.1.

SU Approach

The SU tool follows the overarching system architecture, or design approach, that is displayed in Figure S-2. The basic design has the user connect remotely over the Internet; the tool has four main components. These components are

- Data development module,
- Modes of use (module for submitting analysis),
- Core analytic engine, and
- Results review module.

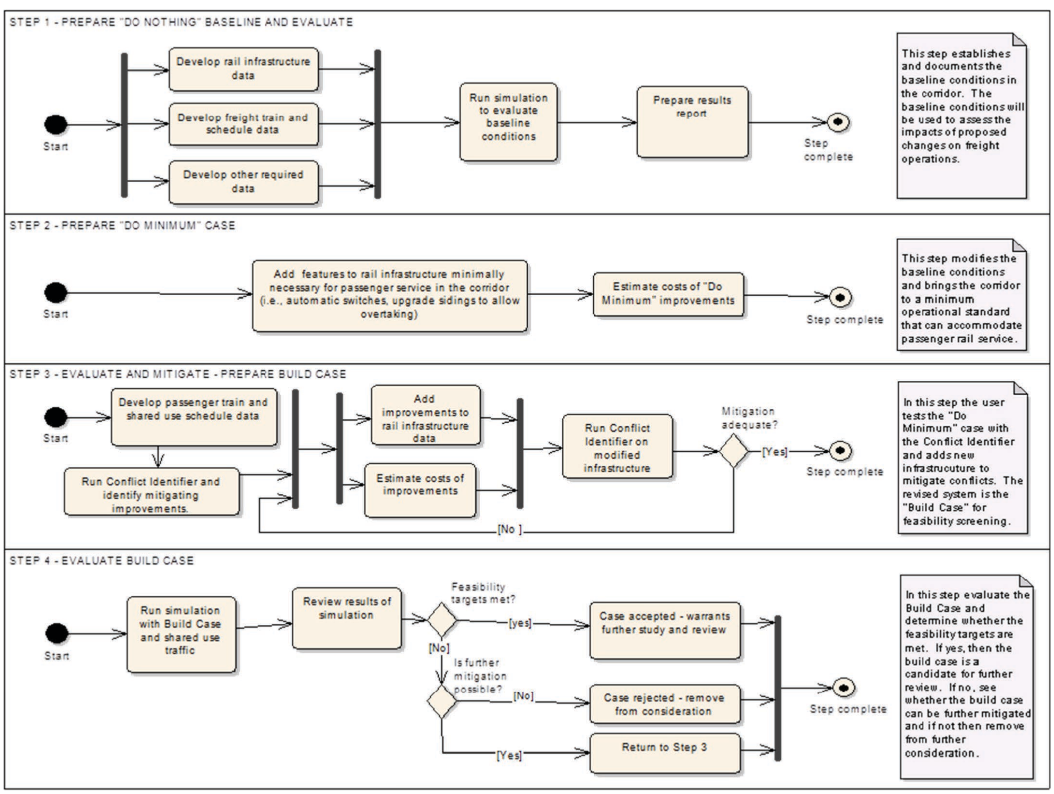

Figure S-1. SU workflows.

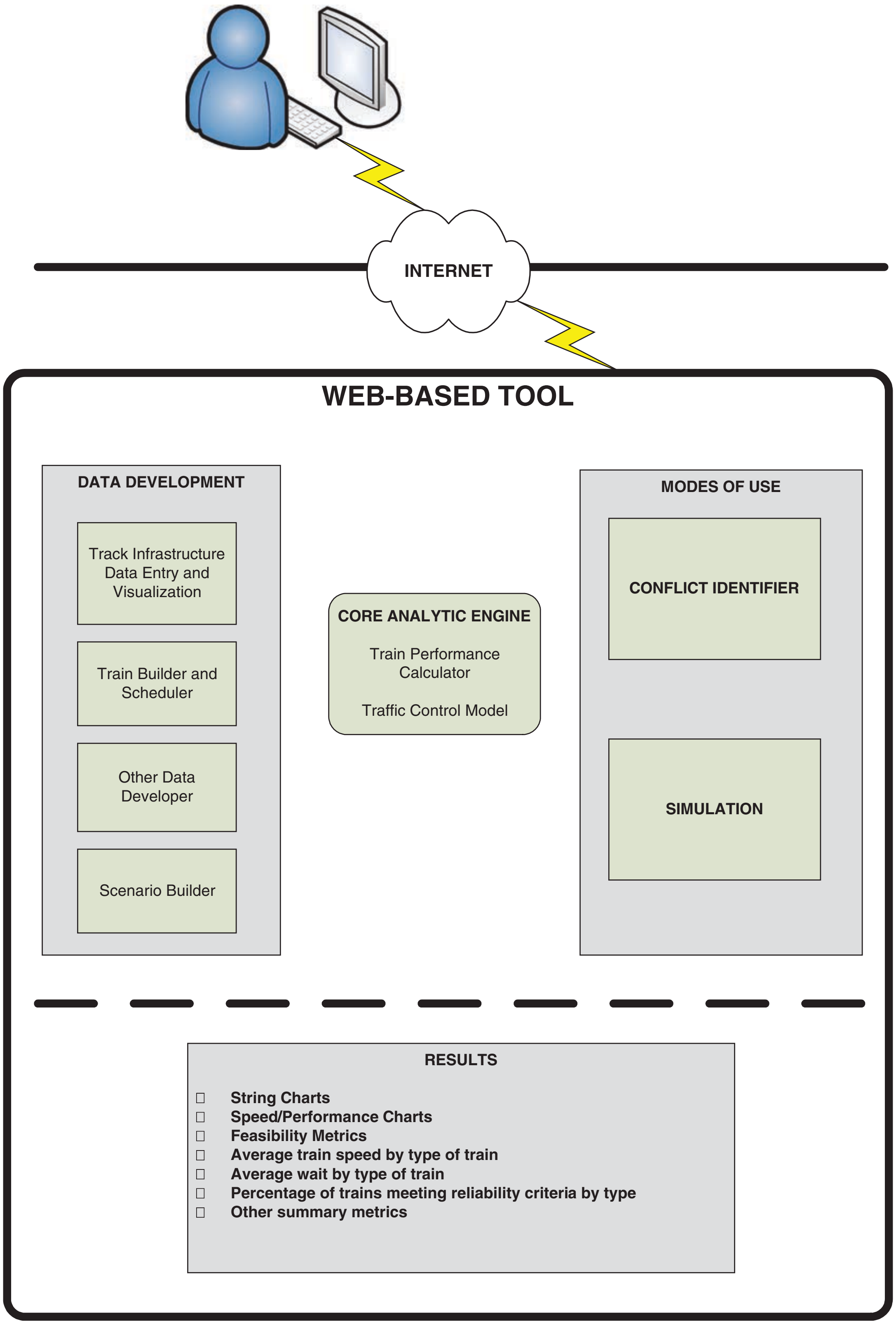

Figure S-2. SU approach.

Web-Based Tool Implementation

The Web-based tool was implemented on a Web content management system (CMS). A Web CMS is a bundled or stand-alone application to create, manage, store, and deploy content on Web pages. Web content includes text and embedded graphics, photos, video, audio, and code (e.g., for applications) that displays content or interacts with the user. A Web CMS may catalog and index content, select or assemble content at runtime, or deliver content to specific visitors in a requested way, such as other languages. Web CMSs usually allow client control over HTML-based content, files, documents, and Web hosting plans based on the system depth and the niche it serves.

The Web CMS permits the integration of custom-designed components, which provide the SU functionality.

User Interface

The user interface is a standard Web page hosted on the FRA datacenter. From the home page, access to the system is limited to users who are registered and authorized by the system administrator. The home page is shown in Figure S-3.

After login, users can access all of the system's features through the main menu. The SU menu structure is shown in Figure S-4.

SU includes a rich Internet application (RIA) called the Track Charting App that enables users to visualize and modify rail infrastructure data directly on a graphical user interface. A sample screen shot from the Track Charting App is shown in Figure S-5.

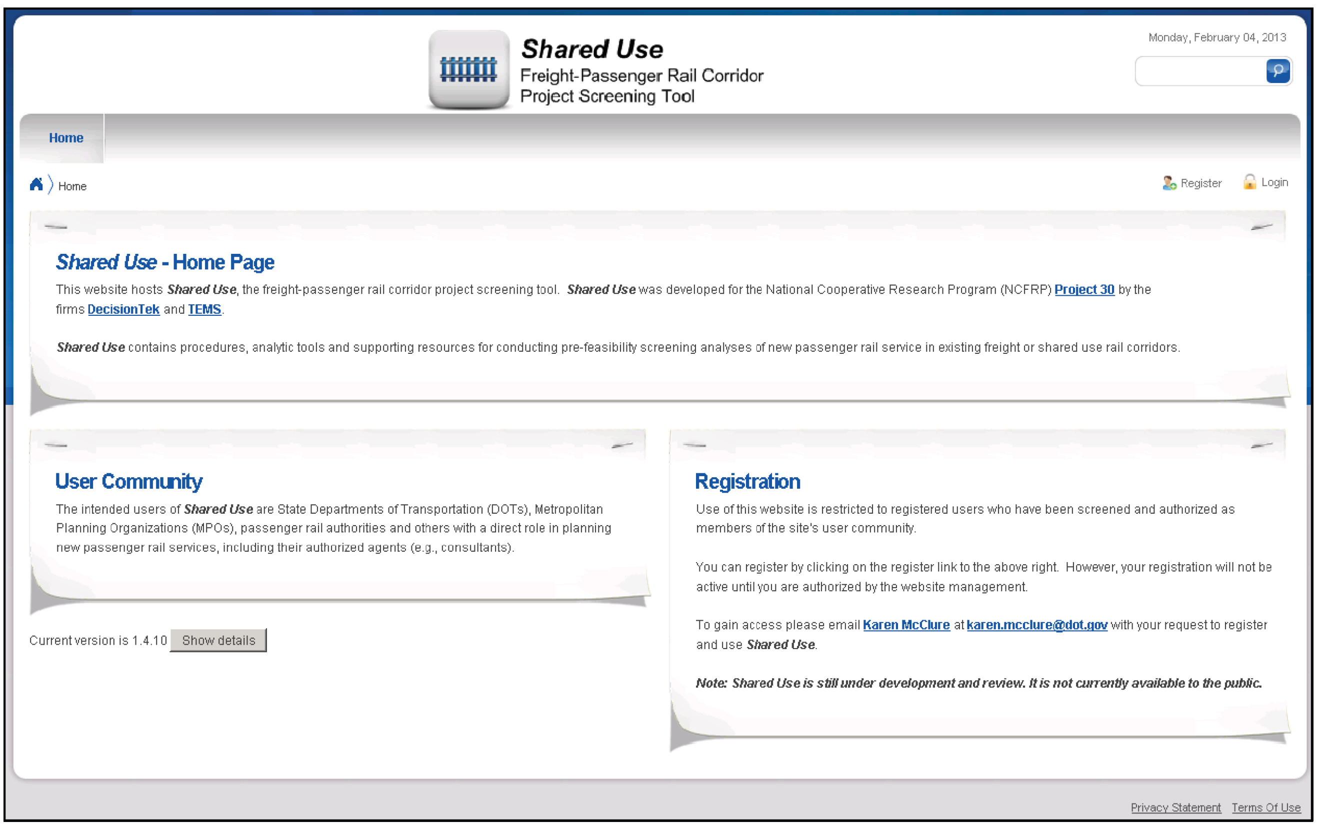

Figure S-3. SU home page.

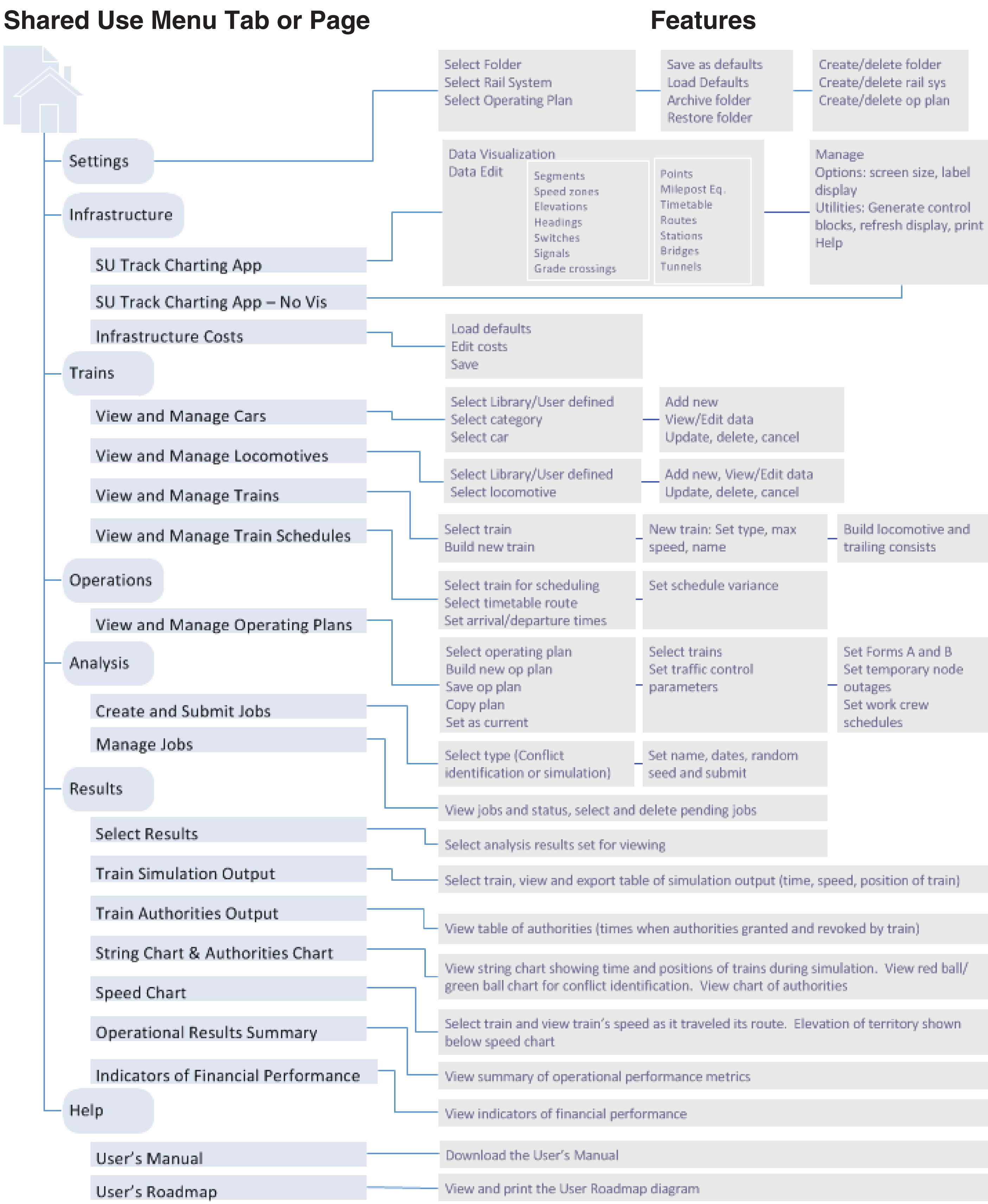

Figure S-4. SU menu structure.

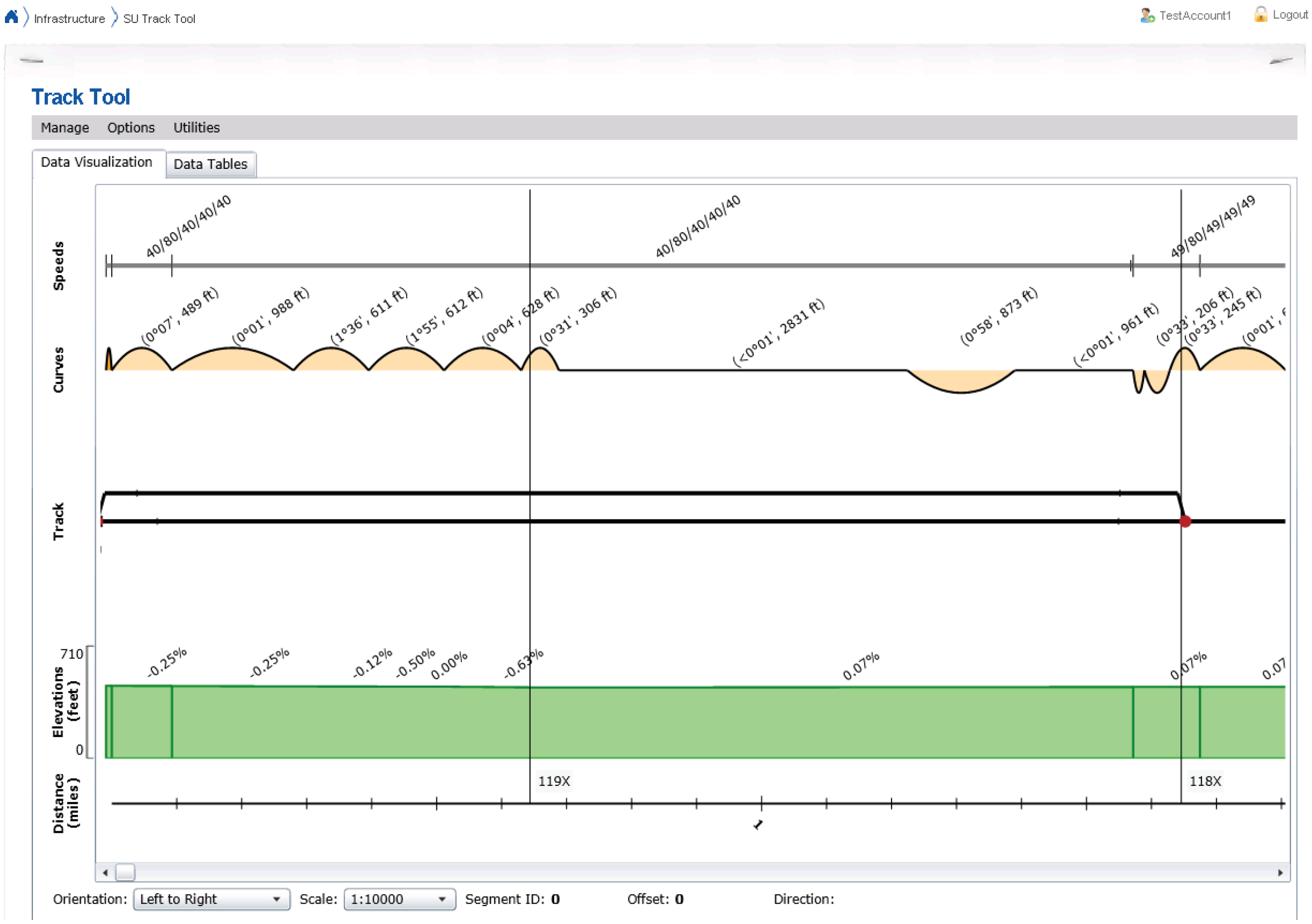

Figure S-5. SU Track Charting App.

All of the features of the Web-based tool and their use are explained in the users manual available on the FRA website.

Database

The data for SU analyses, inputs, and outputs, are stored on the system database, which is implemented on an instance SQL Server. Users may choose to archive their data to a local computer and restore them to the system database for use with a future session with SU.

Runtime Console Application

After users have prepared their data for running an analysis on SU, they submit an analysis job to the SU job queue. A separate console application runs on the server that polls the database and job queue for submitted jobs and executes jobs based on submittal time (first submitted, first executed). The actual runtime logic for SU analyses is implemented in the console application.

CHAPTER 1

Background

1.1 Introduction

The United States faces increased congestion on its highways and capacity constraints on its national rail system. In response to increased public demand for energy efficient transportation alternatives, Congress enacted the Passenger Rail Investment and Improvement Act of 2008. Subpart j of the Act directs the administrator of the FRA to develop partnerships between the freight and passenger railroad industries and to provide assistance in assessing railroad operations, capacity, and capital requirements on shared-use corridors where publicly funded passenger rail trains are operated over privately owned freight rail lines. Nearly all Amtrak service operates over privately owned freight rail lines as will most of the new and enhanced intercity and commuter rail service now under consideration. In fact, the shared-use corridor concept is critical to the further development of all forms of passenger rail service.

Historically, the federal government has provided capital and operating grants to ensure intercity and commuter rail service. The American Recovery and Reinvestment Act (ARRA) of 2009 authorized $9.3 billion to the FRA for high-speed rail corridors and intercity passenger rail service. Several states have well-established rail passenger programs through which capital and operating funds are provided for all forms of passenger rail service. Other states and regional authorities are beginning to implement passenger rail service plans and projects. Given the limited resources available for such projects, it is important that public agencies have a screening tool that will identify rail passenger projects that warrant further detailed investigation utilizing more rigorous analytic tools. NCFRP Project 30 sought to develop such a screening tool to address these needs.

1.2 Research Objective

The objective of the research was to develop a Web-based screening tool to enable states and passenger rail operators to perform preliminary feasibility screening of proposed shared-use passenger and freight rail corridor projects. The goal of the tool is to assist in preliminary analysis as defined in the FRA publication, *Rail Corridor Transportation Plans: A Guidance Manual.* (*1*) The tool is not intended to support either capital budgeting or facility design beyond the schematic/conceptual level.

1.3 Interpretation of the Objective

Based on the objective, the researchers added their understanding of it as follows:

- **Provide practical research culminating in a Web-based tool for screening shared-use rail projects.**
  For practical research to culminate in a tool, the team was mindful of the end solution, understanding the software requirements and challenges that Web-based technologies present. Thus, the software development process was closely integrated with the research at an early stage, rather than decoupling research and software development, which is a common misstep that often results in failure to produce a useful tool.
- **Provide user documentation that offers practical guidance for performing preliminary feasibility screening of projects.**
  The user documentation (users manual and case studies) is a critical component in the successful deployment of the tool. The documentation offers clear and complete guidance in using the tool and conducting analyses with it.

CHAPTER 2

Research Approach

2.1 Background

In seeking to relieve highway congestion, improve travel alternatives, and promote energy efficiency, the Passenger Rail Investment and Improvement Act of 2008 (PRIIA) seeks new partnerships between the freight and passenger railroad industries including cost-sharing arrangements for state supported corridors under 750 miles in length (see PRIIA Section 209). These new partnerships will result in new publicly funded passenger rail services on privately owned freight railroad facilities. This shared-use concept is critical to the further development of all forms of passenger rail service. Public agencies require a screening tool that will identify rail passenger projects that warrant further study with more rigorous analytic tools.

Web-based tools have proven to be an effective means of delivering analytic models and services. NCFRP sought a screening tool accessible over the Internet from a central server and operated on a local computer through a Web browser.

An overarching theme of NCFRP is the development of practical and useful tools that can truly make a difference in transportation investment and planning. In this context, a balance must be struck among the requirements of the *FRA Guidance Manual*, the limitations of available data, and existing methods and tools. This balance was crucial if the research was to yield a Web-based tool for screening shared-use projects, the practicality and usefulness of which would be measured by its acceptance and widespread use among the proponent agencies of new passenger rail service on existing freight corridors.

The following general and task-oriented approaches were developed with the overarching NCFRP objective and this project's objective in sharp focus.

2.2 Factors in Developing an Overall Approach

This section covers several factors that were important in developing the overall approach to the research and to the development of the Shared-Use (SU) tool. Discussed are the use of a Web-based tool and screening processes, the role of public agency due diligence and freight railroad cooperation, the impact of passenger train reliability, freight train infrastructure needs, data requirements, Web-based tool development, and Web browser-based applications.

2.2.1 Web-Based Tool and Screening Process

The principal research product was a Web-based tool for screening projects. The starting point for developing such a tool was to understand the screening process and its application.

The primary role for the screening process is a triage capability. As early as possible, the researchers sought to screen out those proposals that were non-feasible, while leaving for further consideration those proposals that seemed to have merit from a feasibility standpoint.

The secondary role of the screening process was to provide preliminary estimates of the impacts of a proposal, which can be useful for the following:

- Sensitivity analysis and design of a proposal,
- Preliminary discussions among public agencies and railroads, and
- Deciding what analyses to pursue with more rigorous analytic tools in partnership with the freight railroads.

There are many approaches to screening projects for preliminary feasibility. These approaches include rules of thumb, simple analytical models, parametric models, and simulation models of varying complexity. Screening tools are intended to be easier, less costly, and quicker to use, but not as precise or accurate as detailed simulation or other models.

Ideally, a robust tool would address both the primary and secondary roles of the screening process and be broadly applicable at the preliminary feasibility, concept phases of planning. As such, the tool would include an integrated set of models with a full range of capabilities.

The research team had broad experience with both the full range of tools that have or could be used to assess capacity issues and passenger/freight commingling in a given corridor. This experience included the development of simplified tools such as Ideal Day Analysis from the Midwest Regional Rail Initiative (MWRRI) study that provides a broad assessment of needs and impacts, other analytic tools like Miss-IT™, and simulation modeling tools like FRA's General Train Movement Simulator (GTMS). The team also had broad experience applying data- and labor-intensive tools like RAILS, Rail Traffic Controller (RTC), RailSim, etc., that are used in detailed studies to provide very specific and rigorous assessments of train movements, priorities, locations, speeds, etc.

2.2.2 Public Agency Due Diligence and Freight Railroad Cooperation

The public sector has a due diligence process involving concept and feasibility studies to identify options for more detailed analysis. However, the freight railroads have expressed concern that it is a significant resource requirement for them to provide key personnel and other resources to the process. They would prefer a minimal role prior to the start of the Investment Grade/NEPA process, which in large, part duplicates in greater detail the initial feasibility and concept studies.

The freight railroads, therefore, have asked that feasibility studies like those performed for the MWRRI, Ohio Hub, and Florida Vision Plan contain language such as *unnegotiated*, *unfunded*, and *without freight railroad assistance* to conserve its resources for the more critical second-level environmental impact studies (EIS)/investment grade studies.

As a consequence, public agency planning departments often are left to develop and assess feasibility of corridors for passenger rail with relatively limited input from the freight railroads, whose staff generally will be committed to other legitimate business of the freight railroad. It is often the case that the public agency planning staff will face major data needs concerning track charts and commercial freight activity in the corridor and may request such data from the freight railroad. The request for track data is frequently granted while the request for commercial activity in the corridor is more difficult. The freight railroad often regards this data as commercially sensitive with the potential to expose its competitive position in the market vis-à-vis other railroads and competing freight modes. The freight railroads will typically only provide such data within a confidentiality agreement that can be provided once EIS/investment grade studies begin. In any case, the screening process and a Web-based tool should not depend on the freight railroad as a source of data; rather, they must rely on alternative sources.

The Web-based screening tool can provide a feasibility-level analysis that should be practical and provide insight into both the difficulty of operating passenger services in a corridor and the level of slack time that they should include in their schedules. Moreover, the tool should provide an indication of the level of additional infrastructure needed to hold the freight railroad harmless.

Major studies like the MWRRI, Ohio Hub, and Florida Vision Plan, all required that preliminary estimates of passenger train schedule reliability and additional infrastructure needs to hold the freight railroad industry harmless be used to quantify and present to the relevant railroad without involving their technical staffs for more than a review of the results. A feasibility study like the Ohio Hub was able to obtain (with appropriate caveats) sign-off from the freight railroads for feasibility results without having to complete detailed engineering and operations studies. This allowed the Ohio Rail Development Commission to evaluate a wide range of route, technology, and market options to eliminate those that were not effective and to develop its strategy for detailed analysis of the best solutions.

This experience suggests that the Web-based tool for screening corridors would need to allow for the estimation of the following two key outputs:

- Passenger train reliability impacts; and
- Freight train infrastructure needs.

2.2.3 Passenger Train Reliability Impacts

The level of reliability of service is critical to passenger train operations, and timetables need to be adjusted to account for delays experienced along the route. Delays tend to be a function of the volume of trains and the impact of local trains at yards and bottlenecks such as bridges along the route. For example, delays are experienced by Amtrak and the proposed Chicago-Twin Cities passenger trains at the Mississippi Bridge at La Crosse, Wisconsin, due to local train operations that at any hour of the day or night interfere with both passenger and freight operations. Whenever these local trains operate, they cause delay to the long-distance passenger and freight trains. Such delays create major problems for passenger rail operations and, as a result, a reliability factor is a critical element in finalizing the timetable. Therefore, at the feasibility stage, a tool supporting a public agency's efforts needs some means for assessing current and future freight train levels using publicly available data.

One source of contention in developing shared-use arrangements is the occasional tendency by public agencies and Amtrak to promote over-ambitious schedules (i.e., showing high speeds and frequent rush-hour trains). Railroads react negatively to what they perceive to be illogical or unrealistic plans that are difficult to realize consistently and will place the blame for failure on the railroad.

Disruptions related to weather, peak traffic volumes, and scheduled or unscheduled maintenance are all routine circumstances that the railroads must deal with—and that must be considered in establishing plans for shared-use operations. Capacity and service are limited by what can be done under poor conditions (and too often schedules and models assume optimal conditions).

The Web-based tool needed to allow for realistic assessment of these reliability impacts in screening proposed plans.

2.2.4 Freight Train Infrastructure Needs

To hold freight operations harmless (or, to allow some minimally tolerable level of disruption to freight operations) in a corridor is critical if passenger trains are to commingle with freight traffic on freight railways on infrastructure *owned* by the freight railroads. This becomes a more daunting task as passenger train speeds increase. At 79 mph, passenger trains are reasonably compatible with freight trains, but are frequently faster and instead of simply "going with the flow" need to overtake slower speed freight trains such as locals, bulks, and general cargo. As a result, extra sidings are needed to clear a path for the passenger train, which typically has priority. This requirement is further exacerbated as passenger train speeds increase to 90 mph, 110 mph, and—as in the Northeast Corridor—150 mph. To further complicate this problem, freight railroads frequently use mainline track as temporary storage and will leave trains "hanging out" while space is made in a yard. As such, consideration has to be given to yard operations along a track. Providing yard leads can often create more mainline capacity for an existing line than can other kinds of improvements.

As a result, a screening tool must contain at least the functionality needed to deal with passenger train reliability and infrastructure needs for continued freight operations. Consequently, the development of the Web-based tool for screening needed to consider the following:

- The current infrastructure of the route,
- The level and type of freight operations,
- The character of existing and proposed passenger rail operations, and
- The degree of interaction between freight and passenger trains.

2.2.5 Data Requirements

The above discussion indicates that the required data for assessing passenger service reliability impacts and infrastructure needs are as follows:

- **Infrastructure**

  For this purpose, an electronic track database is needed. There is a clear need to be able to observe and identify infrastructure, both existing and needed at any location. The most data-intensive method in a screening toolkit would be simulation. A simulation tool that calculates train performance will require track layout, elevation points indicating grade change, heading points indicating curvature change, and speed zones. Other methods, like the "Ideal Day" method described in Exhibit 2-1, will require a subset of this data.

  Track charts can be obtained from public sources. One good source is the FRA GIS 1:100000 Rail Network database that is available from the U.S.DOT Bureau of Transportation Statistics (BTS). Another possible source of data is Google Earth, which can be used to extract coordinate and identifiable data for points that are distinguishable from satellite photographs. Railroad timetables, which may be publicly available or available on request from the railroads, include elevation data, track speed data, and special operating instructions (i.e., speed restrictions and special procedures at interlocking, wye junctions, and interchanges with other railroads).
- **Train Schedules**

  To screen for any but the simplest, lowest-density corridors, it is critical to obtain train movement data. This can be achieved either by specific train classification counts or time-of-day surveys. Train volume data are partially available from FRA's National Grade Crossing Inventory database and, in some cases, from state rail plans and related planning efforts. The quality of the analysis will be impacted by the source and quality of surveys used to obtain this data, but it can be subject to further ratification and validation by empirical research. The different sources should be checked to assess differences in the results and potential error ranges.

2.2.6 Developing the Web-Based Tool

As noted, some proposals may require very simple methods to screen them from further consideration. The research team's review of tools and data was aimed at identifying those methods for inclusion in the tool.

Those proposals that were deemed worthy of more in-depth analysis focused on the following feasibility assessment criteria:

- Passenger train reliability and
- Freight infrastructure needs.

The application of the screening tool to evaluate feasibility required the key data components of track database and train schedules.

In Exhibits 2-1 and 2-2, the research team presents two alternative methods for conducting the analysis capable of addressing feasibility criteria. Exhibit 2-1 illustrates the Ideal Day Analysis method used by TEMS in the Midwest, Ohio, and Florida. Exhibit 2-2 illustrates analysis with FRA's GTMS developed by DecisionTek. The two tools offer a choice of

Exhibit 2-1. Approach to corridor analysis by planning stage (using the TEMS toolkit).

In the 2001 report, "Methodology for Freight Capacity Analysis for the Midwest Regional Rail Initiative," TEMS developed a framework to identify the type of capacity analysis needed for different stages of the planning and engineering process. Figure 2-1-1 shows the basic structure of the requirements for capacity analysis at each analysis level.

For conceptual planning, TEMS proposed that the analysis consist of a review of potential conflicts and train "meets" (i.e., locations) where trains would ideally pass each other if adequate track capacity were available. At such locations at the conceptual level, preliminary recommendations would be made for additional infrastructure based on the type and class of train and their associated speeds, e.g., 2-mile siding for general freight train, 4-mile siding for an intermodal train, and 10-mile siding for another passenger train so trains could pass at speed. A capital cost can be assigned to the siding for track, switches, signaling, etc. These rules of thumb or benchmark estimates provide a very conceptual understanding of infrastructure needs and, within the typically large error range of such studies, provide a ballpark cost estimate for infrastructure needs. It should be noted that the error range of such analysis is correlated directly with train volumes and speed and may well produce large errors ±50 percent for 110 mph passenger trains on heavily used freight corridors (e.g., Chicago-Milwaukee-Twin Cities). However, for light or medium corridors, the results can be used to give a reasonable assessment of both passenger train delay and freight infrastructure needs.

The second step in the TEMS framework is feasibility planning for which an Ideal Day Analysis is needed. This analysis considers the meets and conflicts of the corridor and assesses the likely delay by train meet based on train volume, level of infrastructure, types of freight train, and quality of signaling system. This type of analysis quantifies both the typical delay that will be experienced for the lower priority trains, as well as the infrastructure needed and costs (see Figure 2-1-2 and Table 2-1-1). The Ideal Day Analysis is a "static" process that assumes that the conditions under which trains operate are identical from day to day and produce identical travel times and delays each day. Because there is no variation in travel times or travel starts, these trains are assumed to operate under ideal—almost scheduled—conditions. As a feasibility tool, the Ideal Day Analysis has a significant error range ±30 percent; however, it is particularly effective as a screening tool and in developing the feasibility estimates of cost before detailed engineering can be performed.

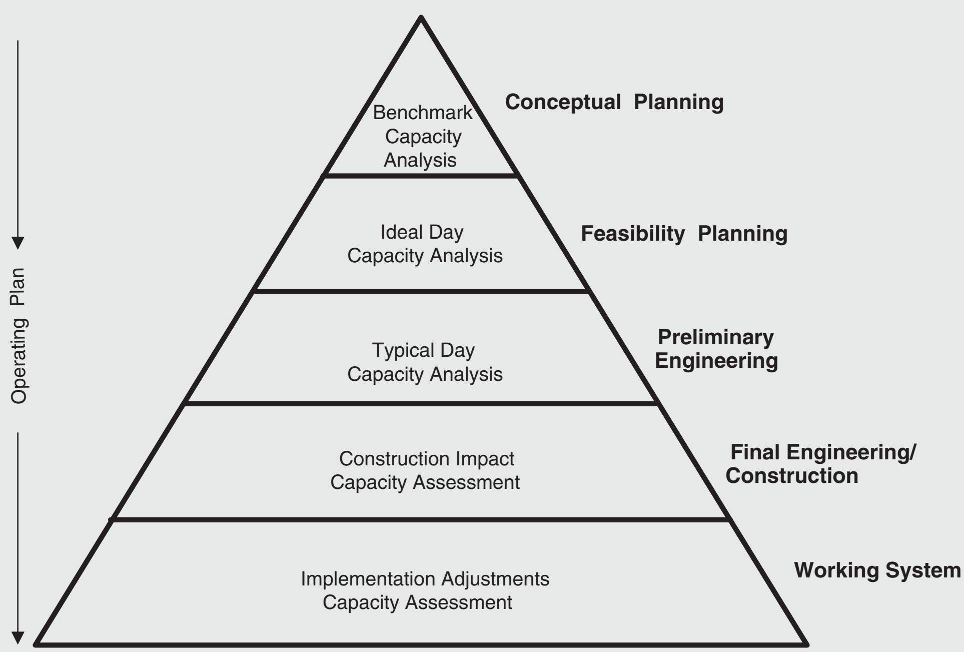

Figure 2-1-1. Levels of capacity analysis required in the planning process.

Exhibit 2-1. (Continued).

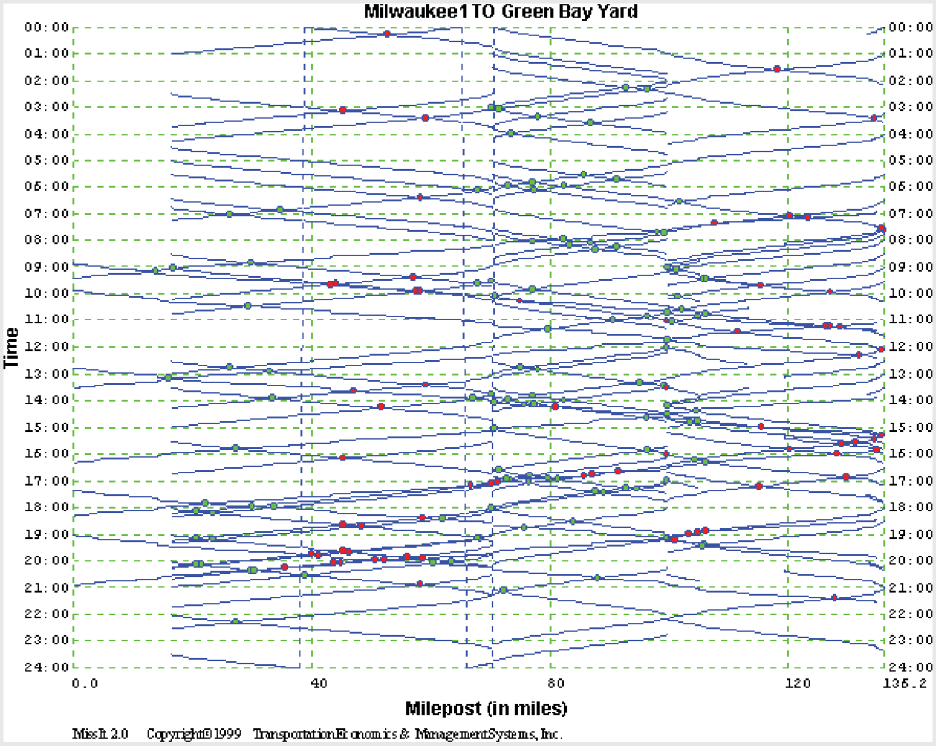

Figure 2-1-2. Conflict points subsequent to analysis.

In the preliminary engineering phase of a project development process, a Typical Day Analysis produces a more detailed analysis than does the Ideal Day Analysis. It considers all of the variation in train performance, particularly actual starting times, route delays, and location issues such as lift bridges, local trains, and yards. This dynamic element provides more typical travel time estimates for trains passing through a corridor and, therefore, a more accurate measure of delay and conflict. It is at this stage that the freight railroads are willing to participate and frequently want to carry out the capacity analysis. Error range in these studies is ±20 percent.

In the final phase of development, final operating plans are produced to show how construction phasing and implementation process will impact train movements. At this stage, detailed analysis of train patterns, movements,

Table 2-1-1. Meet point analysis report sorted by milepost.

Meet Point Summary by Milepost						
No	Milepost	Time	Train1 Number	Train2 Number	Direction	Category
1	0.05	13:00	HIA_335	Metra_2134	Opposite	Clear
2	0.05	8:15	LAKE_CO_WB	Metra_2118	Opposite	Clear
3	0.09	7:40	Metra_2107	Metra_2112	Opposite	Clear
4	0.2	8:35	Metra_2109	Metra_2122	Opposite	Clear
5	0.25	19:35	Metra_2149	Metra_2152	Opposite	Clear
6	0.3	20:35	Metra_2151	Metra_2154	Opposite	Clear
7	0.3	17:30	Metra_2139	Metra_2144	Opposite	Clear
8	0.39	9:07	LAKE_CO_EB	Metra_2126	Same	Conflict
9	0.45	7:41	HIA_330	Metra_2107	Opposite	Clear

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Exhibit 2-1. (Continued).

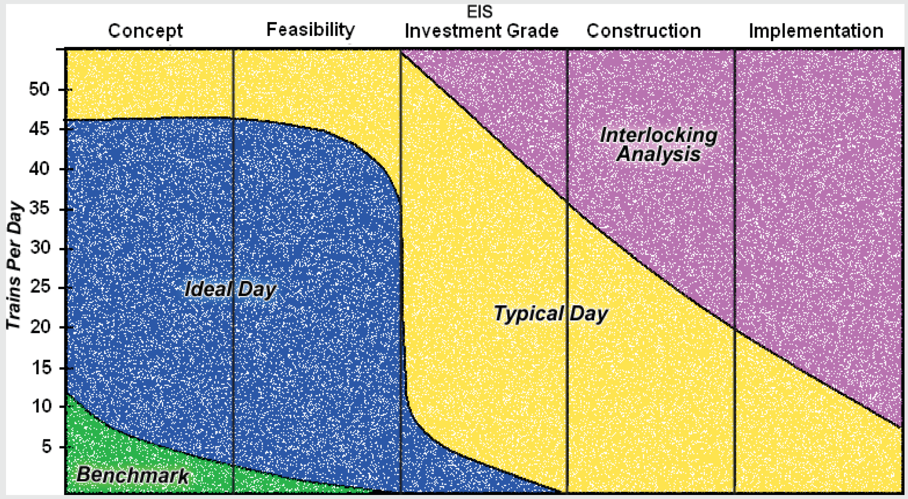

Figure 2-1-3. Appropriate tools for different levels of analysis.

and interlockings is needed. This level of detail requires full simulation of the train operations to ensure the integrity of the infrastructure, signaling, and train movements at all locations along the track.

The impact of these requirements is that different tools are needed for different levels of planning. Figure 2-1-3 shows how the planning level and train volume relate to the typical tool needed for capacity analysis.

It is clear that at low levels of freight rail operation relatively simple tools can be adopted, whereas when the need for accuracy increases because of more detailed planning needs, and train volumes increase because of train volume, the level of detail provided by the tool must increase.

The assessment of data needs at different planning levels suggests that for most feasibility planning a tool can be developed that will provide reasonable solutions for corridors with less than 40 to 50 trains per day. Over 40 to 50 trains per day, a more detailed Typical Day Analysis is likely to be needed due to the complexity of the activity in the corridor. Only by adopting very broad error ranges can cost estimates be reasonably prepared for concept and feasibility studies when the train volume reaches 40 to 50 freight trains per day.

Although the TEMS assessment frameworks provide a first cut at the development of a taxonomy for feasibility analysis tools in different levels of planning, they point to both the character of the tools needed for capacity analysis and their data requirements.

approach, each with its own advantages and disadvantages. Ideal Day was originally developed for low-density routes; the simulation-based approach originally embodied in GTMS can better inform regarding delay-mitigating infrastructure improvements in corridors with higher traffic density. Combining the approaches builds on the strengths of both tools.

The researchers studied the pros and cons of each option, and how inefficiencies might be overcome by improving the technical capability of Ideal Day type models versus improving the openness and clarity of the simulation option. For this purpose, the research team evaluated a range of examples that they had already assessed in completing passenger corridor feasibility and EIS across the country. These include the Midwest, Ohio, the Northeast, Florida, Texas, and Colorado. The aim was to test both heavily used corridors such as Chicago-Cleveland, as well as medium or lightly used corridors like Chicago-Detroit.

Using the results of these assessments, the performance of planning models versus simulation models was assessed and recommendations made as to how a Web-based system would be developed. Given the research team's access and knowledge of planning and simulation tools, the research team was able

Exhibit 2-2. Operations analysis with simulation (using FRA'S GTMS).

A simulation approach offers a number of advantages when conducting operations analysis for preliminary feasibility. The non-simulation approaches may be adequate in some situations, while in others they may include large margins of error and run the risk of over or under screening alternatives. A simulation approach will, however, typically be more data-intensive and require an analyst with more experience.

With simulation of train movements, the analysis accounts for the resistive forces on the trains whose fluctuations may be very significant in undulating terrain, especially for large freight trains. Together with explicit modeling of power requirements and braking, simulation replicates train movements to arrive at realistic estimates of point-to-point run times by type of train. Just as important, simulation captures the impacts of traffic control in the realization of train schedules and the effects of increased traffic density with and without improvements to the infrastructure

In the example shown here, the simulation outputs show a territory that is mostly single track with sidings. The purpose of this illustrative analysis is to demonstrate how simulation can show the effects of added traffic, identify bottlenecks and see whether infrastructure modifications are possible that would pass preliminary feasibility screening (i.e., permit reliable passenger service while leaving freight operations harmless).

As shown in Table 2-2-1, in the base case there are 11 scheduled daily freight trains. The freight trains have a maximum track (normal) speed of 50 mph. The analysis assumes that both main track and sidings can handle the heaviest trains, which are 134-car, 19,000-ton coal trains. In the alternate case, the analysis adds passenger service of six trains (three in the A.M. period and three in the P.M. period) whose maximum speeds are 79 mph. The analysis assumes that there are no infrastructure improvements (except whatever track upgrades may have been necessary to accommodate the higher speed passenger trains).

The Figure 2-2-1 string chart shows the time and position of trains in the simulated system for the base case (time is on the X-axis and distance in miles from the milepost designating the northern system boundary is on the Y-axis). Where lines cross on the chart the train meets are executed. One can observe that there is very little delay (i.e., holding of trains) at this level of traffic density.

In the alternate case string chart shown in Figure 2-2-2, six passenger trains have been added to the schedule (these are labeled P_01, P_02, etc.) The added traffic is seen to result in some delay in both the A.M. and P.M. periods.

The simulation outputs also provide a clear view of the functioning of traffic control. The authorities chart shows each traffic control block (shown on the Y-axis) and the time that movement authority has been granted to a particular train. Authority is revoked after the train has exited the block. Traffic control blocks for the main track (1 through 122) are shown on the bottom of the chart and sidings are at the top of the chart. For each meet it is possible to see which train was directed to a siding, the time authority was granted, and when the train exited the block.

Table 2-2-1. Simulation scenarios.

	Base Case	**Alternate Case**
Infrastructure	150 miles (north-south), single track with sidings	Same as base case
Traffic	11 daily freight trains	11 daily freight trains 6 daily passenger trains
Speed Limit	50 mph maximum for freight	50 mph maximum for freight 79 mph maximum for passenger

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Exhibit 2-2. (Continued).

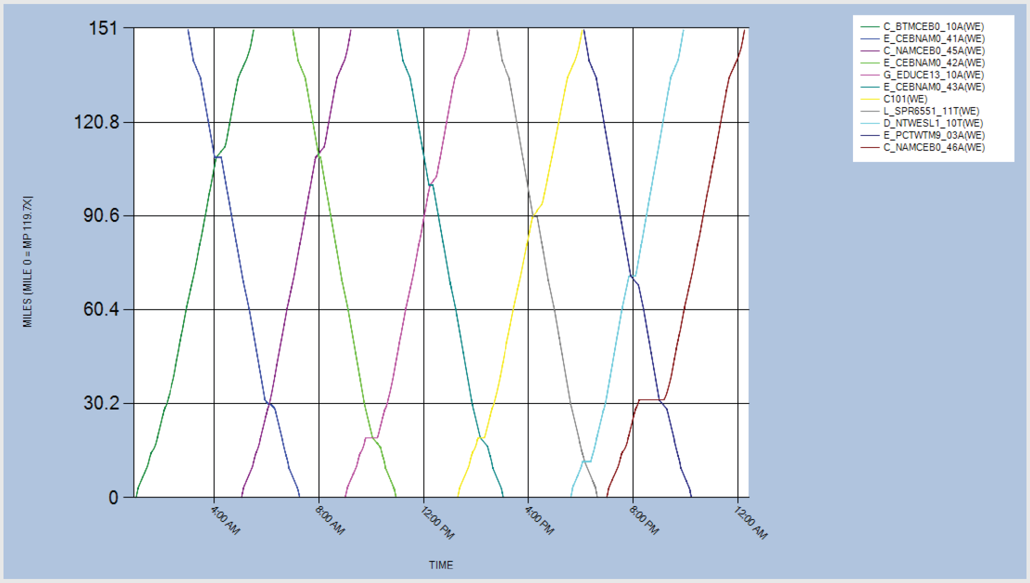

Figure 2-2-1. String chart (base case—freight trains only).

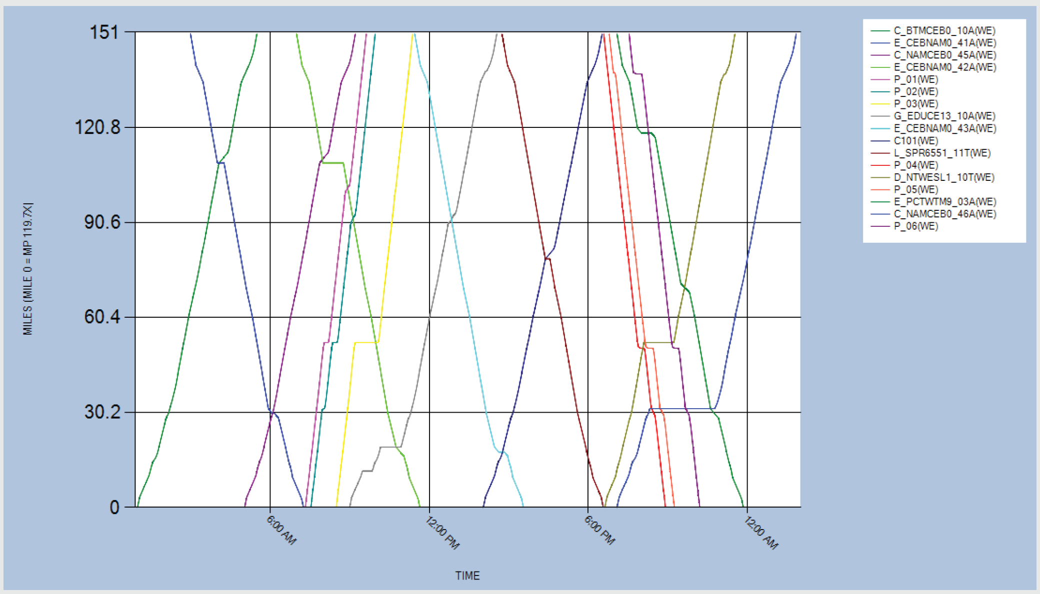

Figure 2-2-2. String chart (alternate case—including passenger trains).

Exhibit 2-2. (Continued).

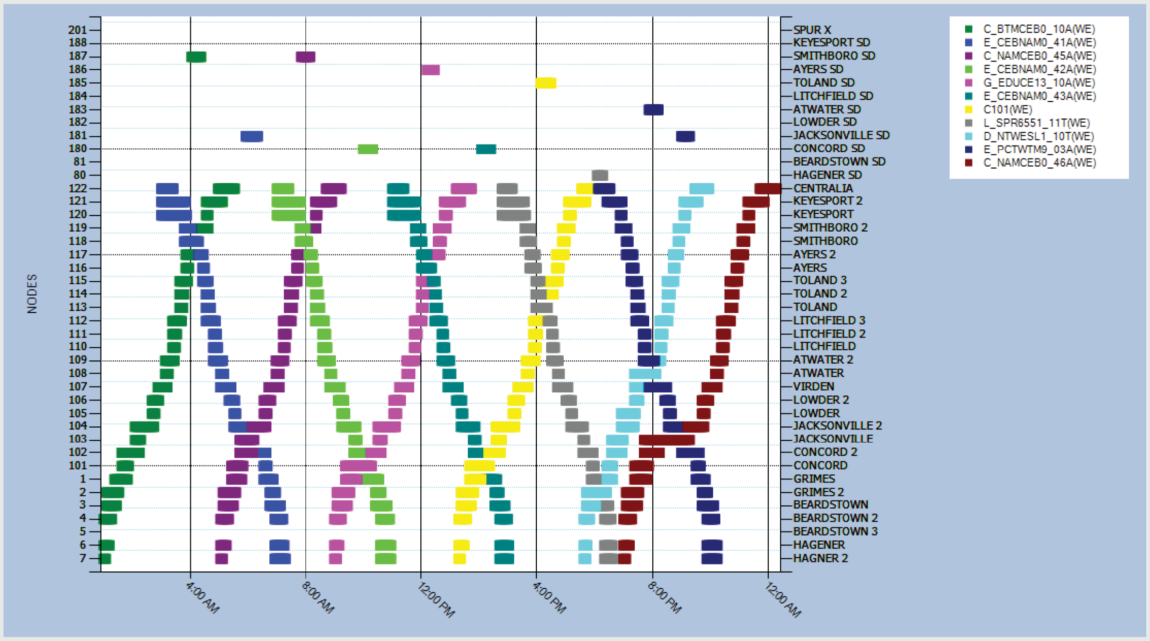

Figure 2-2-3. Chart of authorities (base case—freight trains only).

Below is the same chart for the alternate case. One can observe the more extensive use of sidings when compared with the base case.

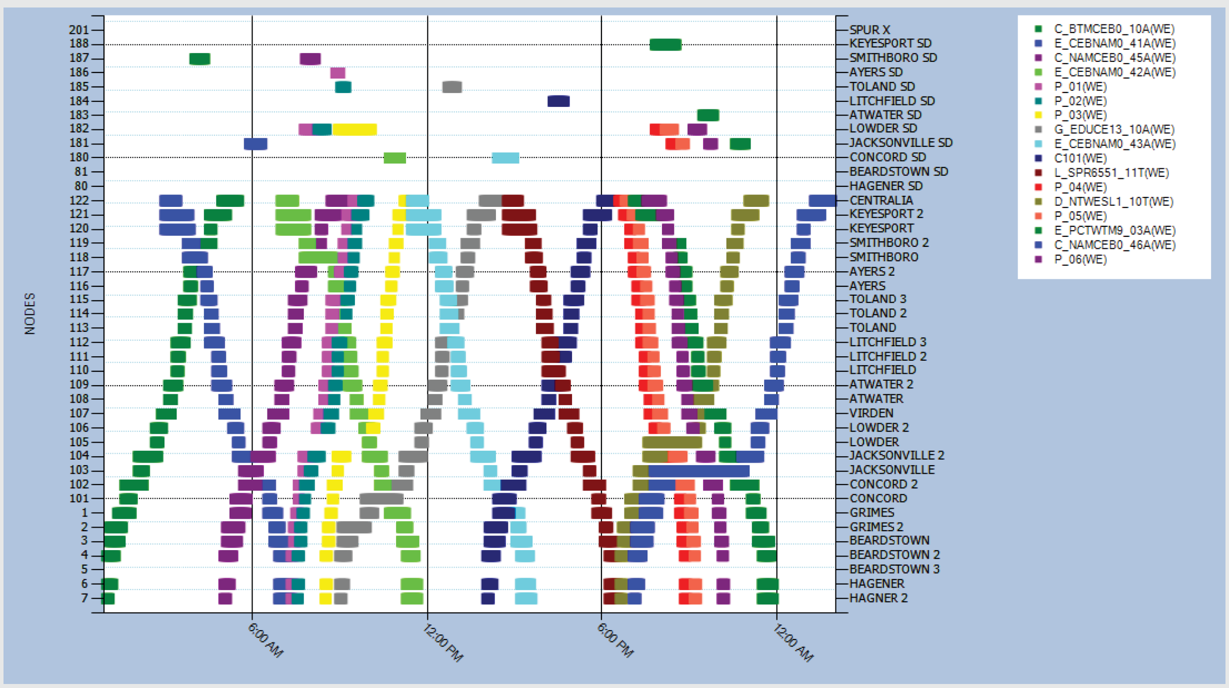

Figure 2-2-4. Chart of authorities (including passenger trains).

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Exhibit 2-2. (Continued).

The following chart shows the speed profile for one of the coal trains, and this chart can be generated for all of the trains. The chart includes the speed profile, elevation, position of controls (throttle and dynamic braking) and the application of air brakes.

A review of these results will lead an analyst to conclude that the added passenger rail traffic without modifications to either the freight schedule or changes to the facility (i.e., additional sidings) would be likely to result in delays to freight movements while not meeting passenger service reliability requirements. The analyst could then propose modifications that could result in acceptable operational outcomes, which could be demonstrated with additional simulations.

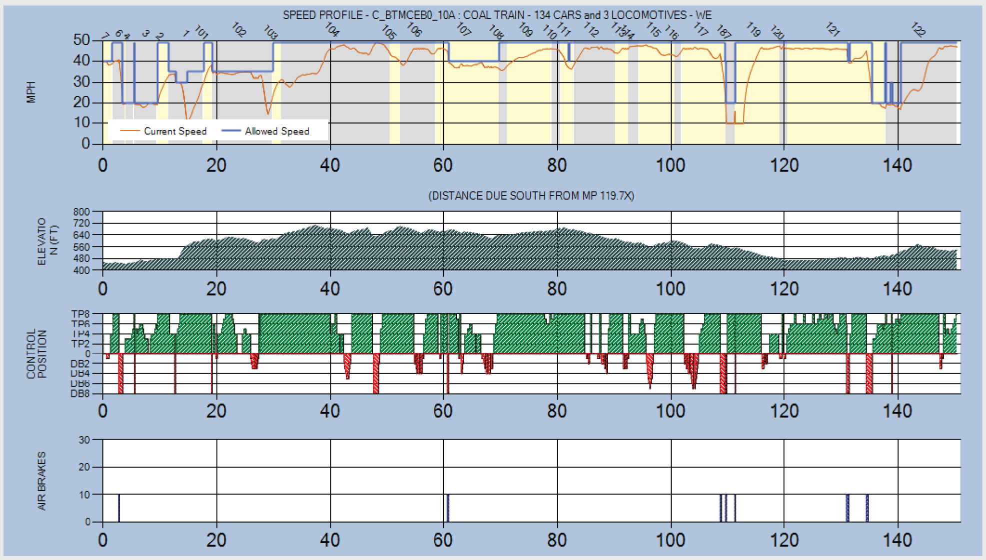


Figure 2-2-5. Speed profile, elevation, train controls (selected freight train).

Average Speed by Train Type (MPH)	Base Case Freight Trains Only		Alternate Case With Passenger Trains	
PASSENGER (6 trains)	N/A		60.4	
COAL (7 trains)	34.2		32.1	
GENERAL (2 trains)	37.0		35.1	
UNIT (2 trains)	34.5		31.9	
Percentage of Trains by Type with Delay in Excess of Tolerance	Aggregate	Net	Aggregate	Net
PASSENGER (delay in excess of 10 minutes)	N/A	N/A	83.3	20.0
COAL (in excess of 30 minutes)	28.6	14.3	42.9	14.3
GENERAL (delay in excess of 30 minutes)	0.0	0.0	50.0	0.0
UNIT (delay in excess of 30 minutes)	0.0	0.0	50.0	50.0
Mean Delay (in mins)	Aggregate	Net	Aggregate	Net
PASSENGER (delay in excess of 10 minutes)	N/A	N/A	17.8	12.0
COAL (in excess of 30 minutes)	9.0	15.0	63.7	105.0
GENERAL (delay in excess of 30 minutes)	0.0	0.0	91.0	0.0
UNIT (delay in excess of 30 minutes)	0.0	0.0	33.0	33.0
Maximum Delay (in mins)	Aggregate	Net	Aggregate	Net
PASSENGER (delay in excess of 10 minutes)	N/A	N/A	27.0	12.0
COAL (in excess of 30 minutes)	15.0	15.0	110.0	105.0
GENERAL (delay in excess of 30 minutes)	0.0	0.0	91.0	0.0
UNIT (delay in excess of 30 minutes)	0.0	0.0	33.0	33.0

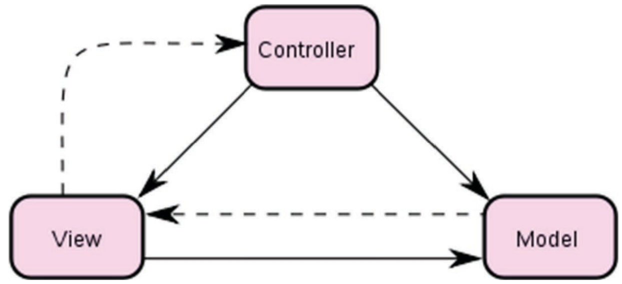
* Aggregate delay is the total minute difference between scheduled and actual arrival time, less tolerance.

** Net delay is the total minute difference between scheduled and actual run time, less tolerance.

Figure 2-2-6. Simulation summary of operational metrics.

to build the option that proved most effective and include a graphics interface, database, model, and output system. The development system was based on a detailed concept design, which identified inputs/outputs, models, and interface requirements for the system.

Once the Web-based system was developed, it was tested on three case studies. The research team had data for a large number of corridors around the country and provided test analyses on a range of different corridors. This included a range of train densities and geographic conditions to test the performance of the model in different environments.



Note: This figure uses the Unified Modeling Language (UML) conventions. Solid lines represent a direct association; dashed lines represent an indirect association via an observer.

Figure 2-1. UML diagram of the MVC software architecture.

2.2.7 About Web Browser-Based Applications

Software Architecture

Applications that run in browsers over the Internet present special challenges that developers need to consider. The basic Web model is one of request-response, that is, the client (local computer and browser) is de-coupled from the server, and sends requests that are processed by the server which, in turn, sends responses back to the client as updated browser pages, after which, the server is free to handle requests from other users. In earlier implementations of Web applications "response-request" usually meant click and wait—the user experience was generally considered much worse than that of a comparable desktop application. Newer applications use technologies that offer a rich client experience in which the application responds almost like a desktop application.

A Web application has components that run in the browser (like events that trigger when a mouse hovers on a location) and other processes that are handled on the server (like database queries and complex procedures). Pages from non-trivial applications such as non-static HTML (HTML stands for hyper text markup language and is used to create structured documents that are viewable in a Web browser) show content that is customized for the user's session and may also rely on stored user data. There is a considerable amount of design that goes into developing a Web application so it can maintain communications between its components and manage the states of the application and its active sessions—all of which are subject to the constraints of the basic request-response model.

A best practice design or software architecture for a Web-based application is one that isolates domain or business logic (i.e., technical calculations) from the presentation layer or "front end," which is the pages and forms that the user sees on screen. One such software architecture is called Model-View-Controller (MVC) and is shown in Figure 2-1. The model represents the business logic, the view is the presentation layer, and the controller represents the elements through which the user interacts with the application (i.e., buttons, text boxes, menus, etc.).

The application's data model is contained within the model component. Even if the application does not store user data, there will still be system data required by the application so the Web-based tool will require a database (i.e., a back end). If the application does not store user data, then the application receives all of its user input in the user session like an online calculator. However, if the application is to have any significant complexity it will store user data and require users to register and set up a user account on the server. (Alternately, user data accounts could be avoided if user data are downloaded to the local computer at the end of a session and then uploaded back to the server when the user starts a new session. However, this is problematic because users will lose a session's data if there is an Internet outage, the local computer hangs, or the user accidentally closes his or her browser.)

The research team's solutions implemented the best practice methods for developing Web applications that are described here and, where applicable, included processes for registration and secure login to access user data.

Implementing Technologies of the Web-Based Tool

The team implemented the solution in ASP.NET using the Microsoft® Visual Studio integrated development environment. The application database used SQL Server 2008. The server ran the MS Windows 2008 Server operating system, which uses the Internet Information Server (IIS) 7.0 Web server. These technologies are industry standards approved by the Office of Management and Budget. The research team had used these technologies extensively and applied them in other Web-based applications.

Federal Requirements for Web-Based Systems

The proposed Web-based tool will run on a FRA server and, as such, will need to meet all the requirements mandated for federal systems and by the agency. The research team was committed to providing the Web-based tool as a fully compliant system meeting all federal and agency requirements including

- Security,
- Privacy, and
- Compliance with Section 508 of the Rehabilitation Act (for disabled accessibility).

In addition, the Web-based tool was designed to be "browser neutral" and fully compatible with post-2005 versions of major browsers (Internet Explorer, Firefox, Safari, and Chrome).

2.3 Approach to Tasks

The research applied the general approach outlined above to perform the following tasks.

2.3.1 Task 1: Identification of Tools

This task was conducted in three principal components, as follows:

- Develop an inventory of tools,
- Assess functionality, and
- Assess potential relevance.

Tools to consider included RAILS RailSim, RTC, GTMS, TRACKMAN, LOCOMOTION, COMPASS, GOODS, and RENTS.

In developing the inventory of tools the research team relied on its extensive experience and its knowledge of industry tools, as well as a new search performed to find existing tools that have been used in recent rail plan feasibility studies. This search for tools included Internet searches and phone interviews with study authors to determine whether there are additional tools in the public domain or commercially available that can support rail feasibility analysis.

After developing an inventory of the tools, the research team assessed the functionality of each tool by

- Specifying the issues the tool addresses (i.e., capacity analysis, scheduling, etc.);
- Specifying the data that are required to use the tool—and whether these data are likely to be publicly available;
- Specifying the output metrics and reporting formats that are provided by the tool;
- Assessing the usefulness of the tool in addressing feasibility analysis concerns; and
- Assessing the extent to which the methods embodied in the tool are replicable in the Web-based tool (i.e., based on publicly available methods or otherwise accessible to the research team and implementable in a Web-based tool given schedule and budget restrictions).

This information was organized in a tabular format with an assessment of the relevance of each tool to the Web-based tool, along with a list of pros and cons associated with it.

2.3.2 Task 2: Description of Data Needed for Identified Tools

In this task the researchers provided a full description of the data needed to populate each of the tools that was identified as relevant to the Web-based tool. The description of the data included a full specification of the data and all of the data attributes at a level that is adequate to gather the data (by interview, survey, request, or other means) and implement a functional database.

One important data need of the Web-based tool was infrastructure unit costs, which can be used to estimate infrastructure costs for added capacity required to integrate passenger and freight trains.

The data descriptions include a mapping to the tools that require them.

2.3.3 Task 3: Gap Analysis of Identified Data

For the data described in Task 2 the researchers determined the following:

- Whether or not the data are publicly available;
- When data are not publicly available, publicly available proxy data or methods for inferring data from other data or independently gathered data was specified;
- Where inferred or proxy data were used in place of source data, the research team analyzed the likely impacts of using the inferred data on the analysis.

As described in the general approach, principal interest areas of the feasibility analysis were passenger train reliability and freight train infrastructure needs. The broad data categories for conducting the analyses were track data and current and projected train volumes.

Preliminary sources that could substitute for railroad-provided track data included the FRA GIS 1:100000 database that is available from BTS. Current railroad timetables contain a wealth of useful information (including general facility information, point-to-point distances, elevations, and speed limits), but are not publicly available. (One reason that railroads may not make these available is that overzealous rail enthusiasts or unfriendly persons could possibly disrupt operations given the dispatcher frequencies and other information contained in the timetables.) However, timetables could, perhaps, be provided on request.

For train volume data, the FRA National Grade Crossing Inventory Database is publicly available and could be a starting point gathering train volume data. Actual surveyed train counts could be a useful means of gathering train volume data.

The research team's gap analysis was designed to determine which tools and methods together with the culled data required to populate them would contribute to an effective Web-based screening tool.

2.3.4 Task 4: Summary of Phase 1 Research and Recommended Approach for Phase 2

This task had the following component parts aimed at developing:

- A summary set of functions and outputs that best meets the FRA *Guidance Manual* using publicly available or inferred data,
- A detailed work plan for the development of the Web-based screening tool, and
- A software development plan.

The results of this task and the preceding tasks were presented in an interim report. The research team included its recommendations for proceeding with the Web-based tool and addressed all the relevant elements of the FRA *Guidance Manual* as were practical.

Functions and Outputs

The researchers developed a proposed list of Web-based tool functions and outputs. The functions describe the procedures that the Web-based tool will implement and the outputs include the metrics, results, and description of the principal result tables and charts that the tool generates. These functions and outputs form the basis for the software requirements described in Task 5.

Work Plan

The Phase 2 work plan covered all of the Phase 2 activities, including tool development, documentation, and preparation of case studies. The work plan included interim milestones that enabled the project panel to track the research team's progress.

Software Development Plan

The software development plan included the tasks required to design, implement, and test and deploy a Web-based tool based on a software architecture for a multi-tiered application with strong separation between the data, logic, and presentation layers.

The software development included a breakout of tasks, an estimate of hours for each task, and the intermediate deliverables leading to the beta and final versions of the Web-based tool.

Figure 2-2 shows the process workflows for software development, phases of development, and the intensity of the workflow in each development phase.

	Phases of Development			
Process Workflows	Inception	Elaboration	Construction	Transition
Modeling	✓	✓✓	✓✓✓	
Requirements	✓✓	✓✓✓	✓	
Analysis & Design	✓	✓✓✓	✓✓	
Implementation		✓✓	✓✓✓	✓
Test		✓✓	✓✓✓	✓✓
Deployment				✓✓✓
Supporting Workflows				
Config Management	✓	✓✓	✓✓✓	✓✓
Management	✓✓	✓✓	✓✓	✓✓

Figure 2-2. Work flow intensity relative to development phase.

2.3.5 Task 5: Web-Based Screening Tool Design

Task 5 was intended to "develop" the Web-based screening tool, and the research team took this to mean "design" the tool, which would logically precede Task 6. (In software development parlance "development" embraces all related activities that are in the process workflows in Figure 2-2.)

Tasks to complete in the tool design phase included modeling, requirements, and analysis/design. *Modeling* refers to the development and testing of concepts for the software. *Requirements* refers to the preparation of a software specification and requirements (SSR) document that lists all the requirements of the Web-based tool (inputs, outputs, processes, and performance characteristics). Each requirement is a firm and testable statement about the capability of the new software. *Analysis/design* refers to the preparation of a design document, which is essentially a series of diagrams and supporting documentation that serves as a blueprint for the implementation of the tool. The design (or system architecture) document includes diagrams representing multiple views of the system: logical (functionality), implementation (software management), process (performance, scalability, throughput), deployment (system topology, delivery, installation, communication), and use case (understandability and usability). All of the system's components including the data model, user interface, error handling, and communications between components are covered in the design document. The design document also includes mockups of pages that will give reviewers an idea of the intended "look and feel" of the Web-based tool.

The team delivered requirements and design of the system in a recommended approach document.

2.3.6 Task 6: FRA-Hosted Beta Version Software and Supporting Documentation

In Task 6, the researchers implemented the requirements and design that were developed in Task 5. The tool was developed on the research team's development platform, and the beta version was to be installed on the FRA server and accessible for review and testing when complete.

The researchers developed a users manual that offers thorough guidance to users and includes several walkthrough examples of how to develop an analysis using the screening tool.

The users manual describes the database for the user and specific page formats and controls that will be provided to allow the user to enter the data and to ensure that data are properly assembled.

Database design and data requirements were in the design documents of Task 5. This task delivered the operational beta version of the Web-based tool installed on the FRA server and the supporting documentation (users manual and annotated source code).

2.3.7 Task 7: Identification of Five Shared-Use Corridors for Case Studies

The researchers selected five shared-use corridors for case studies. The case studies were selected with the intent of illustrating the use of the tool's features and its robustness for a range of operating scenarios. The case studies provided a source of valuable lessons learned for refining the Web-based tool into its release version.

The research team considered the mixes of freight and passenger traffic attributes as shown in Figure 2-3.

The researchers considered stages of planning or execution in selecting the case studies, that is, a mix of corridors that are in concept planning, implementation, or service were considered.

A report to the project panel showed the research team's process, the selection of candidate corridors for case studies, and the rationale behind these recommendations.

2.3.8 Task 8: Preparation of Three Case Studies Using the Beta-Version Tool

Following the project panel's selection of the shared-use corridors for study, the research team conducted three case studies. The case studies included analyses using the Web-based tool to establish feasibility for proposed alternatives.

The case studies also contained the following:

- **Calibration of the Web-based tool—**Where possible, the research team compared estimated metrics using the tool with actual measured metrics and fine-tuned the related models so that minimum differences between the actual and estimated results were achieved.
- **Validation of the Web-based tool—**The research team validated the result outputs by comparing results to actual

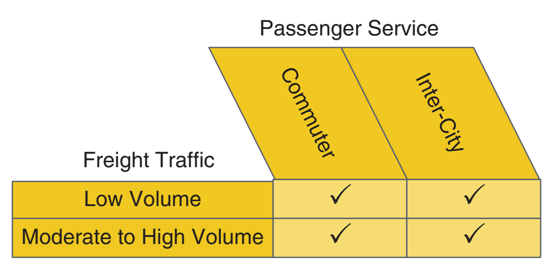


Figure 2-3. Mix of freight and passenger traffic attributes for case studies.

measured outcomes, where possible. When not possible, the research team reviewed and validated case study results with individuals closely involved with the shared-use corridor.

- **Performance of sensitivity analysis—**The case studies were subject to sensitivity analysis of key variables (those factors that are most responsible for the determination of acceptable levels of passenger service reliability and uninterrupted freight operations in the corridor).

The research team delivered three case study reports.

2.3.9 Task 9: Draft Final Report, Draft Final Software with Supporting Documentation

A draft final report was prepared to summarize work completed and for project panel review at the completion of the research. This report reflects the project panel's advice and comments submitted following review and addressing comments. These reports bring together all Web-based tool documentation, the users manual, case studies, and information included in the interim report. The final version of the software and its supporting documentation is available on the FRA server.

CHAPTER 3

Findings and Applications

3.1 Introduction and Study Objectives

The purpose of this chapter is to summarize the findings from the research associated with developing a Web-based tool to enable states and passenger rail operators to perform preliminary feasibility screening of proposed shared-use passenger and freight rail corridor projects. The screening tool would be intended to

- Support preliminary feasibility analysis of rail passenger projects and identify those that warrant further detailed investigation with more rigorous analytic tools.
- Help planners assess railroad operations, capacity, and capital requirements of shared-use corridors where publicly funded passenger rail trains are proposed for operation on privately owned freight rail lines.
- Assist in preliminary analysis as defined in FRA's *Rail Corridor Transportation Plans: A Guidance Manual* (*1*), focusing on simulating train operations and determining capacity needs.

The principal research product from this project is a Web-based tool for screening potential shared-use projects.

Before discussing the research findings and applications from the project, it is useful to review the purposes of screening, the practical application of the process, and the features and functions established for the screening tool to effectively meet its objective.

3.1.1 Purpose of Screening

The primary purpose of the screening process is to identify potential shared-use projects that have merit and those that do not. During the early stages of feasibility assessment, it is particularly important to identify and discard impractical, unfeasible, or cost-prohibitive projects. Doing so will enable planners to focus resources on projects that pass screening.

The secondary purpose of the screening process is to provide preliminary estimates of the impacts of a shared-use proposal. Such estimates could be useful for sensitivity analysis, proposal design, preliminary discussions between public agencies and railroads, and deciding what analyses to pursue more rigorously in partnership with freight railroads.

A robust tool would address both screening purposes and be broadly applicable at the preliminary feasibility and concept phases of planning. As such, the tool would include an integrated set of models with the necessary functionality able to meet either or both of the purposes of screening.

3.1.2 Impacts and Mitigation

In screening corridors for shared-use operations, it is seldom the case that passenger trains can be added without impacting existing corridor operations. It would be expected that mitigation would involve at least some infrastructure improvements to maintain overall capacity for freight operations (even if the capacity is currently underutilized) while allowing for forecast freight and passenger traffic growth.

The disturbance due to the introduction of passenger service is said to be mitigated if some measure of capacity is shown to be undiminished after adding infrastructure.

Capacity can be measured in several ways. The research team identified two relevant approaches. In one approach developed for the Midwest Regional Rail System (MWRRS), the measure of capacity was freight operations delay expressed as the need for additional capacity. In this approach, target delay levels were estimated by simulating freight operations over existing infrastructure in a future forecast year. Mitigation was achieved by adding sufficient infrastructure to maintain freight train delays at the same level, with the additional passenger service.

A second approach to capacity measurement was proposed in a 2007 Cambridge Systematics study sponsored by AAR (*2*) (the "AAR Study"). The study suggested an alternative level of service (LOS) definition that follows the *Highway Capacity Manual* (*3*) approach, stating that satisfactory arrangements between freight railroads and the public could be reached by maintaining a specific LOS (e.g., C or D or better) through the forecasted time horizon. The approach relied on a slot-based capacity approach (i.e., throughput metric) rather than on a delay metric. In this approach, a reduction from maximum theoretical to practical capacity is accomplished by applying a factor, typically in the 70-80 percent range, to ensure that the level of infrastructure is sufficient to maintain free flow conditions with reasonable (small) levels of train delay.

Although a screening tool's ability to develop project alternatives is both limited and not necessarily definitive, with careful analysis of the screening tool outputs and the application of experience, a screening tool could support the process of identifying infrastructure improvements and the likely levels of costs.

3.1.3 Costs

Feasibility screening will need to address the cost of proposed improvements. Detailed engineering cost estimates are beyond the scope of a screening tool, but an approach that applies unit costs (i.e., dollars per new mile of track, etc.) would be useful for screening. The tool could look at cost feasibility thresholds for proposed projects by examining total improvement costs and costs per projected annual passenger-mile. Cost-prohibitive projects would be screened out as infeasible. A simple approach to cost development has been provided with the SU screening tool.

3.1.4 Balancing Ease of Use with Reliability of Results

There are several methodological approaches to screening projects for preliminary feasibility. These approaches range from the relatively simple (e.g., rules of thumb, simple analytical models, parametric models) to very complex simulation models. A Web-based SU tool that strikes a balance between ease of application and reliability of results, and is applicable for broad, preliminary screening, yet can offer staged options with refinement, could be very useful.

3.1.5 Input Data

The SU tool will need to consider a variety of input data, including the following:

- Current infrastructure of the route;
- Freight traffic mix data (i.e., level and types of freight operations);
- Character of existing and proposed passenger rail operations (passenger traffic mix);
- Train schedules (for assessing the degree of interaction between freight and passenger trains);
- Forecast freight and passenger growth; and
- Unit costs.

3.2 Inventory of Tools

In Task 1, Identification of Tools, it was noted that the research team expanded the notion of software tools to include additional methods that have been documented in academic journals and trade publications that address some element of the key concerns of the Web-based tool. The researchers identified five methodological approaches, as follows, in order of increasing complexity:

1. Parametric,
2. Optimization-based methods,
3. Topological,
4. Analytical, and
5. Simulation.

The research team cataloged 29 existing software tools and methods, with methods being algorithms, formulas, or techniques that can be incorporated easily as a screening tool component. The research team then assessed the suitability of each approach and tool for possible inclusion in a Web-based tool for NCFRP Project 30. The assessment criteria were as follows:

- Does the tool generate a feasibility metric of interest, such as train delay and capacity measure, slot capacity and capacity utilization, or is it relevant in shared-use planning, preplanning, or decision making?
- Does the tool inform with regard to the infrastructure and traffic conditions of the specific corridor or route under consideration and reasonably reflect actual and forecast train volumes and traffic mix?
- Are the data requirements excessively onerous or difficult to satisfy?
- Does the tool inform with regard to the interaction of freight and passenger trains and support the identification of areas of conflict or bottlenecks (including with the added infrastructure) and likely levels of delay and reliability?
- Does the tool have significant barriers to use (e.g., proprietary restrictions or excessive training requirements)?
- Is the tool used and accepted in the rail industry?
- Is the tool "upwards compatible" with more detailed assessment conducted in later stages of project development?

The next section summarizes findings from the inventory of tools and methodologies.

3.2.1 Parametric Approaches

Parametric approaches use empirically calibrated formulas rather than equations derived from first principles to establish relationships between infrastructure, train volume, traffic mix, delay, and capacity. The best-known example of this class of model is the 1975 Peat, Marwick, Mitchell line capacity study (*4*). More recently in 2009, Dingler et al. (*5*) developed a parametric study of traffic heterogeneity by using the Berkeley Rail Traffic Controller simulation model. Also in 2009, Lai and Barken (*6*) updated the Peat, Marwick, Mitchell formulas.

Parametric analysis embodies general relationships reflecting the nature of line capacity and train delay. For example, a key finding of the Peat, Marwick, Mitchell study was that train delays actually increase when bi-directional signaling and power crossovers are added to a double-track line. This occurs because the added operational flexibility allows high-priority trains to overtake and pass low-priority trains. These overtakes cause more delay for the low-priority trains.

Although parametric approaches are valid in a general sense, they are only reflective of the line configurations for which the relationships were calibrated. As such they do not reflect the specifics of the local infrastructure and traffic conditions. In addition, the regression equations themselves are based on the "typical" conditions for which they were calibrated, which may not be reflective of the particular rail line or segment under consideration.

Finding: Parametric tools, while requiring minimal data, are not sufficiently robust for corridor screening assessment.

3.2.2 Optimization Approaches

Optimization has had two main applications. Some algorithms have been developed for direct application to real-world train dispatching problems, whereas others have been proposed for "office use" as embedded optimizers in simulation models. A key reason for incorporating optimization capability into simulation models is to improve the performance of the model's train dispatching algorithm. Kraft (*7*) noted that existing local optimization algorithms tend to bunch trains into fleets, whereas in validation comparisons it has been found that human dispatchers often try to maintain spacing between following trains. Once fleets have formed, local optimization algorithms do a poor job of efficiently meeting the fleets to minimize train delay. Human dispatchers minimize the complexity of their problems by minimizing bunching in the first place.

As a result, a case does exist for incorporating optimization into a simulation framework to more accurately replicate dispatcher behavior. However, the question persists: When is there too much optimization? For example, the RAILS2000 Web site (*8*) states that their model "is logic based, with optimizing capabilities deliberately restricted to emulate real-world limitations of train dispatching."

Two well-known models that incorporate optimization are the Schedule Analysis (SCAN) System developed at the University of Pennsylvania (*9*) and Sauder and Westerman's (*10*) optimization. Both were developed for real-time dispatch center applications. The early impetus for development of the SCAN System was in support of Burlington Northern's Advanced Rail Electronic System (ARES), an early Positive Train Control (PTC) project (*11*).

It is important that the Web-based screening tool assume realistic train dispatcher capabilities. To the degree that a simulation may incorporate limited (embedded) optimization, it could be appropriate for replicating train dispatcher behavior and improving the lock-up performance of the algorithm. The optimization should not be taken to such an extent that it exceeds human dispatch capabilities or computationally bogs down the algorithm and inhibits the ability of the user to get a quick response from the software.

Optimization approaches have had two primary applications: for improving train dispatching in a real-time setting and for more accurately replicating human train dispatcher behavior in a simulation modeling context. Some optimization programs have been deployed as "dispatching engines" inside commercially available simulation models. Their data requirements are essentially the same as those for simulation models.

The computational intensity of optimization can increase solution time and make the approach even less suitable for a screening application than a simulation approach would be. If the performance of the optimization exceeds that of a human dispatcher, the tool may not properly represent practical capabilities in a day-to-day operating environment.

As a screening tool, there is a serious risk that an optimization-based assessment could reduce train delay to the point that it underestimates infrastructure requirements. Although some optimization may be appropriate within a simulation mode, it should be used only for the purpose of replicating human dispatch capabilities, not exceeding them.

Finding: Optimization-based tools are overly complex for corridor screening. Issues relating to algorithm performance and efficiency, combined with the need to customize programming for each corridor, render tools of this type unsuitable.

3.2.3 Topological Approaches

This class of models attempts to directly assess the capacity of a rail line based on the concept of schedule "slots." The simplest representative of this class of model is the well-known equation for estimating the capacity of a single-track rail line:

$$C = 12/T \qquad \textbf{(Equation 3-1)}$$

where

C = the capacity of the line in trains per day, each direction
T = the running time of the single-track segment, in hours

It is easy to extend this capacity framework to develop tables of slot-based capacities for both single and multiple tracked rail line. Such tables have been used by U.S. freight railroads as the basis for their own corridor capacity screening. The AAR Study (*2*) implemented a nationwide screening assessment of U.S. rail capacity. As a national study, it employed a very broad and general approach to capacity assessment. Even so, the study pioneered some new methodological approaches that could still be applicable to the future development of a rail capacity screening methodology.

The AAR Study proposed a simple table-based methodology for screening freight capacity needs. In common with topological methods, the AAR Study used factorization to reduce capacity from maximum theoretical of 1.0 to a practical target value. The AAR Study adopted a throughput-oriented view of capacity that is consistent with a topological approach. Table 3-1 shows the proposed LOS grade definitions for rail lines and the associated ratios of volume to capacity. This research suggests that a practical capacity would be 70 percent of a rail line's maximum throughput capacity, or LOS Grade D.

To develop a line-specific measure of maximum throughput capacity for a U.S. freight rail application, Kraft (*12*) developed an approach for assessing the "jam capacity" of a single-track rail line. A simulation was used to measure the throughput capacity of a line in a fully saturated condition. Recently, European railroads have made very extensive use of topological methods. The International Union of Railways in UIC Code 406 (*13*) provides a detailed compression-based methodology for enabling infrastructure managers to carry out capacity calculations—following common definitions, criteria, and internationally accepted methodologies.

Under compression, starting with a simulated or actual time-distance diagram, all single train paths are pushed together up to the minimum theoretical headway according to their timetable order, without adding any buffer time. During the compression process, neither the running times nor the given overtakings, crossings, or station dwell times may be changed. For a corridor, the compression is sequentially done for each line section in turn, until all segments of the corridor have been scanned, and the most limiting section is found. UIC 406 compression is generalized for both single- and multiple-track lines. UIC methodology has been implemented in software packages such as the MOM system (*14-15*), which has been extensively used for assessment of European line capacity issues. In this regard, they provide similar functionality to the MWRRS Ideal Day approach because topological approaches identify locations where infrastructure needs to be added.

Topological methods are not evaluative because they do not establish the feasibility of operating a specific set of train schedules, as a simulation can. Topological methods are more oriented toward ensuring that the overall level of infrastructure is sufficient to meet the capacity needs without regard to specific train schedules. Topological methods show promise and can generate useful metrics. The software development required to implement this approach would be too costly to undertake in the Web-based tool as part of this project. However in the future, compression functionality could provide a useful add-on capability to the shared-use capacity screening tool.

Table 3-1. Volume-to-capacity ratios and level of service (LOS) grades.

LOS Grade	Description		Volume/Capacity Ratio
A	Below Capacity	Low to moderate train flows with capacity to accommodate maintenance and recover from incidents	0.0 to 0.2
B			0.2 to 0.4
C			0.4 to 0.7
D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.7 to 0.8
E	At Capacity	Very heavy train flow with very limited capacity to accommodate maintenance and recover from incidents	0.8 to 1.0
F	Above Capacity	Unstable flows; service breakdown conditions	> 1.00

Source: American Association of Railroads

Finding: The main advantage of topological approaches is their ability to identify directly the bottleneck section(s) of a rail line, pointing directly to the locations where infrastructure additions may be the most needed.

3.2.4 Analytical Approaches

Probability-based delay equations are a type of model that develops algebraic relationships from first principles that describe how trains interact as they move along a line. These models have been developed mostly for the case of opposing train interactions on single-track lines, although relationships can be developed for multiple-track systems as well, where overtakes are the primary cause of train interference. One of the best-known models of this class is the over-the-road delay model by Petersen (*16*). A survey of early analytical models was provided by Kraft in 1988 (*17*) comparing the results to topological, simulation, and optimization-based approaches. These early analytical models only measured average train delay and assumed a uniform distribution of train arrivals and departures throughout the day. Later models developed by Harker and Hong (*18*) and Hallowell (*19*) incorporated specific train schedule information for developing target arrival times needed by a particular optimization-based approach (*20*) and were tested in conjunction with that tool.

Like a parametric approach, analytical models estimate train delay and capacity using equations. However, analytic equations are derived from first principles based on probability theory, so they reflect direct cause-and-effect relationships. As a result, although analytical models do aid in understanding cause-and-effect relationships, it is difficult for simple models to adequately represent the full complexity of the railroad operating environment, especially as traffic volumes rise.

Analytic models such as probability-based delay equations can be customized to local conditions (e.g., the exact length and running time of each line segment), but the equations only reflect the specific kinds of train interactions for which they were developed. Most models are limited to one-on-one train interactions and are typically developed only for single-track or other simple configurations. Analytic equations work reasonably well for light traffic conditions, but as train volumes increase, there is a tendency for this class of model to underestimate train delay—sometimes by a significant margin.

For MWRRS conceptual and feasibility planning, TEMS developed the RightTrack™ system. RightTrack™ provides two methods for capacity assessment: a high-level Ideal Day assessment that is an analytical approach and a more detailed Typical Day assessment based on simulation. The Ideal Day Analysis (*21*) consists of a straightforward review of potential conflicts and train meets (i.e., locations) where trains would pass each other if adequate track capacity were available. By counting the number of locations where meets occur (other than at sidings) an estimate can be developed of the number of sidings that may need to be added to support passenger trains. This is an example of a straightforward analytical approach that can directly derive infrastructure requirements from a direct analysis of a time-distance diagram.

In its initial form, the methodology was based on an idealized time-distance diagram where trains run on a strict timetable. Analysts were given some leeway to manually consolidate conflict points that were close together. For example, if conflicts (identified visually as red balls) occurred within a few miles of one another or close to existing meet/pass infrastructure, these conflict points would be combined. (This is the origin of the "Conflict Threshold" parameter that appears at the bottom of the SU string line display.) Originally, this consolidation was done manually by an experienced analyst.

Finding: The approach of adding a siding wherever a conflict occurs is a reasonable first-cut assessment of infrastructure needs on light-density corridors.

The original method was limited to light-density corridors and needed an experienced analyst to combine close together conflict points. Both the density limitation and subjectivity of the consolidation process could limit the broader applicability of the methodology. However NCFRP Project 30 research has developed a new approach for broadening conflict identification's applicability. For each route segment, the new approach is to count the total number of conflicts and then divide by the number of passenger trains to calculate the average number of conflicts per passenger train.

As demonstrated by the case studies, this methodological enhancement enables extension of the methodology to high-density corridors. It also removes the subjective aspect of the former Ideal Day approach.

Finding: The proposed conflict identification methodology is both quantitative and rigorous and is applicable to all corridors regardless of density. The methodology does not require an experienced rail analyst, and it qualifies as an effective element in a corridor screening tool.

3.2.5 Simulation Approaches

Simulation models are well appreciated for their detail, openness, and visibility of results, as well as for their ability to readily incorporate detail, such as specific train dispatching rules, that would be very difficult to incorporate into an analytical or equations-based model. The ability to practically replicate real-world operations gives the simulation a great deal of credibility. Detailed outputs, including time-distance diagrams and animations, are used to explain results to rail managers and overcome "black box" concerns. Modern simulation models have very sophisticated and user-friendly graphics that both aid input of track and infrastructure data and—with visualization—ensure the network is properly constructed and interconnected. Contemporary simulation models also facilitate displaying, zooming, and scrolling time-distance diagrams and have sophisticated and high-quality animations.

These advantages have made simulation a preferred approach among many rail practitioners. Examples of simulation tools include Berkley's RTC (*22*), SYSTRA's RailSim (*23*), FRA's GTMS (*24*), TEMS' Miss-It™ (part of the RightTrack™ System) (*25*), CANAC's RAILS2000 (*26*), Canadian National's Route Capacity Model (*27*), ALK's Line Capacity Analysis System (*28*), and the Rail Sciences Model, which was subsequently repackaged as the Fast Track II module (*29*) of Oliver Wyman's Multi-Rail (*30*) rail planning suite.

Simulation methods are designed primarily as evaluation tools to verify the operational feasibility of any train operating plan and to assess the likelihood and locations of related train delays. Use of the tools can be demanding to ensure that current operations are adequately represented and validated to serve as a baseline for comparison. However, simulation provides key operational feasibility information even in the absence of an exhaustive level of detail.

Simulation models are evaluative tools because simulations can only assess the options that are given to them and cannot by themselves derive new solutions. Development of the solutions is normally left to experienced analysts with deep knowledge of rail operations. However, simulation methods can be augmented by other approaches, such as conflict identification or topological methods that have the ability to derive solutions.

In the more advanced phases of planning, detailed engineering studies along with extremely accurate simulations are required. These analyses include a level of detail of both the infrastructure and operating plan down to the level of individual switch and signal.

However, the goal of simulation in the screening phase is not to develop a painstaking replication of operations with the expectation that the railroad will concur with its findings. The purpose of simulation for screening is twofold: (1) to develop a reasonable baseline of operational conditions in the corridor that will support an understanding of key issues in the corridor and (2) to validate and test the operational feasibility of any solutions indicated by conflict identification or topological methods. A simulation in the project screening phase demonstrating that a solution is operationally feasible is a necessary (though not sufficient) condition that a solution is indeed feasible. Simulation analysis adds substantial credibility to an analysis. However, planners should recognize that railroad operations are complex, and simulation findings—like all preliminary analysis—may not withstand the scrutiny of more detailed analysis.

There are a number of concerns and caveats regarding simulation models. The performance of the dispatching algorithm is a concern with some models. Rail line simulation models are well known for their tendency to either "lock up" or produce results that do not reasonably reflect the performance of real-world dispatching systems. The results must be carefully inspected and monitored and sometimes "tweaked" by an analyst to get the model to perform adequately. All this effort to collect and check detailed input data along with careful analysis of the outputs (to ensure that the dispatching is advancing or holding trains appropriately) can be very expensive and time consuming. Working with the models can be a very labor-intensive effort requiring a skilled analyst.

However, these challenges increase with the complexity and density of the corridor under consideration. The concerns and caveats that apply to simulation apply equally to other methods when considering highly complex, densely trafficked corridors.

Simulation-based methodologies can be used to assess line capacity and train delay. The performance of the dispatching algorithm must be well understood and subject to limitations to ensure that it will function reliably (e.g., not lock up in daily use). It must be possible to quickly execute the model to obtain answers with a reasonable level of analyst effort, both for setting up data and for running the model. Finally, the model must be sensitive to the issue of statistical convergence and generate a large enough sample to satisfy usual and customary requirements for the statistical convergence of its output.

Finding: Simulation is the key validator of a screening assessment. The data requirements for a simulation are the same as those of the conflict identification methodology. Given robust train movement and dispatching algorithms, simulation provides essential information regarding operational feasibility, and, therefore, is a critical component of the screening assessment. This capability is provided as a core feature of the SU tool and has been demonstrated in the case studies.

3.3 Potential Relevance of Tools

The research team's review of tools and methodological approaches informed the assessment of their relevance to the proposed SU Web-based tool.

First, successful screening methodologies should include the following attributes:

- Be simple, easy to use, and responsive.
- Have statistically valid results, including a sensitivity assessment of the error margin induced by any defaults associated with missing data.
- Have manageable data requirements that are commonly available at early stages of project development.
- Enable development of a site-specific assessment that is particular to the corridor under consideration.
- Use an accepted methodology and be practical to implement under real-world operating conditions, within an acceptable error margin, for a screening analysis.

The research team also noted the following findings regarding relevance to a Web-based SU screening tool:

- Possible viable approaches include analytic, topological, and simulation-based tools.
  – Simulation is an evaluative approach that can assess the effectiveness of capacity solutions that have been defined for it. Simulation is, however, a very sophisticated and potentially expensive approach requiring the skills of an experienced analyst.
  – In conjunction with simulation, analytical or topological approaches could add an auxiliary capability for suggesting possible locations or quantities of added track needed to satisfy capacity requirements. These capabilities could be implemented into the Web-based screening tool as optional "wizards," time and budget permitting.
- In general, parametric tools, as well as analytic train delay models, have been excluded for further consideration because they do not have sufficiently site-specific analytic functionality.
- In general, optimization tools have been excluded because of their complexity and a concern that their dispatching logic may exceed real-world capabilities. This does not, however, exclude incorporating a limited optimization capability within the dispatch logic of a simulation model to emulate the look-ahead capabilities of a human dispatcher.

Of the 29 software tools and methodologies identified in Task 1, the team found the following 3 as most relevant:

- **GTMS**—Developed by DecisionTek for FRA to assess PTC safety plans. This software could be made available and adapted to the Web screening application.
- **RightTrack™**—Developed by TEMS, the software has been extensively used for operational assessment of capacity issues in the Midwest, Ohio, Florida, and elsewhere. It includes TRACKMAN™, a graphical infrastructure editor; LOCOMOTION™, a train performance calculator, and MISS-IT™, a detailed event-oriented train dispatch simulation. The software could be adapted for the Web-based screening application.
  – Ideal Day methodology (*31*), categorized as an analytic approach, was initially implemented using the RightTrack™ tools for MWRRS. It was applied in light-to-medium density shared-use corridors where baseline freight train delays are minimal. One advantage of this approach is its simplicity. Although not initially scalable to complex or high-density evaluations, this limitation has since been addressed.
- **UIC compression methodology**—Categorized as a topological approach, compression can identify infrastructure needs based on an assessment of theoretical and practical capacity within defined time windows. It also can provide an auxiliary slot-based capacity measure and delay-based measures.

3.4 Data Requirements and Gap Analysis

In Task 2, the researchers looked at the data requirements for the inventoried software and methods discussed in Task 1.

The research team noted that, in addition to the preliminary data that establishes a context for feasibility screening, the following three main types of data are needed for corridor capacity screening analyses:

- Infrastructure data;
- Traffic data, which is often difficult to obtain and includes forecast train movements (i.e., schedules) by type of train, trains, and their consists; and
- Cost information, which may be obtainable from published sources or can be developed in house or through consultants.

3.4.1 Preliminary Data

As noted, preliminary data establishes a context. It includes a general description of the corridor rail system, its entry and exit points, stations, and timetable routes available in the corridor. The best sources for preliminary contextual data are the railroad employee timetable document(s), which may be obtainable from the railroad.

3.4.2 Infrastructure/Rail Facility Data

Infrastructure data, also referred to as rail facility data, describes the corridor's physical facilities. This would include core infrastructure and its properties (i.e., track, switches, elevation points, heading points, speed zones), traffic control equipment (i.e., signal systems, interlocking and wayside equipment), and ancillary built features (i.e., bridges, tunnels, and grade crossings).

Although track charts can be useful data sources, they are often incomplete, out-of-date, or unreliable in other ways and hence insufficient for characterizing infrastructure. The more reliable alternatives are photogrammetric imagery, GIS databases, and field inspections. These have proven invaluable for collecting rail system infrastructure data.

The following data sources may be available from the railroads on request and should be sufficient to characterize the rail facility:

- Track survey data,
- Track charts, and
- Field inspections.

The following sources are publicly available and can be used to directly determine or infer a corridor's rail facility data in lieu of or supplementing the sources listed above:

- U.S.DOT FRA GIS 1:100000 Rail Network Database (source: BTS);
- Oak Ridge National Laboratory Center for Transportation Analysis Rail Network Database;
- U.S.DOT FRA Highway-Grade Crossing Database (source: Office of Safety Analysis); and
- Google Earth™ (used to cull and visualize the information provided by the databases above).

Track Survey Data

Track survey data, prepared by survey teams, describe the rail physical infrastructure including inventory and physical location of track and rail and traffic control facilities. Track survey data also include distances, elevations, headings, and exact boundaries of speed limits.

Track surveys are the best data source because they contain the precise measurements made by an on-the-ground survey team. Unfortunately, most of the existing track in the United States has not been surveyed recently, if at all. Track surveys are expensive to conduct and the railroads typically undertake them in advance of major improvement planning.

With a recent track survey in hand, there would be little need for additional validation of rail facility data. If such a survey exists and the railroads are willing to provide the survey data, then the track survey data should be sufficient to conduct the analysis.

Track Charts

In theory, all the infrastructure attributes needed for a screening-level capacity analysis could be identified from a high-quality railroad track chart and employee timetables. In practice, however, track charts have some practical limitations. Consequently, it has been found more effective to couple the use of track charts with other sources—particularly field surveys and photogrammetry—to confirm the track chart data accuracy or to bring it up to date.

In the experience of the research team, track chart data is highly variable in its quality. Some track charts are highly accurate; others are not. Because the methods for producing track charts have changed so much over the years, it is difficult to generalize about track chart data accuracy.

In the past and before modern computer methods, track charts were typically compiled from field notes of local engineering personnel. Older track charts were drawn by hand and generally showed curves, grades, and track configuration. Beyond this, the data elements were highly variable with regard to bridges, culverts, grade crossings, speed limits, crossings of other railroads, and other physical features of the line. Some old charts are not only inaccurate, but very hard to read because of manual preparation. A common problem with track charts is that the distance between mileposts is not exactly 1 mile. Also, there are often significant deviations that are not indicated on the charts. These issues can be resolved using satellite photogrammetry and GIS data, to establish the exact length of each line segment and how different segments join one to another.

Old charts, however, can be useful as a practical matter to indicate the existence of former rail facilities that may not be in place any longer. For example, a line may have had a double track in the past. Because the track bed is usually still intact, the old track bed could be reused. This would reduce the cost of adding capacity to the line.

Thus, it is often helpful to have multiple generations of old and new charts available for the same line segment. Newer charts are not necessarily more accurate than old charts. Discrepancies between charts can be resolved by current satellite photogrammetry and field verification.

Field Inspection

A field inspection of corridor infrastructure is an essential component of the data collection process. For the purpose of a concept or feasibility-level assessment, a field inspection consists of limited site verification from publicly accessible locations. In such an inspection, the field inspection team would observe a sample of critical locations along the track from public crossings, bridges, and stations. Typical field observations are conducted at, or from, highway/railroad crossings, overpasses, and parallel roadways. At each location, engineering notes are compiled and the physical track conditions compared to the latest track charts and to any other information that may have been provided by the railroads. These inspections focus on the condition of the track and its ability to handle joint freight and passenger train operations. The railroad right-of-way needs to be examined as well for its ability to accommodate additional tracks for added capacity. Where possible, other existing facilities are observed, including bridge conditions, vertical/horizontal clearances, passenger train facilities, railroad yards, and terminal operations. Photographic records should be made at many locations.

Use of Other Sources

A data collection process composed of a corridor infrastructure field inspection and the associated track charts can partially fulfill the rail facility data needs listed above. Track charts and field inspections provide a general description of a corridor system that includes track positions and stations.

This method of data collection does not provide sufficient detail to determine system entry and exit points or timetable routes.

To fulfill the preliminary data requirements listed above, the data collection process discussed in this section will have to supplement other sources of rail infrastructure data. This can be accomplished by augmenting track charts and field inspections using satellite photography and GIS data, which is described at length in the following sections.

FRA GIS 1:100000 database. The U.S.DOT FRA GIS 1:100000 Rail Network (FRARN) from BTS is a geographically based representation of the North American railroad network. It was designed and is continuously updated by BTS to support analytic transportation studies. The North American rail system is represented in FRARN as a standard link-node network, and the data is stored in multiple GIS shape files.

FRARN contains data for all track segments and their characteristics, such as length, ownership, and the subdivision to which the track belongs. The database does not include the milepost range, but often this can be cross-referenced from other sources, notably the FRA Grade Crossing Database.

Oak ridge national rail network database. The Oak Ridge National Laboratory (ORNL) Center for Transportation Rail Network database is a geographically based representation of the North American railroad network, based on the U.S.DOT FRA GIS 1:100000 Rail Network (FRARN). It was designed and is continuously updated by ORNL's Center for Transportation to support analytic transportation studies. The data is stored in multiple GIS shape files.

The ORNL network is derived from the FRARN database and boasts a reduced, more simplified set of rail network data. FRARN includes more detail in its description of industrial spurs, yard connections, and sidetracks, but this data is often unused, and its presence complicates the process of identifying mainline track segments. Consequently, it has been found that the ORNL network is a more appropriate database for profiling a corridor's infrastructure. The 2007 CS Study (*32*) used the ORNL network (Version 5-5) to develop its primary corridor network model.

FRA national grade crossing inventory. The U.S.DOT FRA Highway-Grade Crossing Database, available from the Office of Safety Analysis, was established for the purpose of making railroad safety information readily available for analytic transportation studies. The database provides geographic, infrastructure, and traffic information for all highway-grade crossings in the United States. This information can be used in conjunction with the FRARN and ORNL databases to map track segments and switches to railroad, division, subdivision, and milepost information.

Google Earth™ visualization. The FRARN and ORNL databases contain shape files that describe the geometric and geographic properties of track segments. These shape files can be transformed into KML files (*33*) and imported into Google Earth™ where they can be superimposed onto the appropriate aerial photography. This visualization tool cross-references multiple sources of information by simultaneously overlaying different KML files.

Finding: Table 3-2 summarizes the availability of infrastructure data and their sources.

Because existing infrastructure is usually clearly visible in Google Earth™ satellite imagery, this can be considered a primary source of existing infrastructure data. Often current track charts are publicly available or available on request from the freight railroad.

3.4.3 Traffic Data

The required traffic data is divided into two types: train schedule data and train consist data. Train scheduling data is proprietary information and is regarded as commercially sensitive to railroads, but schedules can be inferred using several publicly available sources. Train consist data, which in some cases also is kept private, can be developed through such techniques as direct observation at public grade crossings.

Train Schedules

Train schedules are an essential component for a capacity analysis because they provide information about traffic volume and the mix of freight and passenger trains. Passenger train schedules are publicly available and easy to obtain. Freight train schedules, however, are not easy to obtain because they are usually proprietary due to their commercially sensitive nature. Freight train schedules can be determined or inferred through some publicly available databases.

Train volume. The only public source for train volume, hour-of-day train operations data, is the FRA Grade Crossing Database. This database can be used to establish the relative proportion of daytime/nighttime operations, but it cannot be used to determine the traffic mix. The Grade Crossing Database reports timing in 12-hour windows and provides other useful information, such as freight train count data by location. Simulated train departures could be randomly generated or "seeded" in a screening model using train volume counts operating within predefined time windows. Train departures could be randomly generated across all train types within 12-hour windows, to reflect the relative distribution of daytime and nighttime operations.

Data on the timing of train operations, train volumes, train makeup, and traffic mix also could be collected by trackside

Table 3-2. Data requirements and potential sources.

<table>
<tr><th>Data Category</th><th>Data Required</th><th>Potential Sources</th></tr>
<tr><td rowspan="4">Preliminary</td><td>General description of the corridor rail system</td><td rowspan="14">• Subdivision Time Tables (obtainable with permission from the railroads)
• Track Charts
• Field Inspection Reports
• U.S.DOT FRA GIS 1:100000 Rail Network Database (BTS)
• Oak Ridge National Laboratory Center for Transportation Analysis Rail Network Database
• U.S.DOT FRA Highway-Grade Crossing Database (Office of Safety Analysis)
• Google Earth™ Visualization</td></tr>
<tr><td>System entry and exit points</td></tr>
<tr><td>Stations</td></tr>
<tr><td>Timetable routes</td></tr>
<tr><td rowspan="5">Infrastructure or Core Rail Facility</td><td>Track (segments)</td></tr>
<tr><td>Switches</td></tr>
<tr><td>Elevation Points</td></tr>
<tr><td>Heading Points</td></tr>
<tr><td>Speed Zones</td></tr>
<tr><td rowspan="2">Traffic</td><td>Signal systems</td></tr>
<tr><td>Interlocking and wayside equipment</td></tr>
<tr><td rowspan="3">Ancillary</td><td>Bridges, tunnels, and other structures</td></tr>
<tr><td>Yards</td></tr>
<tr><td>Grade crossings</td></tr>
</table>

survey and used to supplement the traffic volume data from the FRA Grade Crossing Database.

Traffic mix. Traffic mix can be inferred using the two following publicly available sources:

- U.S.DOT Surface Transportation Board's (STB) Carload Waybill Sample, and
- U.S.DOT STB's Uniform Rail Costing System.

The STB Carload Waybill Sample can be used to estimate current corridor volumes based on loaded car movements. Data from the STB Uniform Rail Costing System (URCS) is used to estimate empty car movements. The 2007 CS Study (*34*) determined traffic data using the STB's 2005 Carload Waybill Sample and URCS. Access to the data is restricted and governed by STB procedures (*35*), but state DOTs are authorized requestors for use in state rail planning and other public planning purposes (*36*).

Train Consist Inventory Data

The Web-based tool facilitates the process of building trains by providing an inventory of locomotives, cars, and car types. This data is categorized as equipment specification and equipment classification.

Equipment specification. Equipment specifications can be found on manufacturers' Web sites, third-party Web sites, and railfan sites. The following sources include technical bulletins and general specifications for locomotives and cars:

- PCC Logistics Rail Cars Specifications: http://www.pcclogistics.com/specs/rail.html
- World Trade Ref Guide to Railcars: http://www.worldtraderef.com/WTR_site/Rail_Cars/Guide_to_Rail_Cars.asp
- Locomotive Specifications (railfan site): http://www.geocities.ws/guilford_350/index-2.html

Equipment classification. The inventory of cars provided by the Web-based tool will be classified by type using the car type codes developed by the Association of American Railroads (AAR). Each car code consists of a letter followed by three numbers. The letter identifies the general equipment or trailer/container type and the numbers provide specifics about the size, capacity, and other features of the car. The numeric coding changes according to the equipment type. The codes are explained in the AAR section in the back of the Official Railway Equipment Register, which later became part of the UMLER Data Specification Manual. See Table 3-3 for a sample of railroad car types.

Finding: Table 3-4 summarizes the availability of traffic data and sources.

Generally, traffic data can be derived from the FRA National Grade Crossing Inventory (caveat: some data may be outdated) and/or from direct field observations of trains moving past highway-grade crossings. Sometimes the needed data has already been captured by a state rail planning effort or a

Table 3-3. Sample railroad car types.

Car Type ID	AAR Car Type Code	Car Type Description
1	A405	50-foot box car, equipped, cushioned, 10' plug door
2	A603	60-foot box car, equipped, cushioned, sliding door(s), opening 11' +
23	H351	Hopper, unequipped, three+ hoppers, single rotary coupler, 185,000 lbs+ load limit
26	K342	Hopper, equipped, double rotary coupler, 185,000 lbs. load limit+
10	C112	Covered hopper, 3,000-3,999 cubic foot, gravity outlet
11	C114	Covered hopper, 5,000 cubic foot+, gravity outlets
24	J311	Coal gondola

Source: http://eaneubauer.ipower.com/type.pdf

cooperative freight railroad might be willing to supply the needed traffic data on request.

3.4.4 Infrastructure Costs

Experience indicates that it is highly likely that additional infrastructure or upgrades will be required to accommodate the needs of both freight and passenger operations. Although the capacity screening tool will focus mainly on identifying the need for physical infrastructure improvements, ultimately there will be a need to develop cost estimates both for freight railroad negotiations and budgeting/planning purposes.

Often, very preliminary estimates can be developed by benchmarking costs against other projects. However, once a list of specific improvements is developed, then a unit-costing approach is a more accurate and customary method. In initial feasibility-level planning, infrastructure costs are developed using broad categories of costs with large contingency factors. As the planning progresses and further detail is developed, these costs are further refined.

Feasibility-level infrastructure unit costs are appropriate for developing preliminary cost assessments. Such baseline costs are available from many published rail feasibility studies. One example is the Rocky Mountain Rail Authority (RMRA) High-Speed Rail Feasibility Study (*37*). Appendix E of that study gives a detailed listing of the unit costs employed and shows how they were applied in cost estimation. The RMRA study also included 28 percent for "soft costs" and an additional 30 percent as a contingency factor. Similar cost information for intercity and commuter rail systems is available from other studies and analyses.

The key to the accuracy of a unit-costing approach is to ensure that the cost database appropriately reflects the local market costs for the key inputs (i.e., labor, materials, and equipment). A means for keeping the cost database up to date and regionalizing the factors will be a key requirement for development of any future costing functionality that may be created as an adjunct to the capacity screening tool. Appendix F of the RMRA study explains how this can be done using the Producer Price Index (PPI) and *Engineering News Record* (ENR) indices.

Table 3-4. Traffic data requirements and sources.

Traffic Data	Data Required	Source
Train Schedules	Train Volume	• U.S.DOT FRA Highway-Grade Crossing Database from the Office of Safety Analysis • U.S.DOT STB Carload Waybill Sample • U.S.DOT Surface Transportation Board's Uniform Rail Costing System
	Traffic Mix	
Train Consist Data	Equipment Specification	• http://www.pcclogistics.com/specs/rail.html • http://www.worldtraderef.com/WTR_site/Rail_Cars/Guide_to_Rail_Cars.asp
	Equipment Classification	• http://eaneubauer.ipower.com/type.pdf

Finding: Unit cost data is available from other studies, but will require adjustments for inflation and regional conditions.

3.5 Case Studies: Corridor Selection and Key Findings

For evaluating the SU tool developed with this project, the research team proposed five potential shared-use corridors, each with different levels of commuter, intercity, and freight traffic. The NCFRP Project 30 Panel asked that

- The proposed corridors reflect a mixture of low-volume and high-volume, commuter and intercity passenger rail corridors;
- There be data available to validate the study findings; and
- The case studies provide a sound basis for demonstrating the SU tool capabilities.

The five proposed case study corridors included the features listed above. Moreover, each corridor exhibited unique features that demonstrated the capabilities of the SU tool. These corridors typified examples of specific passenger and freight integration challenges likely to occur elsewhere as shared-use operations expand throughout the United States. The proposed Northeast Corridor case study also dealt with high-speed rail integration. In all, the five proposed case studies covered the full range of opportunities for passenger rail development—from commuter rail through 110-mph comingled systems. Table 3-5 presents the five corridors proposed for consideration.

From these five, three corridors were selected for further detailed study. The selected corridors displayed a tendency toward higher density corridors that would "stress test" the conflict identification functionality of the SU tool. Consequently, the three corridors selected (Numbers 2, 4, and 5) are among the busiest rail corridors in the United States, and they all include highly complex train operations over predominately multiple-track territory.

While the selected case study corridors did "stress test" the SU tool and its computer algorithms and methodologies, the level of complexity that state DOT users would encounter is likely to be much less. For example, the proposed Midwest Regional Rail System (MWRRS) consists of nine light-traffic corridors and three heavy-traffic corridors. Two of the heaviest trafficked corridors (Chicago-Milwaukee and St. Louis-Kansas City) were selected for case studies, but none of the nine lighter density corridors. The lighter density routes are actually more typical.

The selection of only high-volume corridors posed a challenge. The three selected case study corridors were extremely complex simulations and as such, are not ideal "demo" corridors for state DOT planners to learn how to use the tool. It was necessary for the research team to develop new approaches to extend the range of conflict identification functionality so it would be effective on both low- and high-volume corridors.

The three NCFRP Project 30 case studies extend the methodology for application to high-volume corridors. These three case studies are detailed in the Task 8 reports and are summarized in the following sections in this chapter.

3.5.1 Overview of Proposed Screening Methodology

The SU tool is designed for preliminary screening of proposed projects that introduce new passenger service to existing freight or shared-use corridors. The tool is intended to be used very early in the planning process where it offers a rigorous, systematic approach for establishing a framework or starting point from which more detailed discussions and analyses can follow. The methodology is consistent with

Table 3-5. Five corridors proposed as case studies.

		Passenger Service		
	Freight Traffic	Commuter	Intercity	Wild Card
Freight Traffic	Low Volume	1. SunRail: Orlando Commuter Rail (implementation; Double Track, Freight Curfews)	3. Chicago to Detroit (Implementation; Single Track and Multiple Track)	5. Amtrak Northeast Corridor: Baltimore to Wilmington (Freight Tracks in Concept Planning; Intercity and Commuter Rail, Multiple Track, Dedicated Track, Freight Curfews)
	Moderate to High Volume	2, Chicago to Milwaukee (in Service; includes both Commuter and Intercity, Multiple Track)	4. Kansas City to St. Louis (Concept Planning; Single and Multiple Track, Directional Running)	

the requirements of the FRA *Guidance Manual* (*1*) and the analysis is limited by the level of data that is either publicly available or that can be obtained by state DOTs for screening capacity needs.

Figure 3-1 illustrates the SU tool workflows as follows:

- Step 1 (the "do nothing" baseline) uses the SU simulator to establish a base level of freight train delay reflecting current conditions before any additional passenger service is introduced. If there is an existing passenger service, that should be included in the simulation of the base line operation.
- Steps 2 and 3 add passenger trains to the existing infrastructure. The assessment is based on the proposed new passenger schedules, operating with freight trains over the existing infrastructure. The conflict identifier "red ball/green ball" display is used in these steps to identify the level of added infrastructure that may need to be added to the corridor.

Although the conflict identifier can assess likely infrastructure quantities (e.g., miles of track needed) and approximate cost, it cannot determine the specific infrastructure locations. This is because changing the train schedules will shift the locations of the meets and passes that occur along the line, so the sidings would be recommended in different places depending on the schedules. A more detailed engineering-based assessment is needed to do this. However, some rules of thumb can provide general guidelines as to where infrastructure should be placed, so the design will not be too closely linked to one specific train schedule—rather, per FRA guidance, the infrastructure layout should be flexibly designed for robust performance under a wide range of operating conditions. The use of these rules of thumb helps accomplish this.

- Step 4 adds the recommended infrastructure along with passenger trains and runs the simulator module a second

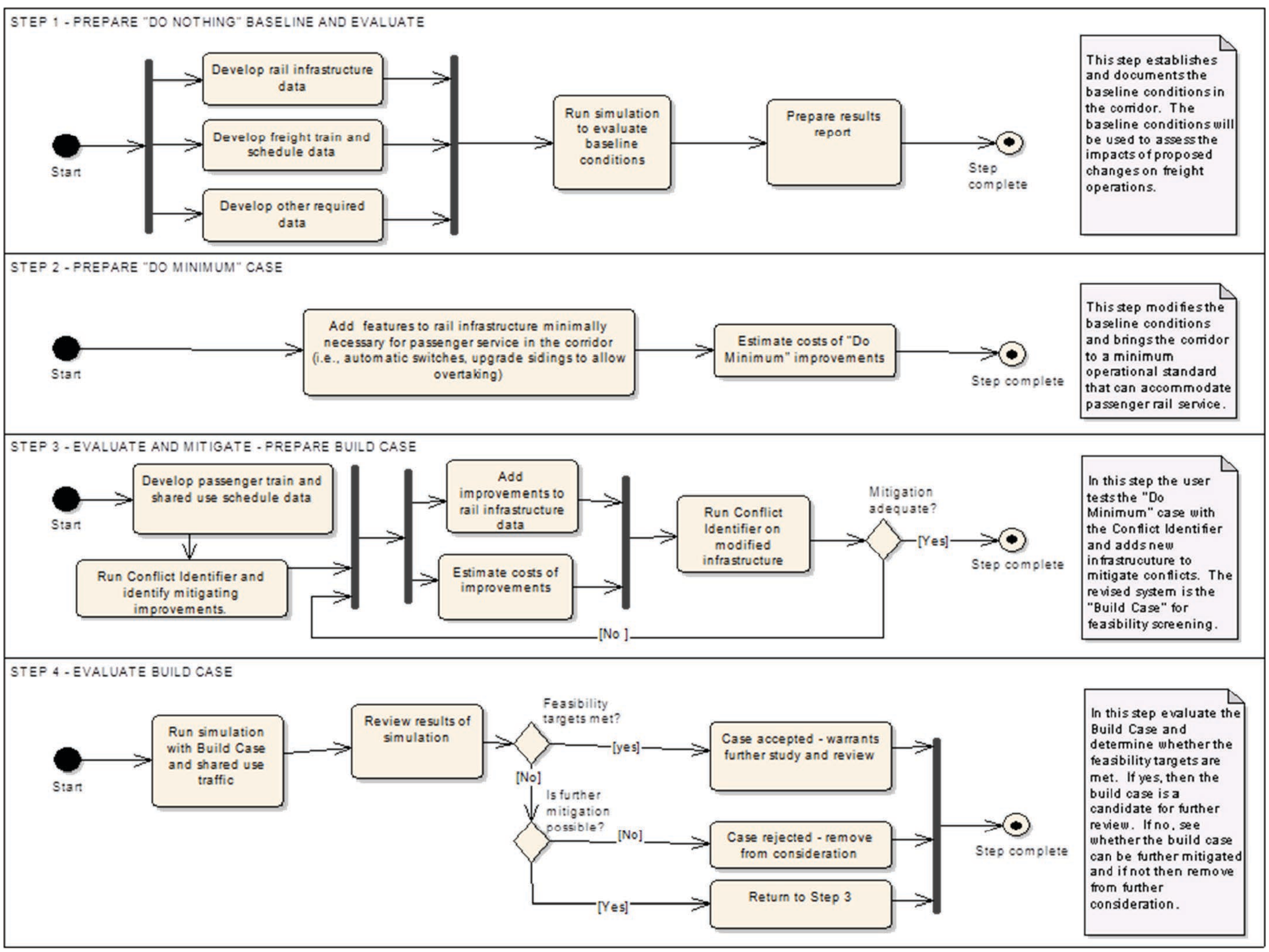


Figure 3-1. SU tool workflows.

time. The simulator needs to test a specific infrastructure plan to see whether freight train delays have increased or decreased from baseline levels and to ensure that delays remain at acceptable levels. If the simulation shows that the proposed level of infrastructure is inadequate, then the capacity plan must be further refined until the simulations show that train operations are fluid and that proposed investments are reasonably utilized. Steps 1 and 4 are optional enhancements to the basic screening methodology, which is actually implemented by the conflict identifier Steps 2 and 3.

An important distinction is that of a pro forma versus a detailed operational schedule. A pro forma train schedule is only an input for developing the infrastructure plan and reflects an idealized aspiration for the service. In particular, a pro forma schedule developed before the infrastructure has been laid out cannot reflect actual train meeting locations. Pro forma schedules provide a starting point for development of an infrastructure plan, but after the infrastructure plans are detailed, the schedules need to be fine-tuned to ensure that meets are occurring in the sidings and double track that have been provided. However, schedule finalization typically does not occur until well into the feasibility-level planning process. Finalized train schedules are typically not available at the time of a preliminary screening analysis.

Also, it is important to understand the role of simulation in the overall process, given the very early stage of project development associated with a typical screening-level analysis. Advancing the infrastructure design and pro forma schedules beyond the conceptual level requires more refined data. Although the SU modeling tools are potentially capable of more refined analysis given better data, this data is not typically available at the time of a preliminary screening.

As a result, it is important to understand that a positive screening analysis does not prove that any specific track design or operating schedule will work. Rather, it indicates that further study may be warranted, which could lead to the acceptance of the proposal, or a variant of it, by the concerned stakeholders (e.g., the new passenger service proponent, the freight railroad and any involved government or regulatory authority). The reason is that any simulations performed in either Steps 1 or 4 are based on limited data, and they may fail to capture the full complexity of real-world operations. Due to the data limitation in the screening phase, feasibility metrics generated by the analysis cannot be considered sufficiently reliable for basing final decisions. Steps 1 and 4 are clearly optional and need be undertaken only if the user has sufficient confidence in the data to warrant the extra effort.

Thus, the Step 4 screening analysis only validates the conflict identifier's suggestion of overall infrastructure quantities as reasonable under assumed conditions. For a screening-level analysis, the simulation is not essential. At that level, it functions only as a qualitative cross-check on the infrastructure being recommended by the conflict identifier functionality. That is, after adding the recommended infrastructure, a visual review of the string-line diagrams should show that capacity is sufficient to support the required rail operations without undue delay of trains.

3.5.2 Rules of Thumb for Laying Out Infrastructure

The use of the simulator (Steps 1 and 4) supports the screening process as a demonstration that capacity may be sufficient. A simplified conflict identifier methodology provides a structured analysis process that employs a level of data that is generally available to the public.

Nonetheless, if it is desired to use the simulator in Step 4, the analyst is required to develop a specific infrastructure layout for evaluation in the simulation tool. Because the tool itself does not say exactly where the infrastructure should be added, it is left up to the analyst to determine this. That is where rules of thumb come in, because there is no single optimal design strategy that can be applied across the board. Rather, the design must be tailored to meet the operating requirements of the specific service(s) being envisioned. If a line is being laid out to accommodate multiple shared-use services, the design often must reflect a compromise between the competing needs of the different kinds of service that will be operated. As such, a line that is intended predominately for passenger use may be laid out differently than one designed for freight or heavy mixed traffic. For example, fast passenger trains may need longer passing sidings but due to their higher speed, could tolerate a greater distance between sidings; slower freight and commuter trains need shorter, more closely spaced sidings.

In general, it is a good idea to space meet and pass infrastructure as uniformly as possible along the line rather than locating it based on any one particular train schedule. Spacing sidings evenly maximizes the capacity of the line and minimizes the design headways for passenger service while affording maximum schedule and operational flexibility. It results in a robust infrastructure design per the FRA *Guidance Manual* (*1*). For laying out the track, the following is recommended:

- The spacing and number of the sidings depend on the anticipated passenger service frequency, minimum peak-hour headway requirements, and forecasted freight traffic volumes. The number of sidings is suggested by the conflict identification analysis.
- A good rule of thumb is to space the meet/pass locations as evenly as possible given the locations of existing double track and proposed stations.

- A determination of how long to make the sidings needs to be made as follows:
  - If trains **are not expected** to run precisely on time, then exact meet/pass locations cannot be precisely determined in advance. For example, because the departure time variability of freight trains often exceeds the running time between sidings, this probabilistic approach is often followed in laying out freight infrastructure (*38*). Expected delay times are minimized by spreading out the double-track mileage along the corridor, locating short passing sidings at frequent intervals. A good prototype based on an existing passenger service is New Jersey Transit's Atlantic City rail line or, for a proposed service, the SEHSR plan.

    The Atlantic City line (*39*) operates 14 round trips per day at up to 79 mph with diesel trains, on a single-tracked line. It has 4,500-foot-long passing sidings at approximately 10-mile spacing or about 10 percent double-track mileage. These sidings are long enough to support moving passenger train meets at a reduced speed of 10–15 mph.

    The proposed SEHSR corridor (*40*) has suggested sidings of 3.5–4.0 miles long, with 11 miles of single track between them or about 26 percent double track. Turnouts giving access to and from sidings would allow for 45 mph passenger speeds (40 mph for freight) and sidings would have intermediate signals, so they could function as short double-tracked sections. These sidings would be long enough to allow moving passenger train meets at a reduced speed of 25–30 mph, but not high-speed meets between passenger trains.
  - If however passenger trains **are expected** to run on time with only a few minutes of variance, then a good case can be made for building longer passing sidings or double-track sections to permit moving meets between passenger trains. Practical experience shows that these double-track sections must be a minimum of 10 miles long or include a station stop. A good prototype based on an existing service is the West of England Main Line, operated by South West Trains as Wessex Route 4.

    Wessex Route 4 (*41*) operates 14 round trips per day as an hourly clock face service from Exeter to London Waterloo station. The line is single-tracked for 25 miles from Salisbury to Templecombe; there is an 11-mile double-track section from Templecombe to Yeovil Junction. From Yeovil Junction to Exeter there is a 46-mile single-track section with a short station siding in the middle at Axminster that facilitates half-hourly peak headways.

Key assumptions in passenger service planning are that the passenger trains will run on time and that sufficient capacity mitigation will be provided to the freight railroads to make this possible. Thus, it can be seen that providing adequate capacity mitigation is in the interest of both the freight and passenger services. Therefore, the MWRRS (*42*) adopted a design standard of a 10-mile-long double-track section every 50 miles. For 110 mph operation, a 50-mile siding spacing is sufficient to support hourly clockwise schedule headways. Based on a schedule tolerance of a few minutes for each passenger train, a 10-mile length of double track is sufficient to allow for "running" train meets without any time loss to either passenger train. Passing sidings shorter than 10 miles are not long enough to permit full-speed moving meets and they may not benefit from installation of high-speed turnouts at each end. As a result, each passenger train meet loses 3–10 minutes on the timetable if the sidings are not long enough. Building fewer, longer sidings also reduces the cost of signal and control infrastructure.

This design is also good for freight trains because it allows the long freight trains to clear the main track quickly at 30–45 mph, rather than having to slow down to pull into a short siding. This reduces the probability that a passenger train will be delayed by a freight train ahead by reducing freight train clearance times, which can allow tighter headways. This design rule of thumb was used in developing the proposed infrastructure layout for the St. Louis to Kansas City corridor and was also suggested for reconfiguring the freight sidings between Truesdell and Milwaukee, by providing a single, long siding rather than three short freight passing sidings.

3.5.3 Methodological Approach to Conflict Identification

The conflict identifier implements an enhanced version of the Ideal Day. The approach consists of a simple review of potential conflicts and locations where trains would pass each other if adequate infrastructure were available. By counting the number of identified conflicts (other than within existing sidings or double track) an estimate can be made of the required number of additional passing locations that need to be added to a corridor. Although previously applied to single-tracked low-density lines, the SU tool has been used to develop multiple-tracked high-density applications as well.

In the SU system, the conflict identifier tool helps **develop** infrastructure plans whereas the simulator is used to **evaluate** infrastructure plans to ensure that the results satisfy design criteria. As such, the two approaches complement rather than compete with one another. As shown in Figure 3-1, both SU methodologies are used together in a four-step process.

- The simulator is used in Steps 1 and 4, and
- The conflict identifier is primarily used in Steps 2 and 3.

As a result, it should be clear that the conflict identifier approach has been developed into an evolved methodology for suggesting the level of capacity that needs to be added to a shared-use corridor. The range of application has been extended well beyond the light-density, single-tracked lines to which Ideal Day methodology was originally applied. The three case studies demonstrate successful application of the tool to some of the densest and most complex rail corridors in the United States.

The SU conflict identifier is built on the base of the SU simulator. The conflict identifier uses SU simulator logic, with train capacity constraints disabled. The central dispatcher routes the trains through the rail network (along preferred routes) as if each train were the only one operating on the rail system. It is essential that routing preferences be set up correctly so they do not send all of the trains down the same track rather than using existing parallel tracks. The "Nodes" table is programmatically generated but it can be edited manually to modify these track routing preferences, if necessary. Although not subject to delays from any other trains, trains are still subject to all the grades, curves, and speed limits associated with each link. The SU simulator uses a built-in Train Performance calculator to calculate the time, speed, and position of each train along its route.

The SU conflict identifier methodology is largely based on, but not identical to, the earlier 2004 Ideal Day methodology, but the SU conflict identifier uses more restrictive logic. In the SU conflict identifier, if trains get within 500 feet of one another on the same track, the conflict identifier will flag a conflict. For each conflict, the SU conflict identifier then uses a proximity parameter (that can be modified by the user, with a default of 2 miles) to determine whether to color the ball red or green as follows:

- Any conflict occurring within the conflict threshold (e.g., 2 miles) of a passing siding or crossover switch will be colored green.
- Otherwise, if the distance to the nearest meet/pass infrastructure exceeds the conflict threshold, then the ball is colored red.
- However, the Ideal Day methodology does not include a proximity parameter. For either of these cases it would generate a red ball.
- If trains' preferred routes cause them to meet or pass on **different** tracks, then the SU conflict identifier will not identify any conflict, and no balls will be generated. In this situation, the Ideal Day methodology would have generated a green ball.

As a result, the SU methodology for coloring balls does not guarantee the **availability** of nearby meet/pass infrastructure, but only indicates the **proximity** of such infrastructure. A possible methodological enhancement would be to scan parallel tracks to see whether they are actually being used. If the parallel infrastructure were found to be conflicted, then some of the green balls may actually be determined to be red balls. As a result, treating all of the balls identified by the SU conflict identifier as if they were red balls (regardless of how they are colored) gives the most conservative treatment, and is the recommended approach.

3.5.4 Approach to Model Validation

The primary purpose of the SU screening tool is to estimate the level of infrastructure that would need to be added to a rail corridor to support a state DOT decision on whether to continue with a proposed passenger rail project. Methodologically, this level of infrastructure need is estimated directly by the conflict identifier, without recourse to train delay statistics or any other surrogate measures of capacity.

Hence, the validation approach here is based on results—to what degree do the conflict identifier recommendations either agree or disagree with the overall capacity plans that were developed by earlier, much more detailed, simulation studies? As a result, the capacity recommendation of the conflict identifier was directly compared with the level of infrastructure that was recommended by the earlier detailed simulation studies.

This was done for two of the three case studies: St. Louis to Kansas City and Chicago to Milwaukee, for which detailed simulation benchmarks and capacity plans were available from the 2004 MWRRS work.

For the St. Louis to Kansas City and Chicago to Milwaukee case studies, additional, more recent simulation benchmarks were also available—but these studies focused on much smaller, incremental changes to the corridor track layouts that were assessed by an extremely detailed RTC-style simulation. These studies recommended changes, like adding crossovers, based on an analysis of localized constraints that require detailed railroad operating data to adequately assess.

As a result, the broader-scoped 2004 proposals for adding larger numbers of passenger trains to corridors were actually more appropriate applications of the tool and were used as the basis of the scenarios and validations performed here. The results show that the SU screening approach performs very well for this type of assessment.

3.6 Case Study Analyses Results

This section summarizes the results of the three case studies undertaken.

3.6.1 Case Study 1: St. Louis to Kansas City

The 2004 MWRRS simulation defines the base line against which the results of the SU tool have been validated. The infrastructure and train databases, therefore, closely follow the structure of the earlier assessment, in order to develop a consistent comparison.

- For the infrastructure database, the data files that were used as the basis of the original St. Louis to Kansas City corridor assessment were reformatted as required by the SU tool. The base case infrastructure was upgraded to include the recently double-tracked Gasconade River Bridge and the California siding extension.
- For the traffic database, freight and passenger trains reflect the current operating pattern (eastbound loads via the river, empties returned via the Sedalia Line) with 2 Amtrak trains and 19 freight trains in each direction. A single daily freight train pair terminates at the Labadie Power plant with the balance continuing east to St. Louis. In addition, two pairs of freight trains operate each day between Kansas City and the MNA connection at Pleasant Hill. This is consistent with the train counts extracted from the FRA grade crossing database.

The scenarios to be assessed here derive from the 2004 study. These scenarios develop the infrastructure needed to introduce an all-day corridor service—six daily round trips using tilting high-speed trains—to replace Amtrak's current two conventional round trips.

As a result of this more aggressive scenario, the infrastructure needs are much greater than those that were found by Missouri's 2007 assessment, which developed only incremental upgrades aimed at short-term improvements. The 2004 plan and this case study do not contradict the results of the 2007 assessment. It is just that the corridor investment needs are much greater for the significant upgrade that was envisioned by the 2004 plan, as compared to simply making incremental upgrades to the existing Amtrak service. At Union Pacific's request, the 2004 assessment used RTC to perform the simulation. However, due to the high volume of forecast freight traffic, the 2004 assessment reported that the RTC model could not handle the forecasted 2020 traffic on current infrastructure. This is based on the MWRRS Project Notebook (page 6-87):

> Union Pacific also requested that a freight-only base case be developed. This request was also accommodated. If freight traffic doubles without adding infrastructure, the performance of the system by 2020 will be very weak. Without investment, it will not even be possible to continue operating Amtrak trains on any acceptable schedule. **The RTC simulation locked up when a 2020 do nothing simulation was attempted, keeping the Amtrak trains on the tracks.** Accordingly, the Amtrak trains were removed from the simulation and a 2020 do nothing scenario was developed without Amtrak trains, which allowed the RTC simulation to run successfully. . . . **Even with new infrastructure added, the RTC model took 4 days to complete one 30-day simulation at 2020 volumes.** The size and complexity of this analysis creates a challenge for the timely completion of computer simulation runs. At 2020 traffic volumes, the simulation performs adequately only if the full packages of proposed infrastructure investments are included. With any fewer investments, the simulation bogs down and often terminates short of completion. This reflects the physical reality of conducting complex, high-volume rail operations. However, to obtain comparative delay statistics, there is often still a desire to obtain a completed simulation of a hypothetical "do nothing" alternative. Because of this difficulty in getting the RTC model to run with less than full infrastructure at 2020 traffic levels, scenario development was performed with MWRRS passenger trains at current 2002 freight traffic levels.

As a result, 2002 traffic volumes were used to develop the mitigation analysis in the 2004 study. Based on the FRA grade crossing data (the most current publicly available source of train traffic data), it can be seen that 2012 train volumes have not changed very much from the 2002 base line volumes that the 2004 assessment used. This calls into question the earlier 2004 plan assumption that freight traffic will double over 20 years, because the data suggests that over the past 10 years, freight traffic on this corridor has been essentially flat. However, revising the future growth forecast is beyond the scope of the current effort. To be clear, to accommodate a forecasted doubling of freight traffic by 2020, the 2004 assessment suggested that fully triple tracking the Jefferson City line may ultimately prove necessary. Following the MWRRS Project Notebook (page 6-91):

> The 2002 base case generates 11 days of freight train delay; by 2020, without double-tracking the Osage and Gasconade River Bridges, this would rise to 121 days in the do nothing scenario even if Amtrak trains were discontinued. Freight delays grow by a factor of 12 when volume less than doubles. This disproportionate increase in train delays clearly shows that the system will be reaching its capacity limit by 2020. If Union Pacific proceeds with double-tracking the two river bridges, then additional triple tracking between Jefferson City and St. Louis (beyond what is included in the current infrastructure plan for the MWRRS) will be needed to reduce 2020 freight delays below the level that would have occurred, if MWRRS did not exist. Development of such a strategy will require an engineering field assessment to determine the areas where triple-tracking may be feasible, along with additional simulation modeling effort to ensure the delay mitigation criteria for the MWRRS are fully satisfied. **A likely scenario is full triple tracking except for the tunnels at Gray's Summit and the Osage and Gasconade River bridges, which may remain only double tracked. It is anticipated this expanded modeling effort will be funded in a future project phase.**"

Therefore, it can be seen that the 2004 infrastructure plan, which was based on 2002 freight traffic volumes, is still an appropriate benchmark to use for validation purposes. This case study develops an infrastructure plan for adding six passenger round trips at today's freight traffic levels. This will develop an infrastructure recommendation that is most consistent with the 2004 validation benchmark. The infrastructure has been updated to reflect some improvements that have occurred since 2004 (e.g., the Gasconade River bridge) but does not include the Osage River Bridge that, although funded, has not been completed as of the time of this report. The Osage River Bridge's expected completion is in 2013.

The conflict identifier identifies capacity requirements for both freight and passenger needs as follows:

- Step 2, defined as the "do minimum" case, defines the infrastructure needs for adding passenger trains alone to the corridor. This consists of the infrastructure improvements that are needed for passenger train operations. They include such things as track condition upgrades, stations and platforms, signal system improvements, and meet/pass infrastructure that are needed for passenger operations. These improvements would have to be made regardless of the level of freight traffic.
- Step 3, defined as the "prepare build" case, defines the additional infrastructure needs for maintaining freight in addition to passenger train service on the corridor.
  – Typically this consists of additional passing sidings and double-track sections needed to provide enough capacity for joint operations of both freight and passenger trains.
  – In addition to mainline track sections (passing sidings and double track), there is often a need to address local train and yard needs. For example, short sidings or pocket tracks can be built clear of the main line to enable local switchers to "lock themselves in" to industrial sidings so they can serve local industries without fouling the main line. The provision of yard lead tracks can enable yard switching to take place without interfering with mainline operations.
  – However, the SU methodology, because it focuses primarily on main-line operations, is well suited to assist in identifying the first area of need (sidings and additional main-line track). The tool is not well suited to analysis of industrial switching or yard operations and will not assess the needs for adding such track.

Two conflict identifier runs, as shown in Figures 3-2 and 3-3, are needed to address both steps of the process.

- The results of the Step 2 "do minimum" or passenger-only run are shown in Figure 3-2. This replaces the current two Amtrak round trips with the six planned MWRRS passenger round trips. The conflict identifier runs assess the capacity infrastructure need for passenger trains only.
  – This analysis shows no need to add passenger train meeting points east of Jefferson City, because the existing rail line is already double-tracked. Note that there are no passenger train conflicts east of Jefferson City.

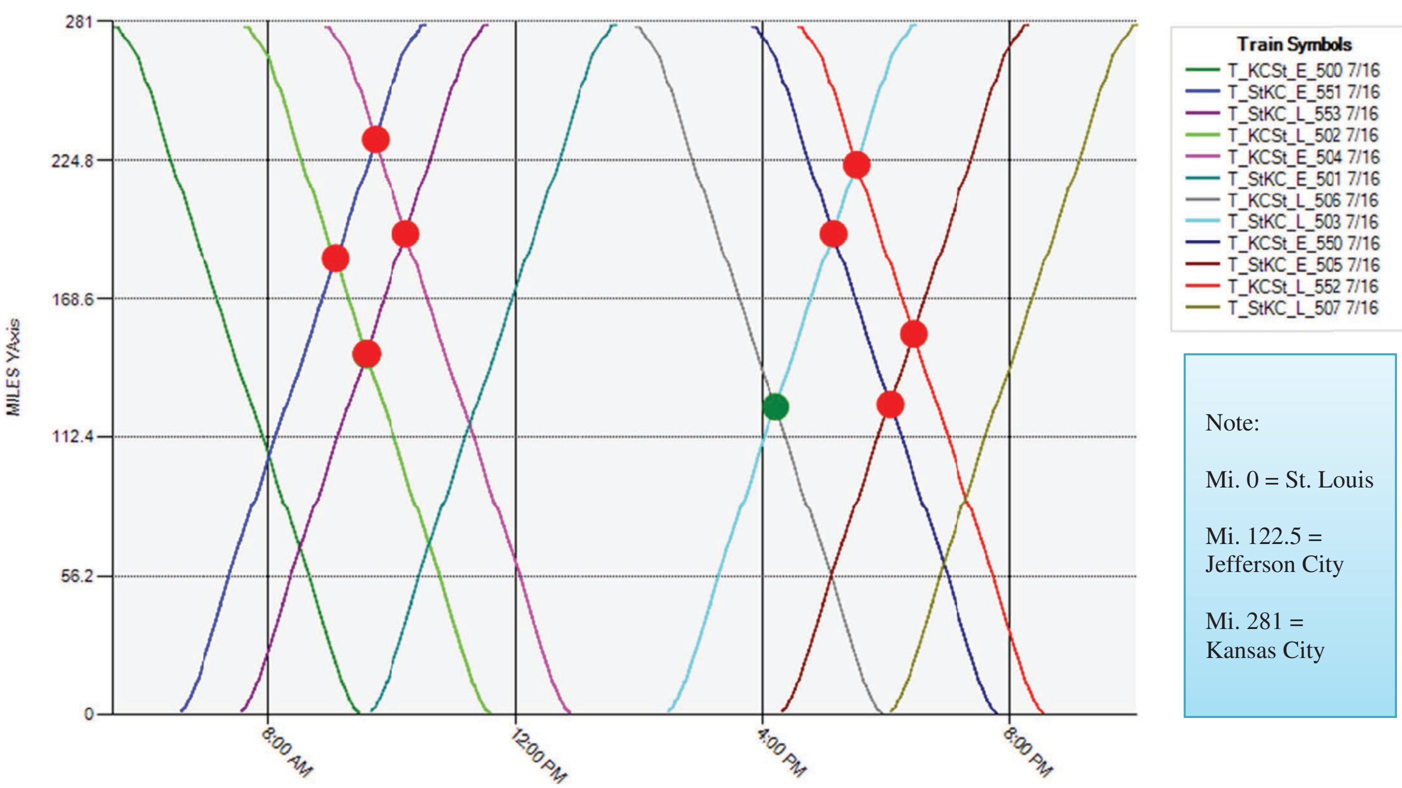


Figure 3-2. St. Louis to Kansas City—"do minimum" conflict identification.

- However on the single-tracked Sedalia Subdivision west of Jefferson City, there are a total of nine passenger-on-passenger train meets. Because each passenger train meet affects two different passenger trains, this count is multiplied by two, so 18 meets divided by the 12 daily passenger trains yields an average of 1.5 meets per train. Rounding 1.5 up to 2, and assuming the passenger train schedules could be adjusted a little bit, this indicates a need to build two 10-mile passing sidings for passenger meets between Jefferson City and Kansas City. This is what would be needed if only passenger trains used the line and all freight trains were diverted to the parallel river subdivision west of Jefferson City.

• The results of the Step 3 "prepare build" (freight plus passenger run) are shown in Figure 3-3. This adds freight trains along with the six planned MWRRS passenger round trips, generating many additional conflicts. There are 41 total conflicts on the single-tracked Sedalia Line west of Jefferson City, and 20 conflicts in the double-tracked territory east of Jefferson City. However, because 9 of the conflicts on the Sedalia Line are between passenger trains—and counting each passenger-passenger conflict twice—there are 50 total conflicts on the single-tracked Sedalia Line west of Jefferson City, and 20 conflicts in the double-tracked territory east of Jefferson City.

- This is 50/12 = 4.2 interactions per passenger train on the Sedalia Line, implying the need to add four passing sidings between Jefferson City and Kansas City.
- On the existing double-tracked line there are 20/12 = 1.7 interactions per passenger train, implying the need to add two passing sidings between St. Louis and Jefferson City.

Figure 3-4 provides a summary of the SU analysis.

Finding: The conflict identifier identified the same required infrastructure as did a more detailed analysis. This demonstrates the tool's ability to perform as intended on a heavily used, shared freight corridor with difficult terrain and challenging operational constraints.

3.6.2 Case Study 2: Northeast Corridor (NEC) Baltimore to Wilmington

This case study is the second of three case studies that demonstrates the capabilities of the SU Web-based tool for prefeasibility screening analysis.

The corridor under study is the Northeast Corridor (NEC) between Baltimore and Wilmington. The corridor is a mix of double-, triple-, and quadruple-tracked rail. It is densely trafficked with commuter and intercity passenger service and with freight trains operating between midnight and 6 A.M.

Note:

Mi. 0 = St. Louis

Mi. 122.5 = Jefferson City

Mi. 281 = Kansas City

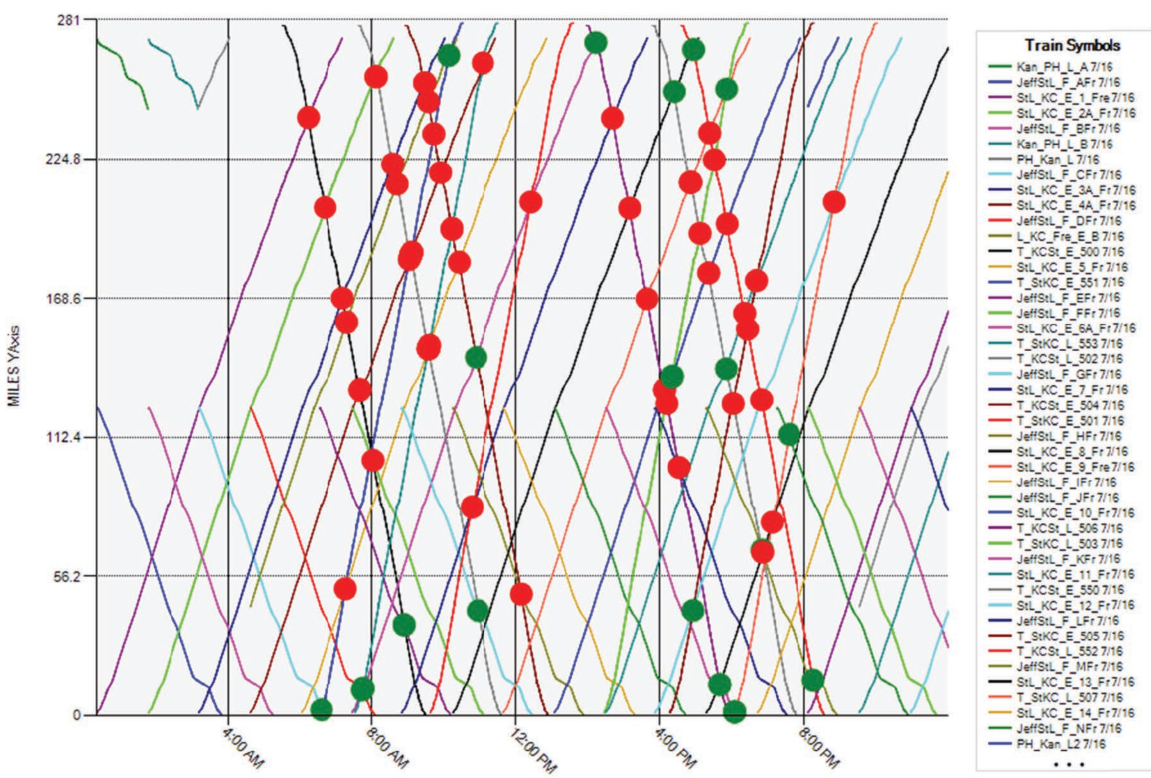
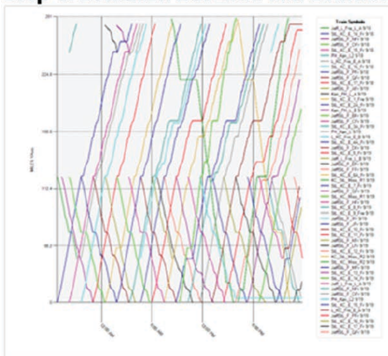


Figure 3-3. St. Louis to Kansas City—"prepare build" conflict identification.

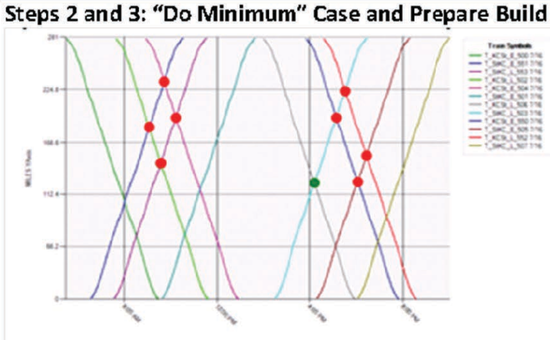
Step 1: Establish Baseline and Evaluate

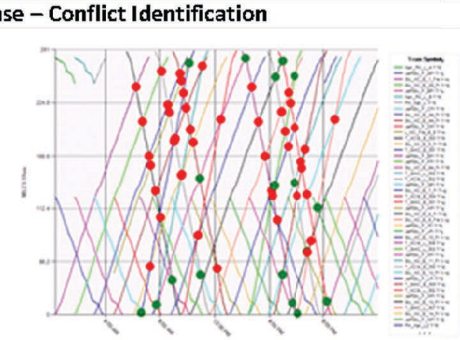


Operational Metrics

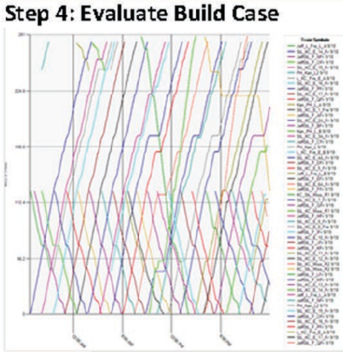
Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	30.5	75.5	132.7	73.6	131.2
PASSENGER 1	42.3	75.0	35.5	75.0	32.3

Steps 2 and 3: "Do Minimum" Case and Prepare Build Case – Conflict Identification





Step 4: Evaluate Build Case



Operational Metrics

Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	31.5	75.5	114.5	73.6	111.0
PASSENGER 1	42.4	50.0	36.3	50.0	35.8

Figure 3-4. Summary of St. Louis to Kansas City SU analysis.

on weekdays. There are, on average, 110 passenger trains and 20 freight trains operating on the territory on a typical weekday.

The case study considers one of several alternative plans that have been proposed for the corridor in the future. The plan envisages developing a new high-speed rail alignment along the NEC that will enable the elimination of Amtrak *Acela Express* trains from the existing rail corridor, thus freeing capacity for 24-hour freight movements (and, possibly, additional passenger services). The analysis includes only the existing corridor and not a proposed new alignment for high-speed rail.

The case study follows the SU methodology, running simulations to establish operational feasibility metrics for baseline operations. The study then uses the conflict identification capability of SU to determine needs for adding infrastructure. The analysis determines that conflicts, given the current schedule and infrastructure, are minimal. The analysis of a future scenario proceeds while assuming no major infrastructure investments in the corridor.

The subsequent step develops a future traffic scenario that removes all 30 daily *Acela Express* trains from the baseline and adds to the schedule 16 new freight trains over the 24-hour day. The analysis assesses the feasibility of restoring freight service to the existing NEC tracks if *Acela Express* were relocated to an entirely new high-speed infrastructure. A simulation of the future traffic scenario on the corridor and the operational metrics indicate no degradation of service for either freight or passenger traffic compared with the baseline.

Six additional passenger trains are added to the schedule in order to analyze the sensitivity of the findings. A comparison of the results with the future scenario provides an indication that the feasibility of the future case scenario is robust.

The NEC from Baltimore to Wilmington was proposed as a "wild card" option because of its unique characteristics as the premier shared-use corridor in the United States. Today, freight operators on the NEC face onerous operating restrictions. Freight operations are severely restricted on the corridor during the day (18 hours) and generally limited to one track during the narrow 6-hour nighttime window. Many of these restrictions were imposed after the Chase, Maryland, accident with a Conrail freight locomotive (*43*) and have succeeded in displacing most freight operations from the NEC, except from Baltimore to Wilmington, where the Norfolk Southern has no practical alternative.

In addition, the Maryland Department of Transportation would like to expand MARC commuter rail service over this same segment north from Baltimore to Newark, Delaware—linking to an expanded SEPTA commuter rail service at Newark.

Taking expanded commuter rail and freight needs into account, the Mid-Atlantic Rail Operations (MAROps) Study (*44*) and Amtrak's Northeast Corridor Master Plan (*45*) have each proposed significant infrastructure additions for expanding NEC capacity from Baltimore to Wilmington as follows:

- A key goal of MAROps capacity expansion has been to provide a **single**, **dedicated freight track**, to allow all-day freight operations along the corridor, completely separate from Amtrak operations. However, this plan would not provide for MARC commuter rail needs.
- However, Maryland Department of Transportation's proposal, the "MARC Capacity Plan" (*46*) would **add two tracks** for shared-use by freight and commuter trains—but not the dedicated freight track that has been proposed by MAROps. Maryland DOT has proposed, for example, a four-track Gunpowder River Bridge by 2020. The "MARC Capacity Plan" is based on a shared-use assumption.

As a result, Maryland's proposal is a bit different than that of Amtrak and MAROps, and somewhat more costly, but it has the advantage of supporting commuter rail as well as freight needs for this segment of the corridor. Development of this option (shared use with MARC commuter trains) may be worthwhile to the freight railroads, because it brings along the possibility of an additional funding source for developing the needed capacity expansion as opposed to dedicated tracks, which would need to be justified based on the freight benefit alone. However, the cost-benefit analysis that was developed for MAROps did not reflect any freight market share increase that would result from construction of the dedicated track. While MAROps clearly underestimates the level of benefit that would result from restoring full-time Norfolk Southern freight rail access to the Ports of Baltimore and Wilmington, it may be more beneficial overall if part of the costs for developing the proposed NEC capacity enhancement could be shared by a commuter rail system.

The section of the Baltimore to Wilmington corridor that is shared with heavy freight operation runs along a segment of the NEC stretching 63 miles from Baltimore Bayview Yard to Shellpot Junction located just south of Wilmington, Delaware. Amtrak has sole ownership of this section of the NEC and handles all dispatching along this portion of the corridor. The Baltimore to Wilmington section of the NEC qualifies as a case study for SU because it is the only section of the NEC that still has heavy freight running on it.

Passenger services along the study corridor from Baltimore to Wilmington are provided by Amtrak, SEPTA, and MARC. The following Amtrak services run the corridor:

- The Northeast Regional, which runs between Newport News and Boston;
- The *Acela Express*, which runs between Washington and Boston;
- The *Carolinian*, which runs between Charlotte and New York;

- The *Crescent*, which runs from New York to New Orleans; and
- The Silver Service, which runs from New York to Miami.

MARC and SEPTA provide local commuter rail services with MARC's Penn Line operating between Baltimore and Perryville, and SEPTA operating between Wilmington and Newark. At present, no local commuter service connects Perryville and Newark.

Currently, NS handles most of the freight operations along the Baltimore to Wilmington segment of the NEC. CSX uses a separate parallel route, which is not part of this study; CP has freight trackage rights, currently inactive. Most of the freight traffic originates from Baltimore, the Delmarva Peninsula, and Wilmington, eventually converging onto the NS Port Road rail line at Perryville where it then follows the Susquehanna River to Harrisburg. There is currently no through north-south freight traffic from Baltimore to Wilmington.

Several competing plans to renew and improve the NEC corridor segment from Baltimore to Wilmington have been proposed. Both Amtrak and MAROps (Mid-Atlantic Rail Operations) (*47*) have proposed plans that would allow freight and high-speed rail lines to have their own dedicated tracks within the corridor. The Maryland Department of Transportation, who operates the MARC commuter rail service, has proposed a plan that would allow a dedicated passenger high-speed rail line in the corridor and a regional passenger rail and freight connection from Baltimore to Newark to Wilmington.

The NEC Baltimore to Wilmington corridor begins at Baltimore's Penn Station. Passing Bayview Yard it travels northeast to the MARC station stop at Martin Airport, where about half the Penn Line trains end. Continuing north, the corridor then reaches the Gunpowder River Bridge. This is the first of three bridges (Gunpowder, Bush, and Susquehanna Rivers) that are limited to double track and that are nearing the end of their life expectancies. Just beyond the Edgewood MARC station, the route crosses the Bush River and travels through a military restricted area near the Aberdeen Proving Grounds and then on to the next stop at the Aberdeen Amtrak station. Continuing north, the route crosses the Susquehanna River Bridge to the Perryville MARC station. This station marks the current end of the Penn Line. The NS Port Road Line also joins at Perryville and is where freight joins or leaves the corridor to/from Harrisburg.

Continuing north, the corridor segment from Principio (just northeast of Perryville) to the town of Bacon (near North East, Maryland) is double tracked. The proposed Chesapeake Connector Project (*48*) would increase this segment to triple track. However, the Maryland DOT has proposed quadruple track for this segment in order to add enough capacity for commuter trains, as well as freight. At Elkton, Maryland, MARC is proposing to build a new station for an extension to the Penn Line that would continue to Newark, Delaware, where it could join up with SEPTA's regional rail line.

Beyond the Newark Amtrak station and freight yard, the Delmarva junction allows freight to leave/enter the corridor. Between Newark and Newport, Delaware, there is a SEPTA commuter rail stop located at Churchman's Crossing. Shellpot Junction, located just southwest of Wilmington, marks the end of the study corridor and is where the NS freight line to Edgemoor Yard diverges from the Amtrak-owned Northeast Corridor. Finally, the corridor reaches the Wilmington, Delaware, Amtrak station that is the northern end point for this analysis.

This section presents the current plans for development of the corridor. For purposes of demonstrating the SU tool, the analysis focuses on the last plan described: the high-speed rail plan. (Note: The use of this plan in the case study for purposes of exposition and demonstration in no way indicates the authors' views with regard to such a plan's merits or the likelihood of it being adopted or funded.)

Amtrak, MARC, and SEPTA all expect greater ridership over the next 20 to 30 years, but potential growth is constrained by the currently existing rail infrastructure (*49*). Various plans such as the MAROps Phase 2 Study (which draws on the Northeast Corridor Infrastructure Master Plan) (*50*) and a competing MARC Growth and Investment Plan (*51*) have been proposed to increase rail capacity in the Baltimore to Wilmington segment of the NEC.

Amtrak and MAROps Plans

Both Amtrak (*52*) and MAROps propose expanding to triple track the entire corridor from Baltimore to Wilmington, two tracks for high-speed Amtrak use and one for freight use. This would heavily restrict the potential for local commuter rail expansion along the route. The Amtrak plan is more intercity-passenger oriented, allowing 15 additional round trips and improving trip times between Washington and Philadelphia (*53);* while the MAROps plan is oriented more toward freight. Amtrak's plan does not fully take into account MARC's proposed plan to extend the Penn Line to Newark, Delaware. However, they both agree on the following key investments:

- Increasing the mainline track from Wilmington to Baltimore to at least triple track, thus allowing a dedicated freight track for NS.
- Replacing the Gunpowder, Susquehanna, and Bush River bridges, thus allowing the route to be increased from double to triple track.

MARC/Maryland DOT Proposal

MARC, along with the Maryland Department of Transportation, proposes expanding the entire Baltimore to Wilmington route to quadruple track; thus allowing double track for high-speed Amtrak use and two tracks for shared use between local commuter and freight trains, as shown in Figure 3-5. By upgrading the Baltimore to Newark segment to quadruple track and connecting to existing quadruple track north of Newark, Amtrak would be able to expand its operations to the level desired in its proposed plan. In addition, MARC/SEPTA would be able to offer a local Baltimore to Wilmington route that would allow passengers to change trains at Newark. However, the MARC Penn Line would still have to share track with NS freight traffic. Like the Amtrak and MAROps plans described above, the Gunpowder, Susquehanna, and Bush River rail bridges would have to be replaced, but with quadruple track instead of triple track.

SEPTA Plan

SEPTA plans to increase the number of commuter trains running between Wilmington and Newark, Delaware, on the Wilmington/Newark Service Line service by four round trips (*54*). Because there are far fewer infrastructure problems north of Newark, SEPTA would only need to reconfigure the Newark station facility and would not need to invest in new infrastructure (such as adding new tracks or bridges, etc.).

High-Speed Rail Plans

Amtrak (*55*) and others (*56*) have been developing plans for implementing true high-speed (e.g., 220 mph) rail service in the NEC. It is known, however, that the current NEC track alignment has too many curves and is not able to support the requirements of true high-speed rail. In some places, curve easements may be possible; in other places the alignment is likely to be too difficult to adjust, so entirely new green field alignments will need to be developed for attaining the service objectives. When this occurs, a possible outcome would be replacement of the existing *Acela Express* service with a new-generation high-speed train. At that point, the capacity of the existing tracks could be redeployed to support more conventional intercity, commuter, and freight services, similar to developments that have occurred in Europe when new high-speed lines were opened.

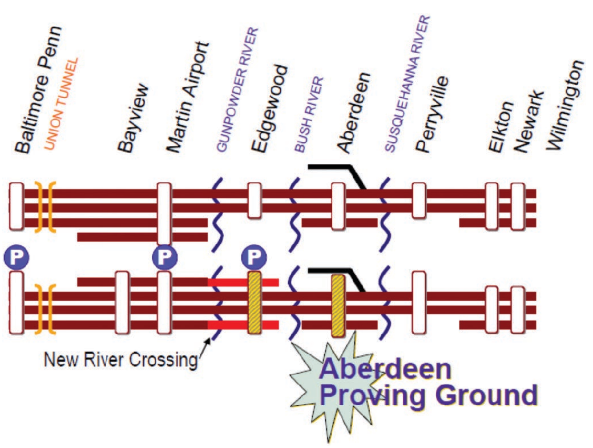


Figure 3-5. Maryland DOT 2020 Plan for NEC Baltimore-Wilmington infrastructure.

Although in the past 20 years freight traffic has declined in the NEC, freight services could be revitalized in the future. Clearly, there are many unknowns associated with the adoption of a plan, the process of approvals, and the actual development of a new green field rail alignment—and subsequent developments on the existing corridor.

Validation

There have been numerous NEC detailed capacity simulations performed for Amtrak and FRA using a variety of tools, including the TAD LogSim model (*57*) (which Amtrak was known to be using for internal planning purposes) and SYSTRA's RailSim tool (*58*). Although these benchmarks are not publicly available, they could possibly support validation if they were made available.

Key Assumptions of the Analysis

Since there are multiple plans for the evolution of the corridor, this study focused on one of these plans and built the case study analysis around it. The plan of focus is the one for high-speed rail, which will result in the removal of the *Acela Express* trains from the existing NEC alignment, to be replaced by high-speed trains on a new alignment. This would result in an increase in capacity on the existing infrastructure that would permit adding freight traffic over a 24-hour period to the NEC between Baltimore and Wilmington. The analysis assumes a future case with no new additional infrastructure, but with modifications to the mix of traffic: 30 daily *Acela Express* trains will be removed from the corridor, and 16 freight trains will be added: 4 in each direction between Perryville and Delmarva Junction (i.e., Newark) and 4 in each direction between Perryville and Bayview Yard (i.e., Baltimore).

The SU methodology is designed to identify the infrastructure need for adding new passenger trains to existing freight or shared-use corridors. However, this case study is atypical because it assesses the prospects for adding *freight* trains to an existing *passenger* corridor, where some of the passenger trains are being removed and replaced with trains on a new alignment.

- Step 1 is the "do nothing" baseline.
- Step 2, defined as the "do minimum" case, identifies conflicts (i.e., areas lacking infrastructure for meets or overtakes when running a modified schedule that includes new services). Because the future case traffic includes a different mix of passenger and freight, the conflict identification

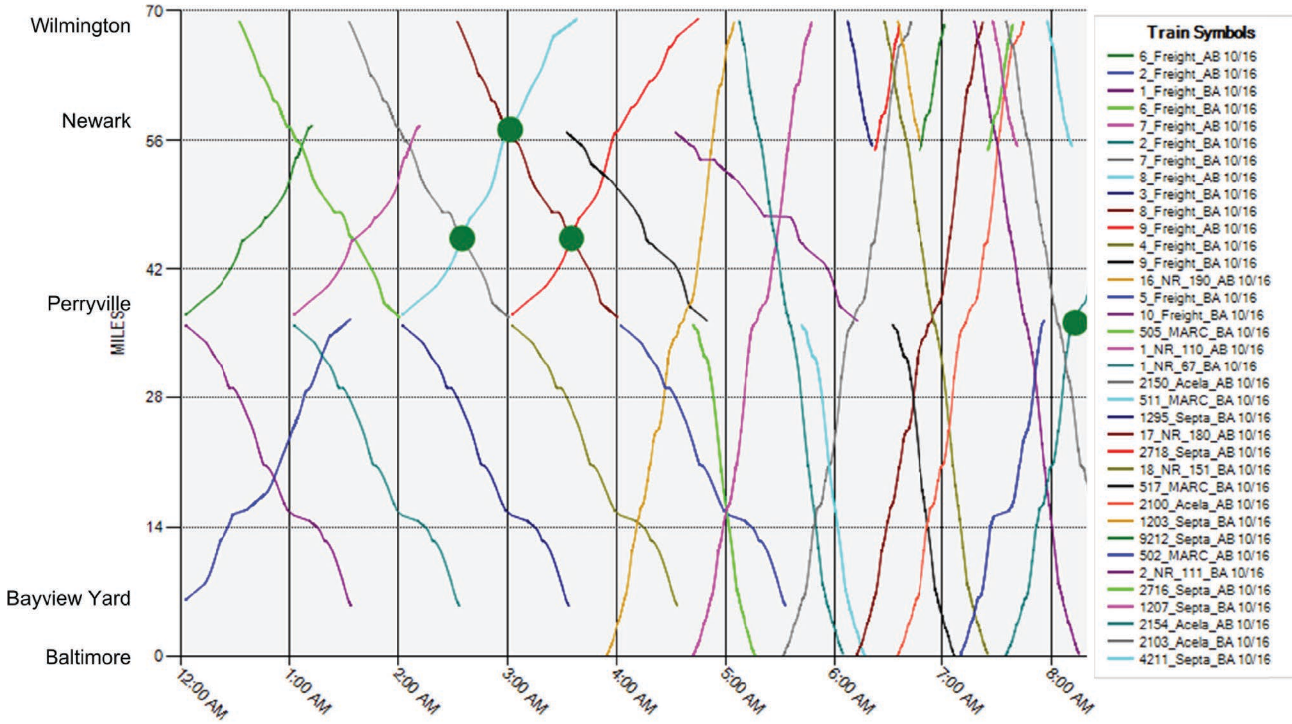


Figure 3-6. Baltimore to Wilmington—conflict identification, 12 A.M.–8 A.M.

will determine the suitability of existing infrastructure to accommodate existing traffic, which by assumption also should accommodate the alternative future traffic containing a different mix of freight (+16) and passenger (−30) trains. The results of this analysis are shown in Figures 3-6 through 3-8.

- Step 3, defined as the "prepare build" case, defines the infrastructure needed for adding freight in addition to passenger trains on the NEC. If the analysis finds that infrastructure is sufficient in the baseline, then the analysis assumes that the future case scenario also can be accommodated (if this is not the case, then feasibility metrics for simulations of the

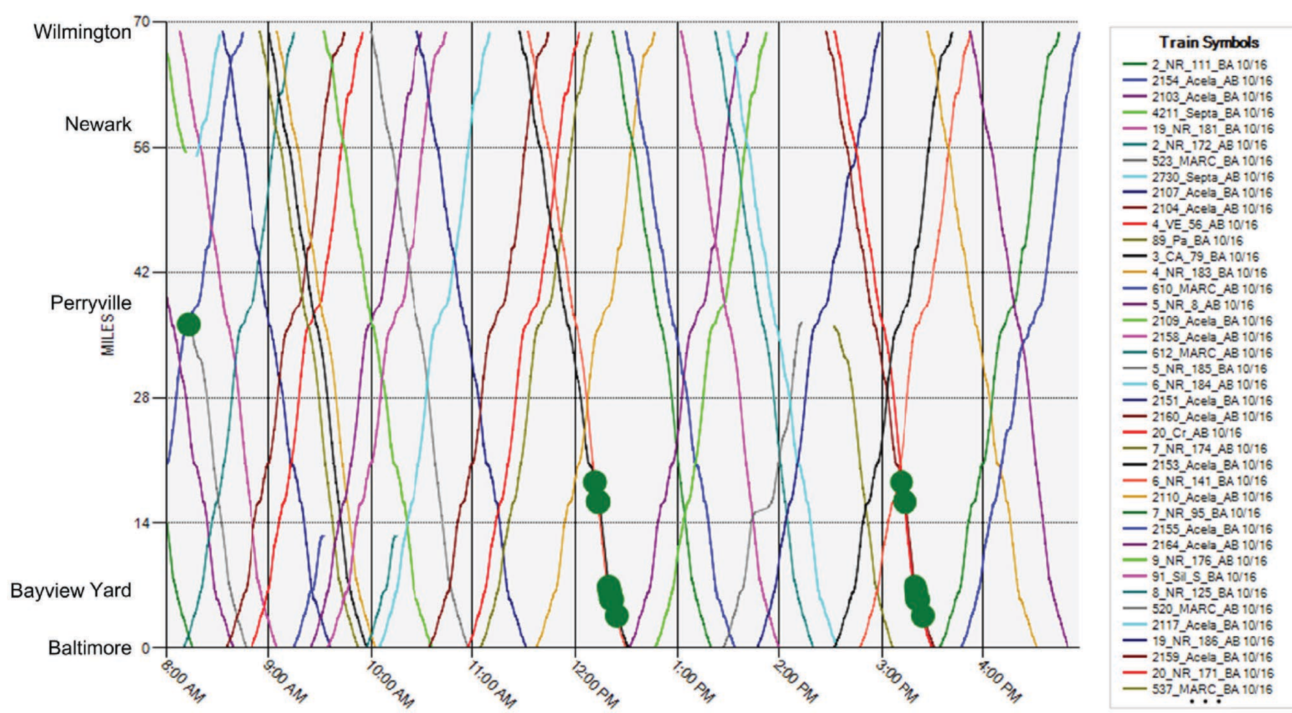


Figure 3-7. Baltimore to Wilmington—conflict identification, 8 A.M.–4 P.M.

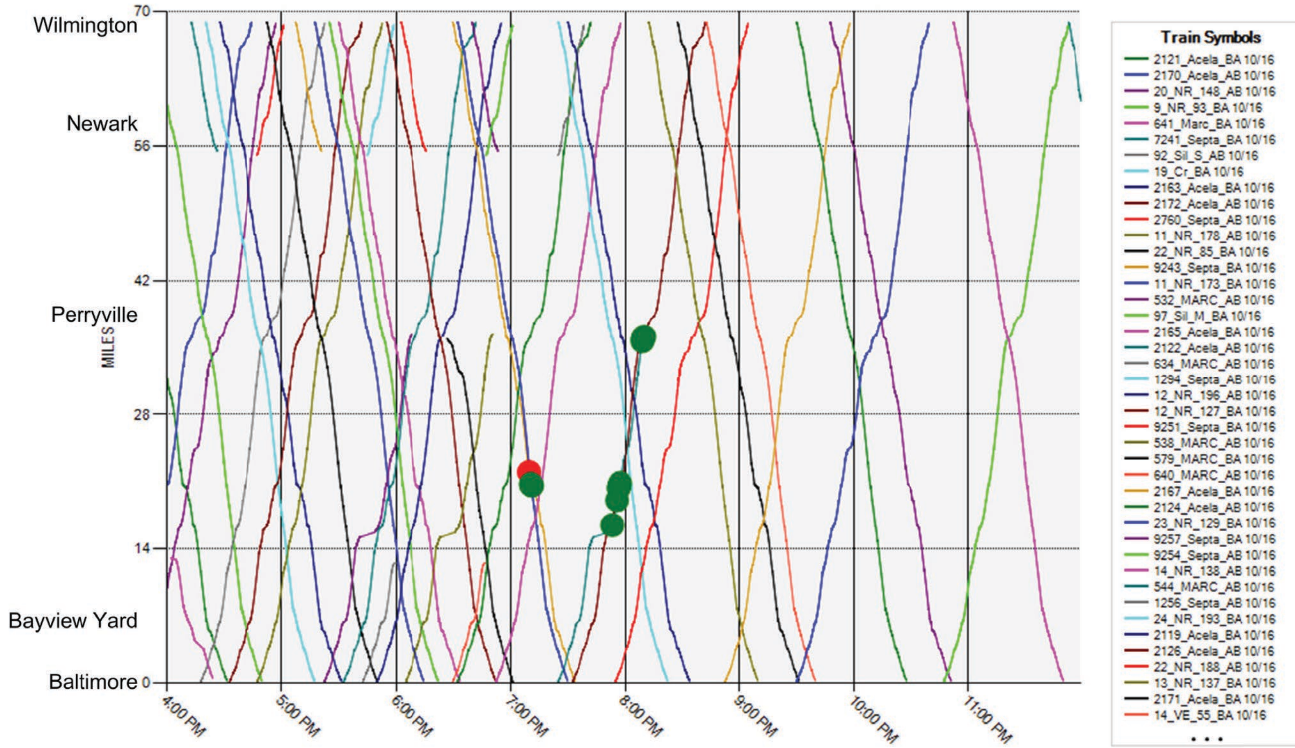


Figure 3-8. Baltimore to Wilmington—conflict identification, 4 P.M.–12 A.M.

future case—Step 4—will indicate degraded service, e.g., increased delay). The results of this analysis are shown in Figures 3-9 through 3-11.

For the "do minimum" case, the conflict identifier found only a single red ball (at 7:15 P.M. near mile 22). That red ball and the clusters of green balls in Figure 3-6 correspond to trains that track each other closely (i.e., run parallel to one another and would probably be dispatched on separate tracks in the real-world operating setting).

The research team concluded that the current infrastructure is generally adequate to support current levels of traffic with on-time performance, while noting that track closures for maintenance or unforeseen mechanical failures could result in significant delays. The research team also added the caveat that further study is required to determine that under normal operations and "ideal" conditions (i.e., no inclement weather, no mechanical failures, and no periodic maintenance) that all scheduled trains can be dispatched in the corridor with delay below an acceptable threshold. Such additional analysis can be conducted with SU.

The final step in the process is to develop a hypothetical future ("build") case for simulation evaluation.

The research team's analysis assumes a future case with no new additional infrastructure, but with modifications to the mix of traffic: 30 daily *Acela Express* trains will be removed from the corridor, and 16 freight trains will be added: 4 in each direction between Perryville and Delmarva Junction (i.e., Newark) and 4 in each direction between Perryville and Bayview Yard (i.e., Baltimore). This scenario assesses the ability to restore freight service to the existing NEC tracks if *Acela Express* were relocated to an entirely new, high-speed infrastructure.

As compared to the base case simulation, Table 3-6 shows that average delay for passenger trains is practically unchanged. Average delay for freight trains increased from 54 to 73 minutes per train. However, when considering that freight throughput in the corridor increased by 80 percent (from 20 to 36 trains per day) the growth in average delay may be a worthwhile trade-off.

Finding: This case study was undertaken as a "double-blind" exercise without a validation benchmark. Regarding the "do minimum" case, the conflict identifier showed that the existing operation can be handled over the existing infrastructure with minimal conflicts. Results indicate the merit of additional study.

Regarding the "future build" scenario, the results of both the conflict identification and simulation screening concur that "full" Norfolk Southern freight service (daytime as well as nighttime) could be restored along this section of the NEC if the high-speed *Acela Express* service were shifted away from the existing tracks onto a new parallel high-speed alignment.

This suggests the potential for a substantial freight benefit associated with the implementation of true high-speed service between Baltimore and Wilmington. Additional study could

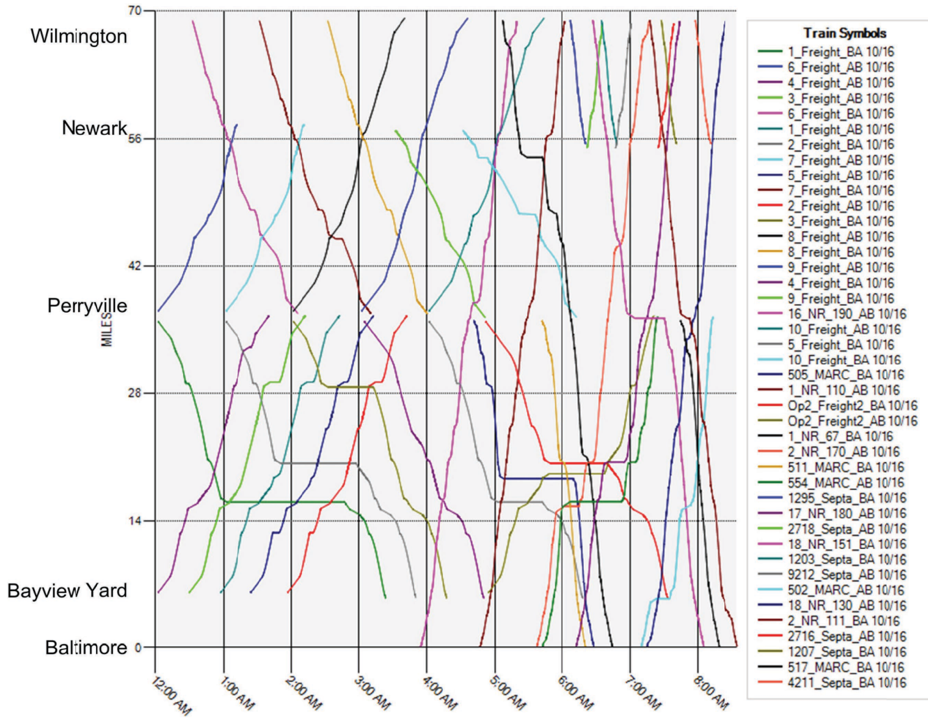


Figure 3-9. Baltimore to Wilmington—future case string line, 12 A.M.–8 A.M.

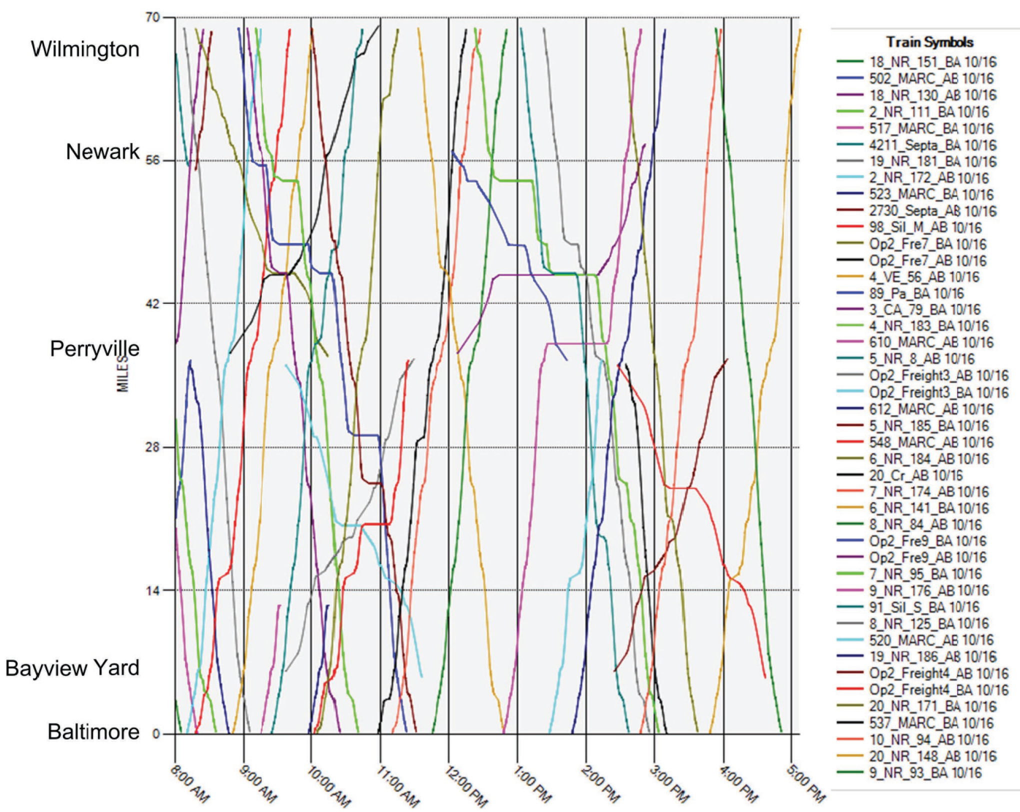


Figure 3-10. Baltimore to Wilmington—future case string line, 8 A.M.–4 P.M.

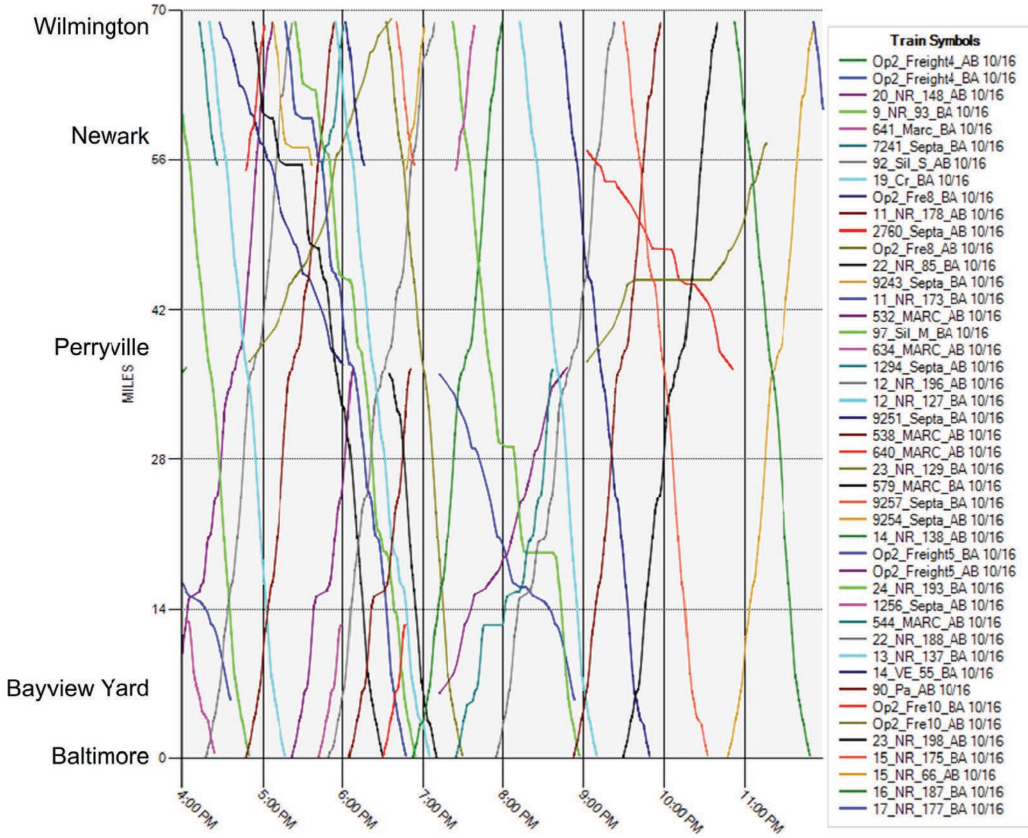


Figure 3-11. Baltimore to Wilmington—future case string line, 4 P.M.–12 A.M.

explore this potential. A summary of this analysis is shown in Figure 3-12.

3.6.3 Case Study 3: Chicago to Milwaukee

The Chicago to Milwaukee rail corridor handles significant volumes of commuter, freight, and intercity rail passenger traffic. Metra commuter rail service (*59*) operates on the south end of the corridor, while Amtrak's *Hiawatha* service (*60*), with its heavily commuter-oriented ridership, operates the full length of the corridor. In addition, the Canadian Pacific Railroad uses this line as its main access into Chicago so the corridor features a complex mixture of intercity, commuter, and freight trains in multiple-track territory.

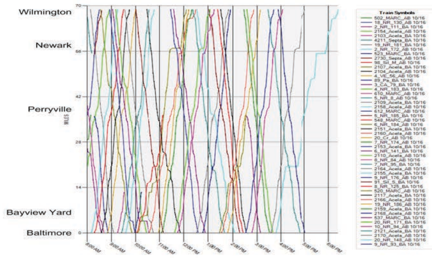
Against this backdrop of existing shared-use operation, regional plans have sought to add a high-speed intercity passenger rail component into the traffic mix. Wisconsin proposed extending the corridor to Madison, Wisconsin, which would have added more ridership to the Chicago-Milwaukee segment of the corridor; currently, environmental studies are underway for extending rail service all the way to the Twin Cities. Any service extension north of Milwaukee would need more capacity on the Chicago to Milwaukee segment, but adding more passenger trains to this segment would impact all existing freight and commuter rail services.

This case study employs the SU Web-based tool to gain a better understanding of issues pertaining to increased passenger train speeds and frequency on the Chicago to Milwaukee segment. The analysis also supports plans for improved service on the existing *Hiawatha* corridor, and it lays the groundwork for addressing issues relating to future extensions to Madison, Green Bay, and the Twin Cities.

Table 3-6. Baltimore to Wilmington—future case summary delay statistics.

Operational Metrics					
Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	15.9	55.6	73.3	52.8	68.0
PASSENGER 1	52.1	75.3	31.8	67.1	30.4

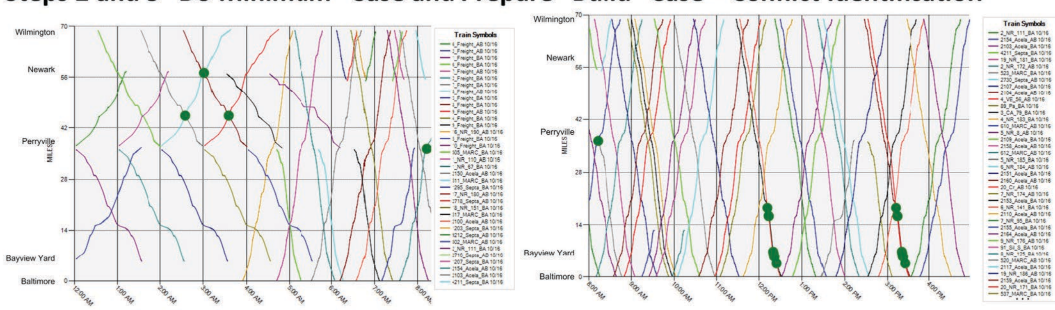
Step 1 Establish Baseline and Evaluate



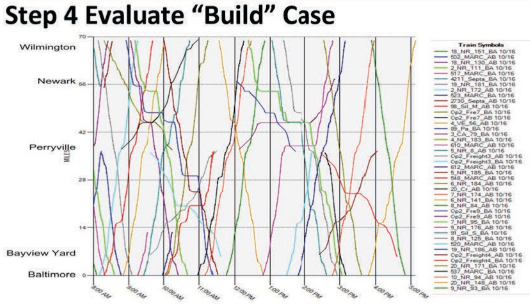
Operational Metrics

Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	16.9	55.0	57.4	55.0	55.7
PASSENGER 1	52.5	86.1	30.5	80.9	30.5

Steps 2 and 3 "Do Minimum" Case and Prepare "Build" Case – Conflict Identification



Step 4 Evaluate "Build" Case



Operational Metrics

Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	15.9	55.6	73.3	52.8	68.0
PASSENGER 1	52.1	75.3	31.8	67.1	30.4

Note: String line charts in Steps 1 and 4 are for 8 A.M.–4 P.M. on day of analysis. Steps 2 and 3 show conflict identifier charts for 12 A.M.–4 P.M.

Figure 3-12. Summary of SU analysis, NEC.

Rail operations along the Milwaukee to Chicago study corridor are shared among commuter, intercity passenger, and freight services. For a short distance between Chicago Union Station and Lake Street, Amtrak controls the line while Metra dispatchers operate the line from Lake Street to Western Avenue. From Western Avenue all the way to Milwaukee, Canadian Pacific Railroad (CP) handles all freight and passenger train dispatching.[61]

For most of the study corridor, CTC (centralized train control) signaling is used with the exception of ABS (automatic block signaling) used for some track segments located within the city centers of Chicago and Milwaukee (*62*). Top passenger timetable speeds along the corridor range from 70 to 79 mph according to the data in the FRA National Grade Crossing Inventory.

Currently, the study corridor handles a significant volume of commuter, freight, and intercity rail passenger traffic. The daily intercity passenger train volume north of Rondout is 8 round trips or 16 trains per day from Monday to Saturday and 14 trains on Sunday. South of Rondout, the volume of daily commuter and intercity passenger rail trips ranges from approximately 176 trips between Chicago and Pacific Junction to 76 trips from Pacific Junction to Rondout. The FRA National Grade Crossing Inventory shows 18 freight trains per day on the route from Techny to Milwaukee, however, this does not agree with the freight train volumes that have been used in recent simulation studies. This is discussed in more detail in the following sections.

Amtrak Passenger Service

Amtrak's *Hiawatha* service runs the full length of the corridor from Chicago to Milwaukee, operating seven daily round trips between Monday and Saturday (only six on Sunday). The *Empire Builder*, which operates 1 daily trip from Chicago to Portland-Seattle, runs a portion of its route along the corridor making stops at Chicago, Glenview, and Milwaukee before continuing westward. This brings the weekday passenger trip total to 8 round trips or 16 daily one-way trips. The schedule for Amtrak's *Hiawatha* service is shown in Table 3-7.

The 2004 MWRRS plans would replace these 7 round trips with 17 daily round trips for extending service to Madison, the Twin Cities, and Green Bay. Amtrak's long-distance *Empire Builder* service is assumed to continue, which would bring the weekday intercity passenger train total to 18 trains in each direction, or 36 trains total.

Metra Commuter Rail Service

Metra commuter rail service operates on the south end of the corridor from Chicago to Rondout. According to the current schedule, the Metra MD-N service makes 30 daily weekday round trips between Chicago Union Station and Rondout (*63*). (Six of these trips end at Deerfield. It is unknown if these trips continue on as return trips or as deadhead trips or empty trains.) On weekends, 10 to 12 daily round trips run between Chicago Union Station and Rondout. Additional Metra trains from the NC-S and MD-W lines also share the corridor from Chicago Union Station to Pacific Junction.

Freight Operations

As noted earlier, CP handles the freight operations along the Chicago to Milwaukee corridor. CP uses this corridor as its main route bringing freight into and out of Chicago. A few CP road trains and locals (*64*) operate between Pacific Junction and Techny; data from the FRA National Grade Crossing Inventory suggest that up to four freight trains operate per day over this short stretch of track. The research team

Table 3-7. Amtrak *Hiawatha* service (Monday through Saturday) (*66*).

Station	Chicago to Milwaukee (Northbound) Train #						
	329	331	333	335	337	339	341
Chicago Union Station, IL	6:00 AM	8:25 AM	10:20 AM	1:05 PM	3:15 PM	5:08 PM	8:05 PM
Glenview, IL	6:22 AM	8:47 AM	10:42 AM	1:27 PM	3:37 PM	5:32 PM	8:27 PM
Sturtevant, WI	7:00 AM	9:25 AM	11:20 AM	2:05 PM	4:15 PM	6:14 PM	9:05 PM
Milwaukee Airport	7:14 AM	9:39 AM	11:34 AM	2:19 PM	4:29 PM	6:28 PM	9:19 PM
Milwaukee, WI	7:29 AM	9:54 AM	11:49 AM	2:34 PM	4:44 PM	6:45 PM	9:34 PM

Station	Milwaukee to Chicago (Southbound) Train #						
	330	332	334	336	338	340	342
Milwaukee, WI	6:15 AM	8:00 AM	11:00 AM	1:00 PM	3:00 PM	5:45 PM	7:35 PM
Milwaukee Airport	6:26 AM	8:10 AM	11:10 AM	1:10 PM	3:10 PM	5:55 PM	7:45 PM
Sturtevant, WI	6:43 AM	8:23 AM	11:23 AM	1:23 PM	3:23 PM	6:08 PM	7:58 PM
Glenview, IL	7:25 AM	9:01 AM	12:01 PM	2:01 PM	4:01 PM	6:46 PM	8:36 PM
Chicago Union Station, IL	7:57 AM	9:29 AM	12:29 PM	2:29 PM	4:29 PM	7:14 PM	9:04 PM

assumed they are mostly short locals serving industrial customers along the line.

North of Techny to Milwaukee, the FRA National Grade Crossing Inventory reports 18 daily freight trains, or 9 trains in each direction. A recent 2010 HNTB capacity analysis (*65*) used 25 trains per day in 2010, increasing to 37 trains per day in 2030. Summarizing, both previous benchmark studies agreed that the future freight train volumes (including locals) should be 37 to 42 trains and that this will be attained in the 2020–2030 timeframe. Notwithstanding possible concerns regarding the validity of this forecast, for direct comparability to the previous validation benchmarks, a freight train volume of 18 daily through trains each way (36 total trains per day) was used in the development of this case study. (The two previous benchmarks were based on forecast freight train volumes of 37 to 42 trains per day, including locals. Excluding locals, the projected through train counts were in the range of 33 to 38 trains per day.)

Note that these forecasts fully double the train counts that the FRA National Grade Crossing Inventory shows for the line today. It is not clear whether the data in the FRA database underreport the actual freight train volumes or CP instructed the simulation study teams to use traffic volumes that are more representative of peak rather than average days. This issue requires further investigation, because it significantly impacts both the need for, and optimal timing of, infrastructure additions to the corridor.

Much of the historical growth in rail traffic has been fueled by expansion of Pacific Rim intermodal as well as Powder River Basin coal, but as a restructured economy emerges from the recession, it is not clear that these historical growth patterns will resume under changed economic conditions. As a result, it is essential to give attention to development of a rigorous process not only for estimating current train counts, but also for developing reasonable corridor-specific forecasts that are in line with national economic projections.

Total Train Volumes

Figure 3-13 maps daily rail volumes along the corridor for 2010, as derived from the FRA National Grade Crossing Inventory, with confirmation of passenger train counts based on Amtrak timetables.

However, for the reasons given above, this case study uses 18 freight trains each way as reflective of forecast future year traffic volumes, rather than the 18 total freight trains shown in Figure 3-13. This may be an overly aggressive freight traffic forecast, but is needed for compatibility with the simulation validation benchmarks.

Future Plans

Wisconsin is currently seeking to enhance the Amtrak *Hiawatha* line to improve travel between Chicago and Milwaukee (*66*). Its plan is to implement the Truesdell connection and extend the station platform at Milwaukee Airport. At the same time, there are plans to replace/repair two bridges near Wadsworth (*67*). These improvements would allow the number of Chicago-Milwaukee Amtrak round trips to increase by

Figure 3-13. Passenger and freight train volumes for the Chicago to Milwaukee Corridor.

1 to 3 trips per day (*68*) while reducing travel times by up to 30 percent (*69*).

For the longer term (including extensions both to Green Bay and the Twin Cities), one of the major suggestions to improve the Chicago to Milwaukee corridor is the separating of CP operations at Truesdell and providing a separate line for these trains to Techny, where currently the CP trains turn off for Bensenville. Currently, freight trains from Bensenville yard join the corridor at Techny and share the CP line to Milwaukee, thus resulting in schedule conflicts with passenger trains. By diverting these freight trains to the parallel UP freight line, overall conflict could be reduced by separating freight and passenger trains on the southern half of the corridor. Building a connection at Truesdell would allow freight traffic to rejoin the route there. For the Chicago to Milwaukee segment, the 1997 *Chicago/Milwaukee Rail Corridor Study*[70] proposed the following three capacity measures:

- Triple track from Chicago Union Station to Rondout MP 32.5. (The section from Union Station to Western Avenue is already triple-tracked.)
- Separate CP operations at Truesdell and provide a separate line for these trains to Techny, where today the CP trains turn off for Bensenville.
- Provide three 2-mile freight sidings at 10-mile intervals north of Truesdell.

In the years prior to the 1997 corridor capacity study, CP (mainly through its subsidiary Soo Line) purchased extensive stretches of track from failing railroads in the West and Midwest, many of which were in poor condition. CP opted to convert most of these railroads now under its control to single-track. CP finished single-tracking its line from St. Paul to Milwaukee just before the 1997 *Chicago/Milwaukee Rail Corridor Study* was performed. Subsequent to the study, there was continued activity of divestment and acquisition of rail lines by CP in the western states and along the Mississippi River.

The 1997 study asserted that CP could handle all its freight traffic between Truesdell and Milwaukee on a single track because, indeed, it was already doing so. In view of subsequent divestment by CP, the 1997 study may have understated CP's need for capacity in the corridor. The 1997 *Chicago/Milwaukee Rail Corridor Study* proposed that CP should sell one of its existing tracks to the State of Wisconsin for passenger trains and continue to use just one track for freight service as follows:

- Adding three 2-mile freight sidings at 10-mile intervals north of Truesdell, to accommodate single-track operations by CP.
- Upgrading parallel existing track, a distance of approximately 34 miles, to 110 mph dedicated exclusively to passenger use.

The 1997 study assumed a volume of freight trains consistent with the capacity of the single-tracked line. However, the 1997 study was based on only 12 passenger round trips, and so its suggestion that this number of passenger trains could be handled over a 34-mile single-track segment is quite reasonable. A scenario that was tested adopts operational changes from the 1997 study that seem necessary given the traffic growth since the time of the study. This case study assessment assumes comingled, shared rather than dedicated, track operation, in order to see whether the existing double-track line, particularly north of Truesdell to Milwaukee, can accommodate the comingled increased passenger and freight volumes.

For supporting this type of comingled double-track operation, a key requirement is a passing capability to allow passenger trains to overtake slower-moving freight trains. Even though train volumes are high, the distance from Truesdell to Milwaukee is only 34 miles, therefore

- A freight train could immediately follow a passenger train in each direction to utilize capacity in the "shadow" of the passenger train's schedule slot. For example, a northbound freight could wait at Truesdell until the northbound passenger train passes. If the freight train then followed the passenger train, the freight train could likely reach Milwaukee and clear the line segment ahead of the next passenger train.
- If an intermediate passing siding were needed, instead of building the three short passing sidings as proposed by the 1997 study, a single 6-mile-long triple track section could be built at equivalent cost, approximately midway between Truesdell and Milwaukee. This would result in triple tracking 18 percent of the corridor and would reduce the length of the critical distance between clearance points from 34 miles down to 14 miles.

As such, it appears that a comingled operation could be possible from Truesdell to Milwaukee using about the same level of infrastructure in the 1997 study. The case study tests the assumption that this level of infrastructure can indeed support the proposed comingled operations.

The SU conflict identifier pinpoints conflicts that require mitigation with new infrastructure. In reference to the SU methodology, note the following:

- Step 2, defined as the "do minimum" case, defines the infrastructure needs for adding passenger trains alone to the corridor. However, because the line is currently double tracked, there are no scheduled conflicts between the additional passenger trains north of Rondout. This indicates that the capacity of the existing double-tracked line is sufficient to support the needs of passenger service.
- Step 3, defined as the prepare build case, defines the additional infrastructure needed for maintaining freight and existing

commuter, in addition to expanded passenger, train service on the corridor. The case adds freight trains along with the 19 planned additional passenger round trips. The case infrastructure is the same as the base and do minimum cases, and the trains will run comingled on all available track.

- Figures 3-14 through 3-16 show the conflict identifier run for the prepare build case:
  - In the double-tracked territory on the north end of the line from Truesdell to Milwaukee, there are 37 total conflicts vs. 38 passenger trains. This is 37/38 = 0.97 freight interactions per additional passenger train between Truesdell and Milwaukee. This validates the earlier recommendation for adding one 6-mile-long center passing siding between Truesdell and Milwaukee for supporting comingled freight and passenger train operations over this segment.
  - In the Metra commuter territory on the south end of the line, from Union Station to Rondout, there are 109 total conflicts between new and Metra commuter trains. This is 109/38 = 2.87 commuter train interactions per new passenger train between Truesdell and Milwaukee. It is clear that the level of Metra conflict south of Rondout is much greater than the freight conflict north of Truesdell and will require a more aggressive approach to capacity remediation in this section. This result suggests that at least three sections of additional passing track will be needed in this 30-mile stretch to eliminate these conflicts between new and Metra trains. As a practical matter, this result supports the earlier study finding that one track would be needed the entire way from Chicago to Rondout to allow the proposed new service to operate alongside the existing Metra commuter trains.

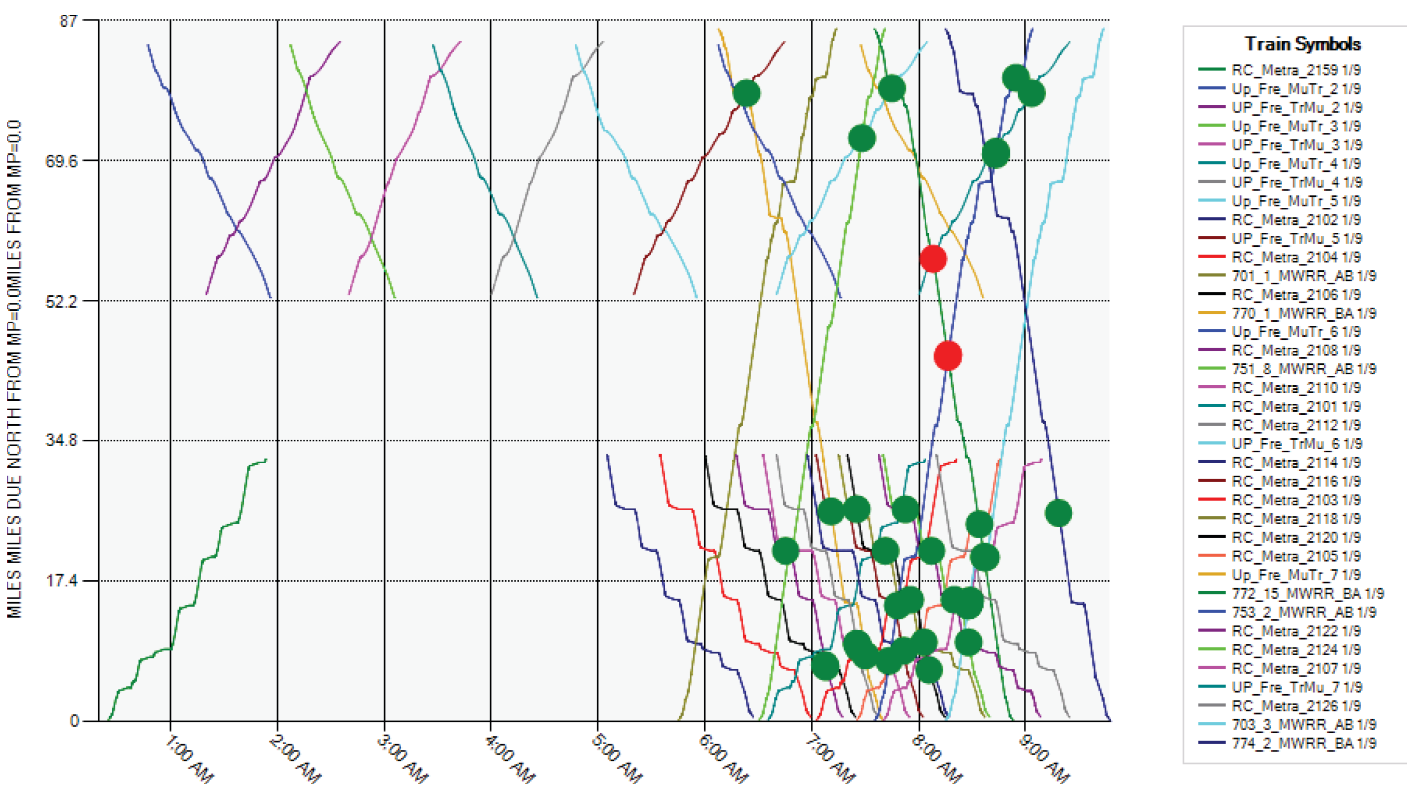
Finding: Just as in Case Study 1: St. Louis to Kansas City, the conflict identifier (CI) identified the same required infrastructure as the detailed MWRRS RTC-based analysis.

This shows the ability of the conflict identifier tool to recognize a reasonable infrastructure requirement for heavily used shared freight corridors. In particular, the key areas of agreement between the conflict identifier analysis and the previous simulation study are the need for adding (1) an additional track from Chicago to Rondout for eliminating Metra commuter train conflict and (2) a passing track halfway between Truesdell and Milwaukee for allowing the added trains to overtake slower freight trains.

3.7 Summary of Findings

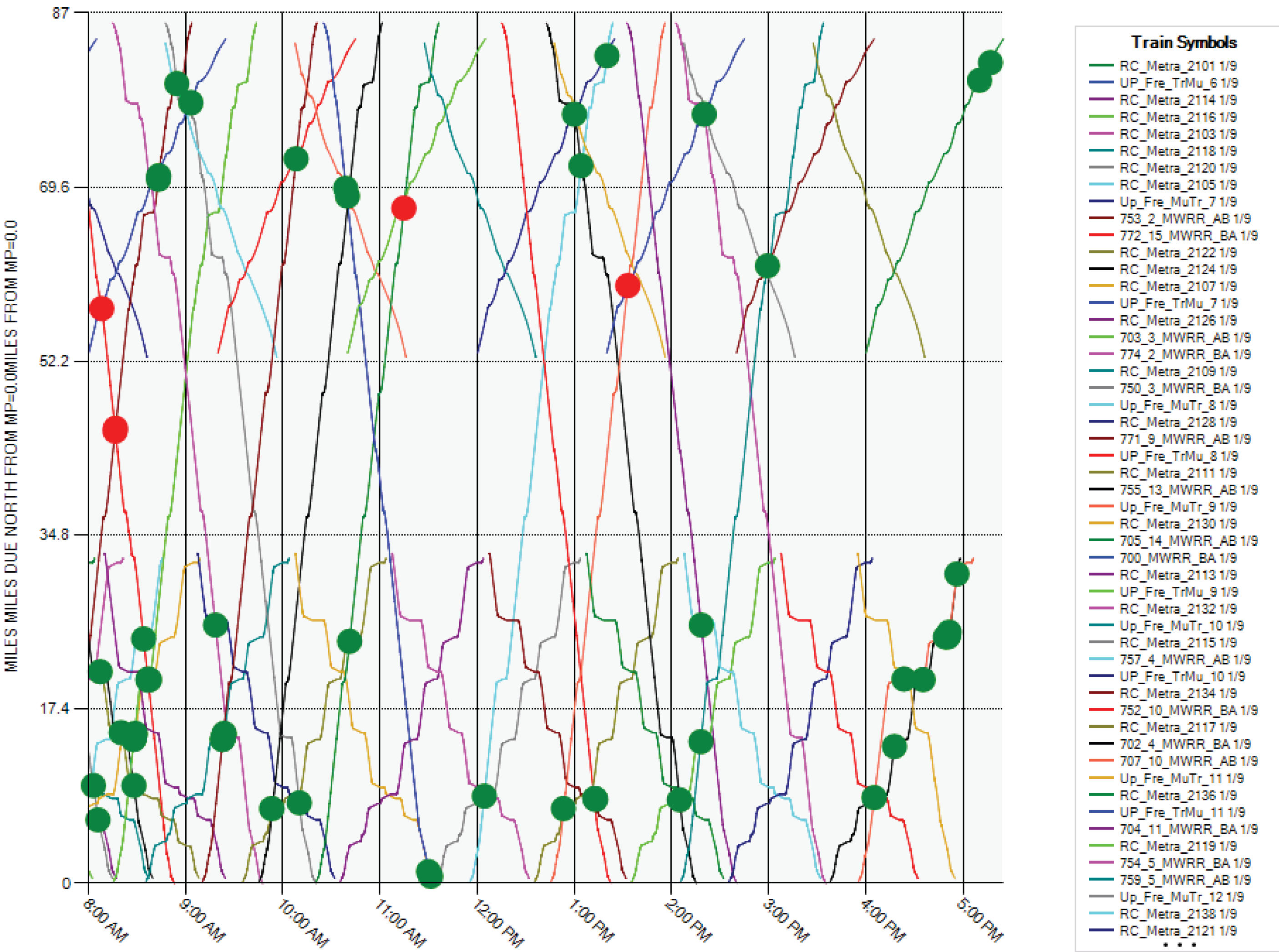
In regard to screening methodologies:

- Five methodological approaches to rail capacity analysis are documented in the literature.



Note: Milepost 0 = Chicago; Milepost 87 = Milwaukee

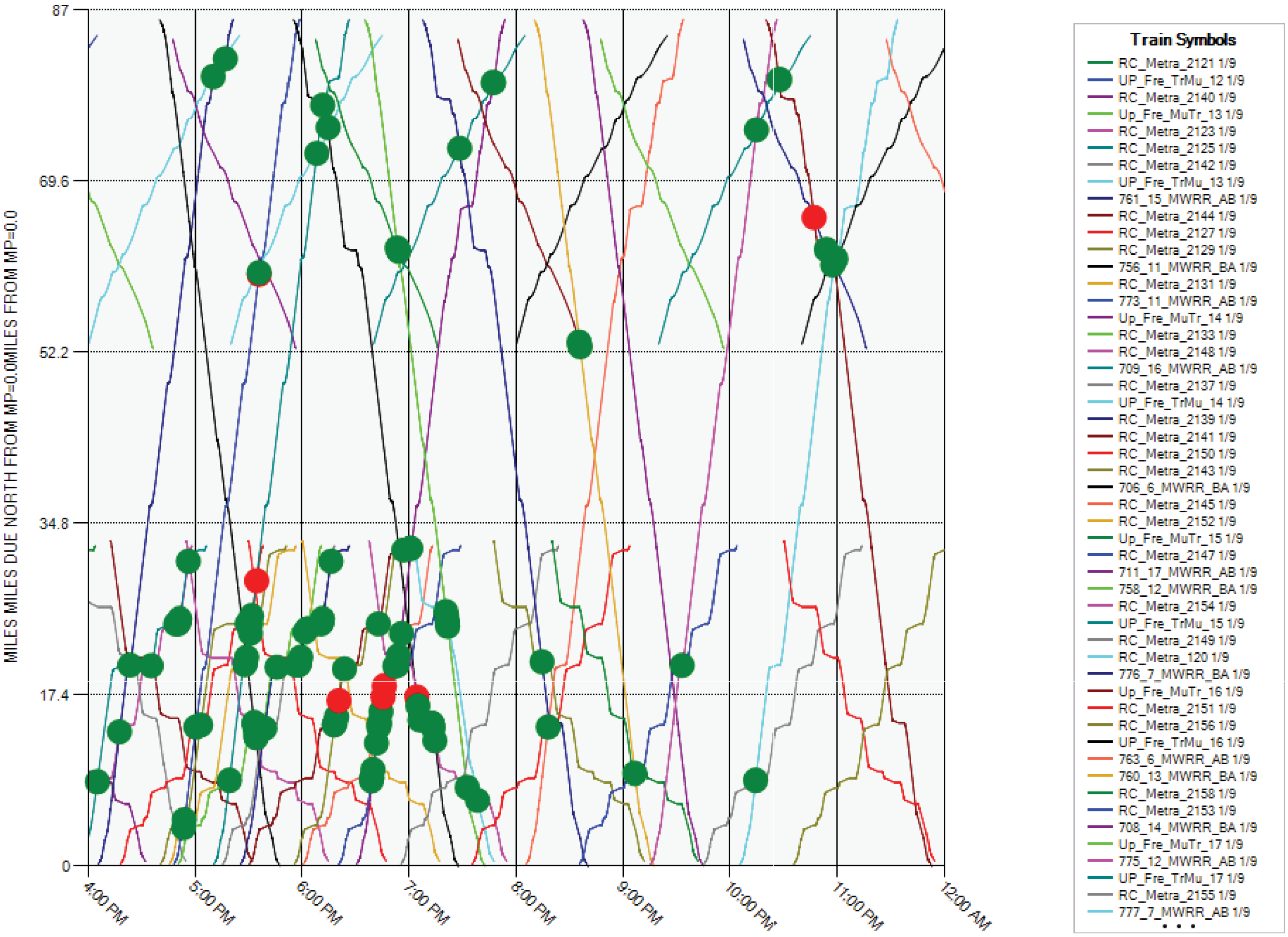
Figure 3-14. Conflict identification "prepare build" 12 A.M.–8 A.M.



Note: Milepost 0 = Chicago; Milepost 87 = Milwaukee

Figure 3-15. Conflict identification "prepare build" 8 A.M.–4 A.M.

- Although the data requirements of a parametric tool are minimal, they are actually not sufficiently tailored to local conditions to produce a credible corridor-specific screening assessment.
- An optimization-based tool is not likely to prove useful for addressing the needs of a Web-based screening tool. The optimizing aspect, related algorithm performance issues, and questions regarding the reality of its dispatching capability render this tool unsuitable for the Web-based screening application.
- Topological methods also show promise and can generate useful metrics. Although the approach was not selected for implementation here, in the future, compression functionality could provide a useful add-on capability to the SU capacity screening tool. The main advantage of topological approaches is their ability to directly identify the bottleneck section(s) of a rail line, pointing directly to the locations where infrastructure additions are the most needed. In this regard, they provide similar functionality to the conflict identification approach because topological approaches can directly find the locations were infrastructure needs to be added. A compression-based methodology is compatible with the CS Study methodology that was proposed by AAR for capacity screening. In the future, consideration should be given to developing an enhanced compression capability to augment the current conflict identification tool.
- In terms of analytical approaches, the conflict identification approach (adopted from the MWRRS Ideal Day method) for adding a siding wherever a conflict occurs was shown to give a reasonable first-cut assessment of infrastructure needs on light-density corridors. As enhanced by this study, the proposed conflict identification methodology is both quantitative and rigorous, without any subjective element or needing an experienced rail analyst, and the approach can be applied regardless of corridor density. This qualifies the conflict identification methodology for effective use as a feasibility screening tool. Phase I research indicates merits of this approach for screening projects.



Note: Milepost 0 = Chicago; Milepost 87 = Milwaukee

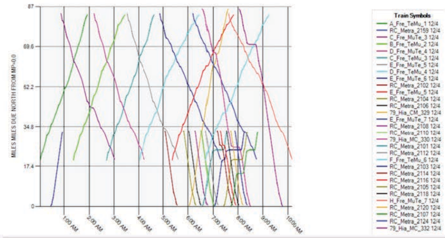
Figure 3-16. Conflict identification "prepare build" 4 P.M.–12 P.M.

- The screening tool also provides a simulation tool that can be used to both validate and support the credibility of the results of conflict identification. The simulation capability is provided as a core feature of the SU tool and has been demonstrated in the case studies.

In regard to data needs and availability:

- At the early stage of planning, proponents are largely "on their own" so that the method relies on publicly available data. Because existing infrastructure is usually clearly visible in Google Earth™ satellite imagery, this can be considered a primary source of existing infrastructure data. Often, current track charts are publicly available or available on request from the freight railroad.
- Traffic data can generally be derived from the FRA National Grade Crossing Inventory and/or from direct field observations of trains moving past highway-grade crossings. State DOTs can directly obtain traffic data based on the STB Waybill Sample and can use this on a confidential basis. Alternatively, a cooperative freight railroad might be willing to supply the needed traffic data on request. Public agencies often can obtain data from a freight railroad by executing a non-disclosure agreement. Even so, the freight railroads are not likely to be willing to commit significant resources to a project until it reaches more advanced project development stages (e.g., EIS) and also on the likely availability of funding to actually complete the project.
- It should be noted that unit costs from other studies need appropriate adjustment for inflationary changes and regional cost adjustment.
- The three case studies indicate the applicability and usefulness of the tool on extremely complex corridors. The case studies show that the conflict identification methodology has been successfully extended so that it is effective for both high-volume and low-volume rail corridors.
  - The St. Louis to Kansas City infrastructure recommendation matches what was recommended by the MWRRS RTC-based analysis.

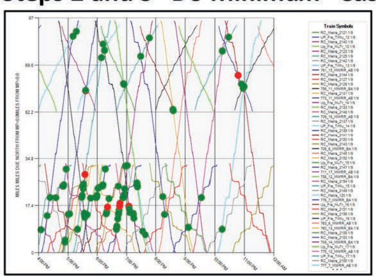
Step 1 Establish Baseline and Evaluate



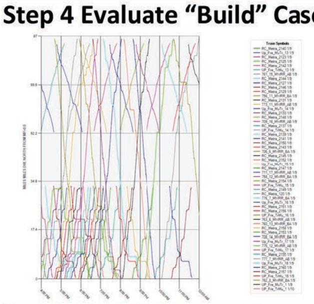
Operational Metrics

Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	28.4	0.0	0.0	0.0	0.0
PASSENGER 1	54.4	5.3	0.0	5.3	19.0

Steps 2 and 3 "Do Minimum" Case and Prepare "Build" Case – Conflict Identification



Step 4 Evaluate "Build" Case



Train Type	Average Speed (in mph)	Percentage of Trains with Delay	Average Delay (in minutes)	Percentage of Trains with Delay Net of Departure Delay	Average Delay Net of Departure Delay (in minutes)
BULK	27.3	0.0	0.0	0.0	0.0
PASSENGER 1	39.9	58.1	27.7	53.8	27.6

Passenger Train	Number of trains	Total time in system (minutes)	Total time waiting in stations (minutes)	Total average speed (mph)	Avg. speed net of wait time in stations (mph)
Commuter train	60.0	64.7	5.5	30.8	34.0
Intercity train	33.0	92.2	0.0	57.1	57.1

Note: Step 1 chart is for 12 A.M.–8 A.M. on day of analysis. Other charts are for 4 P.M. to 12 A.M.

Figure 3-17. Summary of SU analysis, Chicago-Milwaukee Corridor.

  – The NEC study was undertaken as a double-blind exercise without a validation benchmark. However the results of both the conflict identification and simulation screening indicate the potential feasibility of restoring full Norfolk Southern freight service (daytime as well as nighttime) along this section of the Northeast Corridor, if the high-speed *Acela Express* service were shifted away from the existing tracks onto a new parallel high-speed alignment. This suggests the potential for a substantial freight benefit associated with the implementation of true high-speed service between Baltimore and Wilmington. It is suggested that this potential be further explored by future studies.
  – For the Chicago to Milwaukee corridor, the SU tool confirms the capacity mitigation that was developed by the earlier 2004 feasibility study. For supporting shared-use operations, the key areas of agreement needed in this corridor are for adding a track from Chicago to Rondout (for eliminating Metra commuter train conflict) and for adding a passing track halfway between Truesdell and Milwaukee for allowing the added trains to overtake slower freight trains.
- The three high-volume case studies are far more complex than the screening requirement of more typical rail corridors that prospective DOT rail users are likely to encounter. For DOT user training purposes, it is recommended that simpler demo case studies be developed.

The conflict identifier tool performed well in replicating the results of previous, detailed feasibility studies on the two corridors (St. Louis to Kansas City, and Chicago to Milwaukee) for which direct benchmark comparisons could be performed. For the Northeast Corridor, the conflict identifier gave a reasonable and plausible result, both in regard to its assessment of current operations (e.g., minimal conflicts) and to the prospect for restoring freight if the *Acela Express* operations were moved to a separate alignment. This result is reasonable for the NEC because freight did successfully comingle with passenger trains there, prior to the introduction of the *Acela Express* service.

CHAPTER 4

Recommended Approach, Implementation, and Suggested Research

4.1 Introduction

This research has produced a software tool called Shared-Use (SU) and a users manual whose underlying methods and effectiveness for corridor planning have been demonstrated in three case studies. The tool meets the research objective and should prove a useful and effective tool in support of screening proposed new rail services in shared-use corridors.

This chapter has three subsequent sections. The first section includes the recommended approach for the design of the Web-based tool given the findings from the review of methodologies. The second section describes the implementation of the Web-based tool. The final section includes suggested research and next steps.

4.2 Recommended Approach for a Web-Based Tool

- Description of the Web-based tool,
- System goals and constraints,
- SU system features, and
- SU use cases.

4.2.1 Description of the Web-Based Tool

This section describes the recommended approach for the Web-based tool, beginning with a general description of its system architecture.

The Web-based tool will be a three-tiered (presentation, business logic, database) application with standard multi-user, account-based data support and security features. The capabilities of the Web-based tool for shared-use rail corridor feasibility screening can be divided into the following three groups:

- Data development,
- Analysis modalities, and
- Results exposition.

An overview of the approach for SU is provided in Figure 4-1.

4.2.2 System Goals and Constraints

The system goals and constraints that guided the development of the recommended approach are as follows:

- Overarching Goal—SU will be an effective tool for pre-feasibility screening of shared-use rail corridor projects.
- Web-Based—SU will be deployed on a central server that users will access via the Internet with a minimally configured computer and Web browser equipped with the Microsoft Silverlight add-on, available as a free download (*71*).
- Configurability—SU is intended for corridor-specific analyses and will be generally applicable to a broad range of rail corridors and traffic control systems. System users must be able to provide input data and parameters as required to accurately simulate a specific rail system.
- Usability—The system will be accessible and, with minimal training, usable by government personnel, other rail project proponents, and their consultants.
- Standards Based—SU will be developed from widely used technologies without reliance on specialized tools or skill sets (minimizing vendor and consultant lock-in).
- Flexibility—SU will enable users to manage and organize related datasets (e.g., track plans, operational plans, train sets, randomization parameters, and analysis results) to support various analysis scenarios and rail systems and to support easy modification of scenarios as project plans evolve over time.
- Performance and Scalability—SU will be able to perform realistically complex analyses of sufficient duration that provide robust results for specific corridor feasibility assessments, while achieving an optimal balance of run time and system resource utilization.

4.2.3 SU System Features

SU conducts preliminary feasibility analyses of proposed shared-use rail corridors. The main purpose of SU is to screen

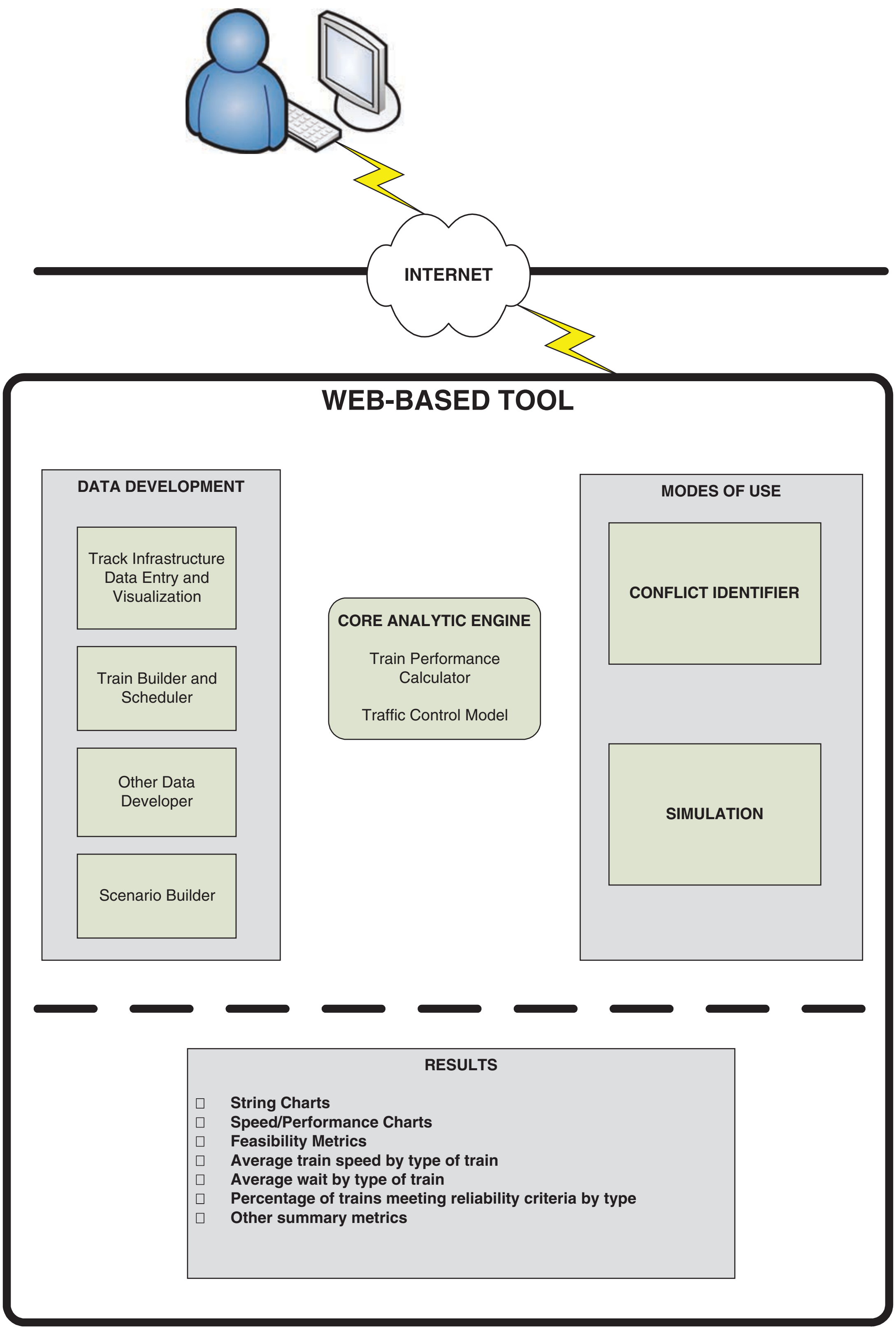


Figure 4-1. Recommended approach.

projects—removing unworthy candidates from further consideration while flagging those having merit for additional, more rigorous analysis.

Key features of system include the following:

- General
  - Ability to manage, share, and manipulate data representing a railroad's physical plant; train schedules, traffic volumes, and train consists; railroad operating schedules; traffic control; alternative analysis scenarios.
  - Ability to store and retrieve input data and results.
  - Ability to conduct meaningful pre-feasibility analyses in support of project screening.
- Data entry and visualization
  - Ability to define and develop datasets in support of screening analyses.
  - Ability to enter and visualize track and related railroad physical plant data, including adequate detail to account for grade, curvature, and track needed to manage over-the-road (outside yard and terminal limit) operations of freight and passenger trains.
  - Ability to enter train, train consist, and schedule data, including built-in libraries of rolling stock to cover a wide range of operational scenarios.
  - Ability to enter data to support a minimal set of unit costs and other assumptions.
- Conflict identification
  - Ability to identify points of potential conflicts (meets of opposing trains and overtakes by fast trains). The basis for conflict identification will be simulated movements in which conflicts are ignored (i.e., movements are unimpeded as if there were infinite capacity), but are identified in reports and graphical representation.
  - Ability to indicate location and type of infrastructure modification that mitigates unacceptable levels of conflict.
- Simulation
  - Ability to model detailed train movement including time, position, speed, and the forces acting on a train. Train movements account for changes in terrain and track curvature as a train moves through a defined territory while observing speed limits and directives for routing and movement authorizations.
  - A central dispatcher that prioritizes train movements, makes routing decisions, prevents train deadlock, and effects the safe separation of trains.
  - Ability to specify the random distribution of departure delays affecting each scheduled train.
- Results exposition
  - SU will contain a set of tables and charts for reporting results and enabling the screening of candidate passenger rail projects.
  - System outputs will include raw outputs (time-speed-position data of trains, dispatcher authorizations to trains by time, added infrastructure cost estimates, numbers of conflicts, numbers of meets/passes) and processed outputs (string chart, speed chart, authorities chart, total delay, and by components).

4.2.4 Use Cases

Use cases describe how an "actor" interacts with the system. The primary actor for the system description is the SU user. An additional role and its functions will be defined in the system documentation for the SU administrator.

Registration

The user will browse to a URL, encounter an introductory page and, if not already registered, he or she will be prompted to register. Registration will establish a user ID and password, set up an account, and seed the account with necessary start-up data and files.

Login

The user logs in with his or her credentials (user ID or password). Login will include a forgotten password recovery feature.

Folder Maintenance

Folders will contain user data. This use case provides the ability for the user to archive and download a folder to the local computer, upload and restore an archived folder, set a folder to be used as default, reload the default folder, add a new folder, and delete a folder.

Maintain Rail Infrastructure

This use case provides the ability for the user to add or delete tables representing rail infrastructure data for the corridor of study.

Set Up Trains

This use case represents the ability of the user to view and update train information including train consists and schedules.

Edit cars. The user specifies physical car attributes including car type, weight, length, load limits, number of axles, and reference documentation.

Edit locomotives. The user specifies physical locomotive attributes including length, transmission factor, weight, rated power (HP), type, axles, driven axles, and air resistance.

Edit trains. The user develops train consists, selecting from user-defined or system-provided cars and locomotives, and provides a name for the train.

Edit schedules. The user specifies a schedule for each train, providing scheduled station arrival and departure times and days of operation.

Set Up Analysis

This use case describes how the user sets up analysis and traffic control parameters and runs the analysis.

Set Up Traffic Control

The user provides various traffic control parameters that influence the dispatcher algorithm.

Set Up Speed Restrictions (GCOR Forms A and B)

The user may apply temporary speed restrictions conforming to standard rail operations in the General Code of Operating Rules–Forms A and B (*72*).

Select Trains

The user selects from among the defined trains and also may set up a distribution (mean and standard deviation) for generating a random schedule delay for each train.

View Track Schema

The user may view a previously provided schematic diagram of the track schema.

Run Analysis

The user provides (or overwrites the default value of) a results file name, analysis start date-time, and end date-time. Optionally, the user may modify the random seed value, choose to ignore weight restrictions, and enable or disable real-time reporting. The user also may save the current settings as a job to be run at a later time. Once the parameters are set, the user invokes the analysis.

View Results

This use case describes how the user views analysis results. The user selects from a list of results files to view. The user may also delete, rename, or share/unshare selected results.

View table. The user may view raw analysis data in table form for a selected train.

View speed chart. The user may view a chart showing allowed and actual speed over the distance traveled for a selected train along with the corresponding terrain elevation profile.

View string chart. The user may view a chart showing time and distance of train meets.

View block authorizations chart. The user may view a chart showing locations and time spans of authorizations granted to all trains.

View block authorizations table. The user may view a chart showing authorizations in tabular form for a selected train.

Node Network Diagram

The user may view a previously provided schematic diagram of the node network.

4.2.5 Data Development Capabilities

Data development capabilities refer to the features that allow users to populate the tool, or that facilitate the process of doing so. The data development elements are the following:

- Track infrastructure data entry and visualization,
- Train builder and scheduler,
- Other data developer, and
- Scenario builder.

These elements are described in the following subsections.

Track Infrastructure Data Entry and Visualization

Infrastructure data permits users to fully characterize the rail system and support analyses with the screening tool. The process of entering data into the tool can be facilitated with the introduction of a data visualization tool, which permits users to build, visualize, and validate rail system data. With the integrated data visualization tool, the user will develop rail infrastructure datasets within the SU software and store them in the database. The following items are part of the visualization tool use case.

Set up or modify rail infrastructure dataset identifiers. The user specifies a rail infrastructure dataset including the name of the system whose rail infrastructure is being developed, the length of the corridor, and other characteristic data.

Set up or modify rail infrastructure system boundaries and timetable routes. The user specifies the boundaries of the system including its entry and exit points, stations, and timetable routes.

Set up or modify complex items. The user specifies complex rail facility data such as crossovers, track interconnections, diamonds, double-ended sidings, slips, and multiple tracks.

Set up or modify ancillary items. The user specifies ancillary data such as bridges and tunnels, highway-grade crossings, junctions and single-ended sidings, and yards.

Generate or modify node network. The node network is a logical construct that is developed from the track data and is a required component for effecting deadlock-free traffic control. The user will be able to generate a basic node network or modify it.

Train Builder and Scheduler

When rail infrastructure data is imported into the tool, the user must define the trains that will operate over the simulated corridor. The tool will provide forms for building train consist data, with the ability to select from an inventory of car and locomotive data. A scheduling feature will also permit users to select schedules for each train, which include the days of operation, departure and arrival times, and station stops along the timetable route.

Other Data Developer

In addition to rail infrastructure and traffic mix data, users must define infrastructure unit costs. The unit cost component is intended to estimate infrastructure costs for added capacity required to integrate passenger and freight trains.

Scenario Builder

The Web-based tool will have a scenario builder, capable of conducting analyses for each mode of use. A scenario consists of a list of trains (developed with the train builder), a simulation start and end date, a set of a traffic control parameters, and optional features such as GCOR Forms A and B, temporary track outages, or train crew work schedule settings. The tool will allow users to save built scenarios and load them for future analyses.

4.2.6 Data Development Functionality

Grade and Elevation Data

The user enters data for track grade by section, which is the change in elevation divided by the length of the section (expressed as a percentage). Elevations at the section endpoints are derived from the grade information.

Curve and Heading Data

The user enters data for track curvature of a section, which is given by the section length and an angle of curvature. Headings at the section endpoints are derived from the curvature information.

Speed Zone Data

The user specifies the speed zone data for each track segment, defined as the maximum allowable ("normal" or "track") speed, by train class, on all portions of track within the segment (expressed in miles per hour).

Traffic Control Data

Signals. The user specifies the signals associated to specific tracks, specifying their type (e.g., automatic block signaling or ABS, centralized train control or CTC, positive train control or PTC), the side of the track they are on, and the direction(s) they face.

Control points and towers. The user specifies the control points and towers associated with interlock complexes, specifying a control point symbol, which indicates a location where switches or signals are remotely controlled by a dispatcher, and providing a milepost to specify their location.

Interlockings. The user specifies each interlocking by selecting a set of switches and signals that allow trains to safely switch or cross tracks where there may be some potential for a train collision.

Ancillary Data

Bridges and tunnels. The user specifies bridges by selecting type (drawbridge, over, tunnel, under, or viaduct), the beginning milepost, and bridge or tunnel length in feet.

Crossings. The user specifies highway crossings at grade, specifying milepost number, crossing name, description, and level of crossing protection (e.g., flashing lights, flashing lights and gates, private crossings, and signal-only cross-bucks).

Crossovers and track interconnections. The user specifies crossovers and track interconnections, specifying the turnouts, their milepost location, and a speed restriction based on the sharpness of the turnouts used.

Diamonds. The user specifies diamonds, specifying the number of tracks involved (single or double) and the direction (left, right, and perpendicular).

FRA track class. The user specifies the FRA track class, specifying the maximum speed limit for each train type (passenger or freight) and track class (Class I through VII).

Track weight limit. The user specifies the maximum carload weight limit (e.g., 286K lbs.) for the track.

Junctions and single-ended sidings. The user specifies junctions, noting the single-ended siding or series of sidings that create a connection to another route, railway, or significant yard complex.

Multiple tracks. The user specifies multiple tracks, including double, triple, and quadruple track types. The user specifies maximum speed by train class and a normal operating direction.

Double-ended sidings. The user specifies the double-ended siding, specifying the points on the track that it connects to, and its position relative to the main track (above or below).

Slips. The user specifies each slip, or slip-switch—a complex switch-point work incorporated in yards and stations where the properties of a diamond and turnout are combined—specifying their milepost and designation (double or single).

Yards. The user specifies each yard, specifying its name, position relative to the main line (above or below), and the range of mileposts over which it extends.

Other Data

The user specifies basic unit cost information that will enable a rough order of magnitude calculation of improvement costs. The system will include aggregate level high- and low-value guidance for several cost metrics.

4.3 Web-Based Tool Implementation

The Web-based tool, whose design was described in the previous section, was implemented on a Web CMS called DotNetNuke™ (DNN) (*73*). A Web CMS is a bundled or stand-alone application to create, manage, store, and deploy content on Web pages. Web content includes text and embedded graphics, photos, video, audio, and code (e.g., for applications) that displays content or interacts with the user. A Web CMS

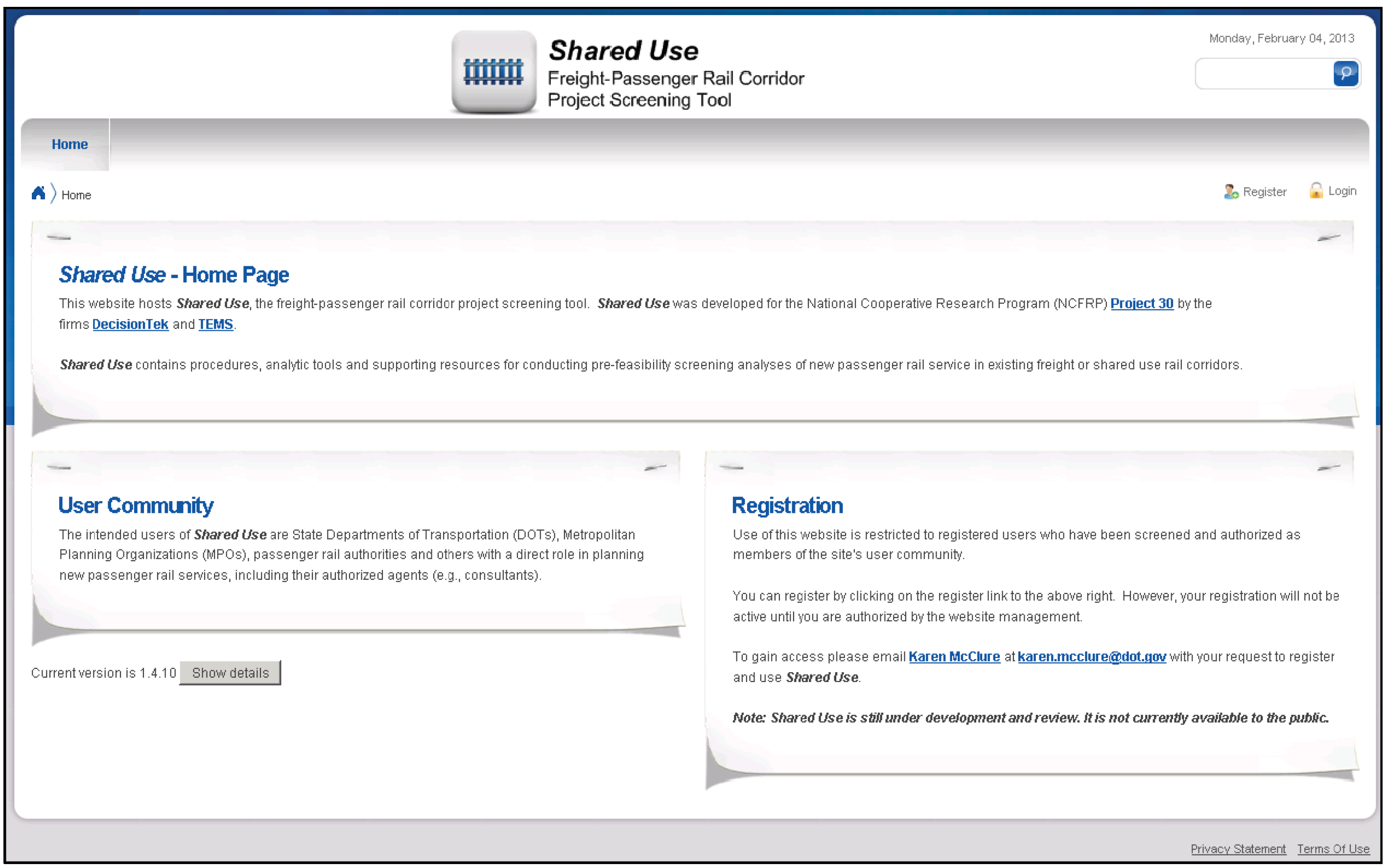


Figure 4-2. SU home page.

may catalog and index content, select or assemble content at runtime, or deliver content to specific visitors in a requested way, such as other languages. Web CMSs usually allow client control over HTML-based content, files, documents, and Web hosting plans based on the system depth and the niche it serves.

DNN is built on the Microsoft ASP.NET Web development platform, and the DNN community edition that was used is both royalty free and open source. Many of the commonly used features of a Web-based system (e.g., registration, login) are built in to DNN. DNN permits the integration of custom-coded components, which is where all the SU programmed elements are contained.

4.3.1 User Interface

The user interface is a standard Web page, accessible on the FRA datacenter). From the home page, access to the system is limited to users who are registered and authorized by the system administrator.

After login, users can access all of the system's features through the main menu. The menu structure of SU is shown in Figure 4-3. SU includes an RIA called the Track Charting App that enables users to visualize and modify rail infrastructure data directly on a graphical user interface. Figure 4-4 shows a sample screen shot from the Track Charting App.

All of the features of the Web-based tool and their use are explained in the users manual available on the FRA website.

4.3.2 Database

The data for SU analyses, inputs, and outputs, are stored on the system database, which is implemented on an instance of SQL Server. Users may choose to archive their data to a local computer and restore them to the system database for use with a future session with SU.

4.3.3 Runtime Console Application

After users have prepared their data for running an analysis on SU, they submit an analysis job to the SU job queue. A separate console application runs on the server that polls the database and job queue for submitted jobs and executes jobs based on submittal time (first submitted, first executed). The actual runtime logic for SU analyses is implemented in the console application.

4.3.4 Hosting Environment

The system has several components that require hosting for Internet-based use as follows:

- Web server,
- Database, and
- Runtime console application.

All of these components could be hosted on a single physical or virtual server. However, the requirements for the Web application are relatively light while the database and runtime console application require significant CPU and memory resources. For this reason, it is recommended that SU be hosted on a local area network with two servers:

1. Shared or virtualized Web server,
2. A database server and runtime console application.

The specifications for the two servers shown in Table 4-1 should deliver good user experiences.

The Web experience will not degrade with even 100 simultaneous user sessions—well beyond the anticipated maximum use of the system. Submitted jobs, however, could take up to 5 minutes each to run. Many users submitting multiple jobs simultaneously could result in long wait times. A future improvement could allow for multiple instances of the console application running simultaneously to reduce wait times.

4.4 Suggested Research and Next Steps

The SU Web-based tool is a complete and tested product that should prove its usefulness with practitioners. Experience shows that the adoption of tools can be accelerated through appropriate improvements so that the return on the research investment is maximized. The proposed improvements to the Web-based tool have been divided into the following three categories:

- Refined capabilities,
- Integration with corridor planning process, and
- Walkthrough examples.

4.4.1 Refined Capabilities

The following are proposed refinements to the Web-based tool that will enhance its performance and make it applicable to more operationally complex situation than in its current form.

Dispatcher Algorithm Refinements

The central dispatcher (CD) algorithm in SU is a deadlock-preventing algorithm. However, it makes decisions to grant authorities that may cause high-priority trains to be blocked for extended periods resulting in unacceptable outcomes.

The existing rule-based algorithm can be extended with user-specified strategies, combinatoric methods, and heuristic

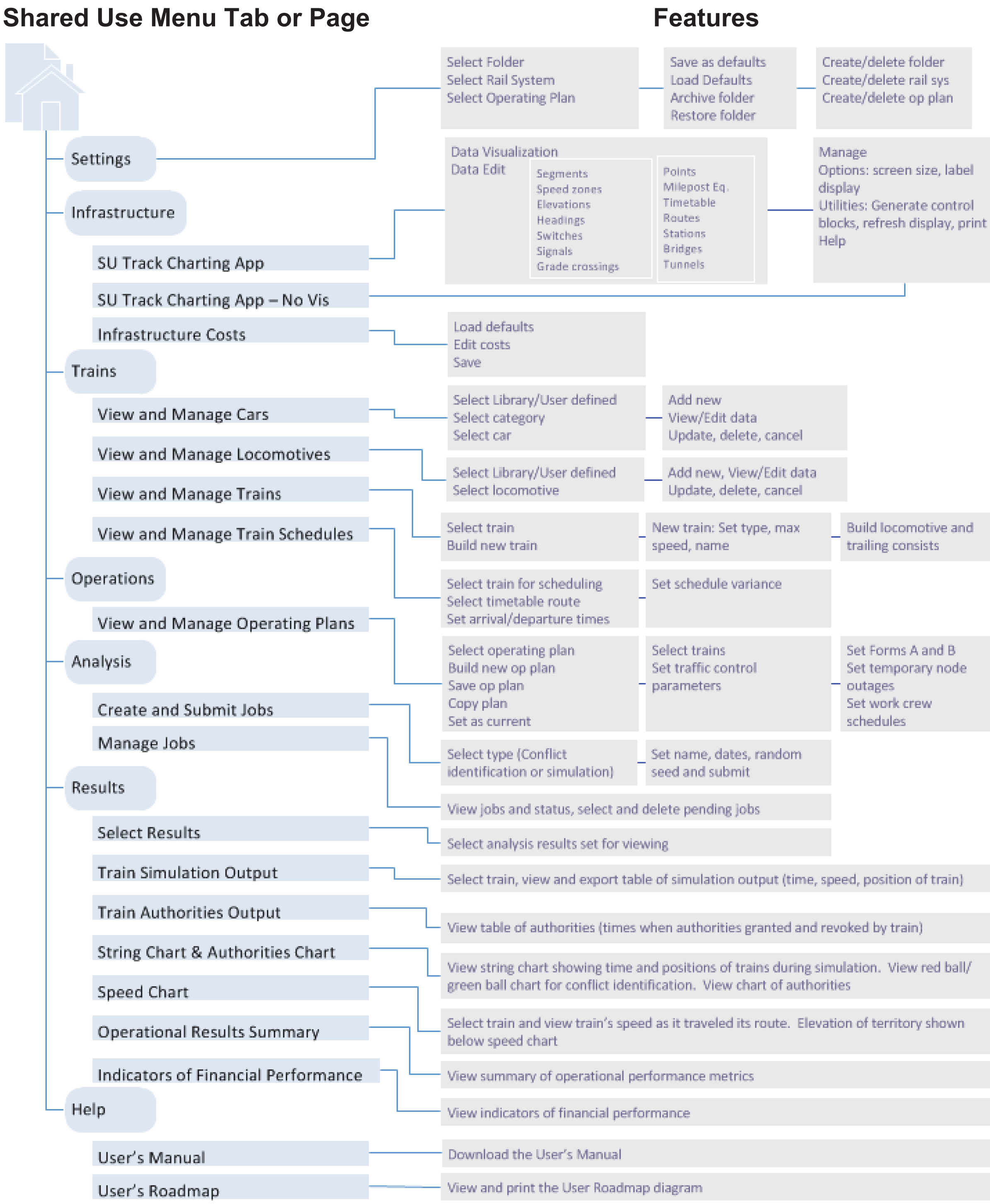


Figure 4-3. SU menu structure.

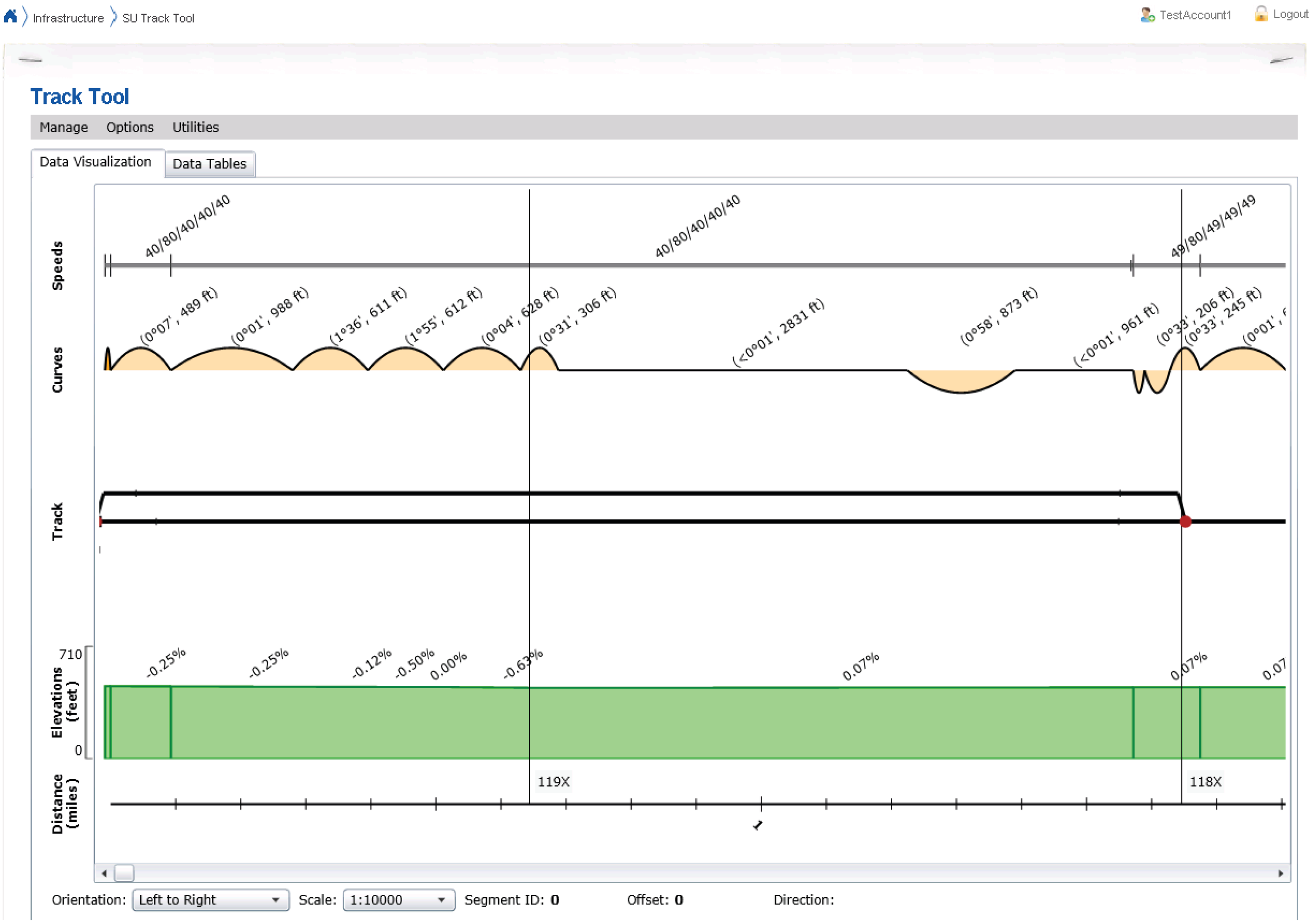


Figure 4-4. SU Track Charting App.

Table 4-1. Specification of servers hosting SU.

	Operating System	CPU	Random Access Memory	Disk Requirement	Other Specifications
Web server (if virtualized, resources available to the virtual machine)	Windows Server 2008 R2 or 2012	Single, multi-core processor	4GB	50GB	Installation of .Net framework and DotNetNuke
Database server and runtime console application	Windows Server 2008 R2 or 2012	Dual, multi-core processor	32GB or more	200GB (preferably inline SAS drives)	SQL Server 2008 R2 or 2012

methods so that it will generate acceptable outcomes in a wider range of operational situations than currently available.

The three proposed improvements that would make SU more applicable to many challenging operational situations where it currently has limited usefulness are as follows:

- Automated repeated simulations;
- Find best dispatching from multiple sketch runs, then apply to full simulation; and
- Apply a priori heuristics.

The following sections describe these improvements.

Improvement 1: Automated Repeated Simulations. The proposed improvement is to halt a simulation when it encounters a "fail" condition (e.g., passenger train delayed more than 20 minutes), then re-run the simulation with a new random seed or alternate set of inputs. Continue running simulations until one finally completes without hitting a fail condition.

One advantage of this approach is not waiting until a simulation completes once it fails. For instance, a simulation with a 5-minute run time may hit a fail condition after just 1 minute.

Improvement 2: Find Best Dispatching from Multiple Sketch Runs, then Apply to Full Simulation. About 70 percent of simulation time is spent on the train movement algorithm. A "sketch" run would approximate train movement. In a short time, multiple sketch simulations could be run while tracking the CD decisions. Then, a set of CD decisions would be selected based on the sketch run with the least estimated delay. Finally, the selected set of CD decisions would be applied to a full simulation.

Improvement 3: Apply a Priori Heuristics. Although there is no way to ensure a particular outcome, simulation results can be improved by selectively applying some strategies and combinations of strategies. For example:

- Let trains of a particular type (e.g., freight) only advance along buffers and not by single nodes,
- Set conditions for holding trains that will permit higher priority trains to advance, and
- Designate certain track elements as freight only or passenger only.

Train Movement Algorithm Refinements

The train movement algorithm was adopted from the Train Performance Calculator developed at the Volpe National Transportation Systems Center. The algorithm is general, but more closely tailored to freight trains. There are multiple passenger train technologies that warrant dedicated refinements to the train movement algorithm in order to better reflect the train movement of passenger trains (i.e., acceleration, deceleration, braking, performance on different terrains, and refined fuel consumption calculation). This refinement would enable SU to report more reliably on the advantages and disadvantages of alternative passenger train technologies and their comingling with freight traffic.

Data Conversion

The effort of data entry is a significant impediment to adoption, and this could be reduced if there were more features that enabled the conversion of data from other widely used simulation programs. Additional data interchange methods would speed adoption of SU.

Additional Operational Strategies

SU includes a number of features to capture special operating conditions (e.g., slow orders, work zones, temporary track closures). A number of additional features that would support real-world operating conditions and operating strategies that railroads employ could be added to SU to better replicate actual operations.

Additional Planning Features and User Interfaces

With a series of user workshops, feedback could be solicited that could guide additional development that would facilitate ease of use and potential adoption of SU.

4.4.2 Integration with Corridor Planning Process

Additional guidance could be developed along with software modifications that could support the integration of SU with the corridor planning process to reduce the difficulty and cost of complying with the process.

4.4.3 Walkthrough Examples

A number of additional step-by-step walkthrough examples of new services and corridor enhancements would help users adopt and make the best use of SU.

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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