Submitted To

Rocky Mountain Rail Authority

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High-Speed Rail Feasibility Study Business Plan

Submitted by

TEMS

Transportation Economics & Management Systems, Inc.

in association with
Quandel Consultants, LLC
GBSM, Inc.

Preface

The Rocky Mountain Rail Authority (RMRA) hereby submits the final report for the feasibility study conducted with an allocation from Senate Bill 97-001 transit funds and the contributions of 52 local governments and transportation special districts and authorities in Colorado. The study was conducted over a period of 22 months beginning in June 2008 and ending in March 2010. The Rocky Mountain Rail Authority worked closely with local municipal leaders and staff in both the I-25 and I-70 corridors to gather input on various aspects of the potential projects including alignment, technologies, station locations, community/social/economic issues, and more.

The RMRA Board is grateful for the professional management guidance provided by the consulting firm PBS&J, the extensive analysis performed by the study consultant, Transportation Economics & Management Systems, Inc. (TEMS) and the uncountable hours of voluntary work by the members of the Feasibility Study Steering Committee and Board. RMRA member agencies are represent counties, municipalities, and regional governments along the Front Range from Trinidad to Ft. Collins and the I-70 Mountain Corridor from Denver to Grand Junction. These member agencies and their representatives are listed in Appendix A. The RMRA Board also wishes to acknowledge the financial support and technical guidance provided by the Colorado Department of Transportation.

The RMRA Study demonstrates the feasibility of developing high speed transportation corridors generally paralleling two major Interstate highways in the Colorado. The corridors studied were I-70 from the Denver International Airport to Grand Junction and I-25 from Fort Collins to Trinidad. To illustrate one feasible alternative, a more detailed example was developed using the conservative assumptions required by current Federal Railroad Administration standards and currently available technology. That alternative is referred to as the FRA Developed Option; but should not be interpreted in any way to preclude the development of other alternatives based on emerging technologies better suited to one or both major corridors.

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Table of Contents

Appendices

List of Exhibits

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1 High-Speed Rail Planning Process

1.1 Study Objectives

This Rail Feasibility Study has been prepared for the Rocky Mountain Rail Authority (RMRA) to provide an assessment of the feasibility of providing intercity rail service in the I-70 and I-25 corridors as shown in Exhibit 1-1, including secondary corridors to Craig through Steamboat Springs, Aspen, Breckenridge, Winter Park, and Central City. In assessing feasibility and evaluating options, it specifically uses the Federal Railroad Administration's (FRA's) public-private criteria[1] and six feasibility factors that are critical to receiving a FRA High-Speed Rail Designation for each project corridor.

Exhibit 1-1: Potential Colorado High-Speed Rail Corridors

[1] High-Speed Ground Transportation for America, USDOT FRA 1997, and Maglev Deployment Program: USDOT FRA, 1999

By meeting FRA criteria, the RMRA High-Speed Rail Feasibility Study provides a mechanism for supporting:

- Designation of Colorado I-70 and I-25 corridors as high-speed rail corridors
- Potential Federal funding (most likely 50-80 percent) for a proposed project
- Creation of a high-speed rail project that might be developed as a public-private partnership by the communities of Colorado.

The overall objective of the study is to complete a fresh, objective assessment of the feasibility of implementing high-speed rail service in the Colorado corridors and to identify the next steps that should be pursued by RMRA and partner agencies in the implementation of that service. By building on previous efforts, coordinating closely with other ongoing relevant studies, surveying stakeholders within the two corridors, and identifying the most effective high-speed rail options for each corridor, the RMRA and Colorado are positioned to gain high-speed rail designation from the FRA for the two corridors.

The FRA public-private partnership criteria, which are explained further in Chapter 9, are:

1. Positive operating ratio (operating revenue/operating costs > 1.00)
2. Positive cost benefit ratio (total project benefit/total project cost > 1.00)

The six FRA high-speed rail feasibility factors are as follows:

1. Whether the proposed corridors include rail lines where railroad speeds of 90 miles or more per hour are occurring or can reasonably be expected to occur in the future.
2. The projected ridership associated with the proposed corridors.
3. The percentage of the corridors over which trains will be able to operate at maximum cruise speed, taking into account such factors as topography and other traffic on the line.
4. The projected benefits to non-riders, such as congestion relief on other modes of transportation servicing the corridors.
5. The amount of Federal, state and local financial support that can reasonably be anticipated for the improvement of the line and related facilities.
6. The cooperation of the owner of the rights-of-way that can be reasonably expected in the operation of the high-speed rail passenger service in the corridors.

Additional objectives for the study are as follows:

1. To identify the most feasible technology(s) that are applicable for Colorado (recognizing that these technologies may vary depending on the corridors).
2. To identify the need for and benefits to Colorado of implementing high-speed rail service.
3. To identify opportunities and concerns of local governments within the corridors regarding implementation of high-speed rail service.
4. To define potential station locations and pros and cons of each.
5. To identify the opportunity to maximize the use of existing transportation corridors.

6. To identify recent and emerging vehicle and guideway technology innovations having potential to minimize cost and environmental impacts, particularly in the mountainous terrain of the studied corridors. This has been addressed in Appendix K.
7. To identify systems that are inter-operable in the primary corridors and that could be developed in system phases.

1.2 Alternatives Development and Business Planning Process

To ensure all of the FRA criteria and factors are fully evaluated, the study team has used a Business Plan Approach. As specified by the FRA, the selection of an appropriate high-speed rail system is "market driven." The difference in the selection of one high-speed rail option over another is heavily dependent on the potential ridership and revenue. A set of reasonable alternatives have been developed for evaluation based on the potential of each alignment option to improve market access, raise train speed, or to reduce cost. These alternatives provide a full range of tradeoff options for configuring the rail system to best meet Colorado's need.

To ensure that market potential is properly measured, the TEMS Business Plan Approach carries out a very detailed and comprehensive market analysis. The output of this market analysis is then used to determine the right rail technology and engineering infrastructure for the corridors. The Business Plan Approach, as shown in Exhibit 1-2, sets out a six-step process for accessing corridors and measuring FRA issues and criteria. The six steps are:

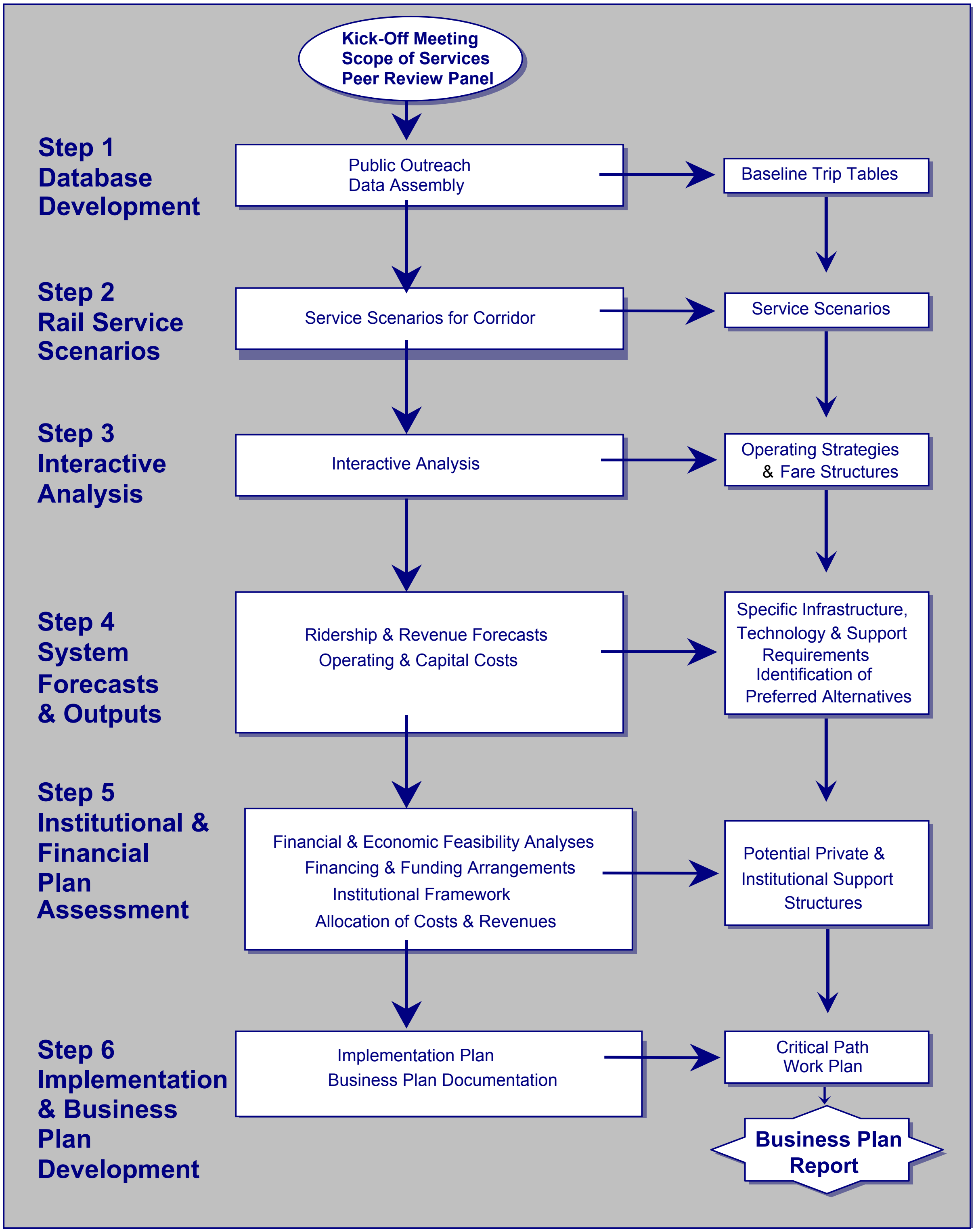
1. Public Outreach and Database Development – Assembling the engineering, market, operational, technology, and community station data as input to the process.
2. Formulation of Rail Service Scenarios – Setting up the rail/maglev options to be considered for the study.
3. Interactive Analysis – Assessing engineering, market, operational, technology, and land use data to identify and develop the most effective rail/maglev alternatives.
4. System Forecasts and Outputs – For the most effective alternatives, generating ridership, revenue, operating costs, capital costs, and financial and economic feasibility solutions.
5. Assessment of Institutional and Financial Plan Options – Developing the institutional framework, and funding plan for developing the Rocky Mountain Rail System.
6. Implementation and Business Plan – Developing both Implementation and Business Plans along with pro forma financial cash flows.

The study methodology was developed to ensure an appropriate balance between market potential, train operations, and engineering costs for a feasibility study. It provides an understanding of the financial and economic value of selected alternatives and the needs of the implementation process in terms of both the timeline to implement the proposed system and the funding requirements during implementation. The method reflects closely the procedures adopted by the USDOT FRA for high-speed rail and maglev planning as defined by their own publications:

- High-Speed Ground Transportation of America, USDOT FRA, Sept. 1997
- Maglev Deployment Program, USDOT FRA, 1999

The result is an assessment that is intended to fully satisfy Federal requirements for qualifying for high-speed corridor designation and funding, while remaining sensitive to local needs and preferences.

Exhibit 1-2: Business Plan Six-Step Process



1.3 Public Involvement Process

The public outreach process was designed to ensure that the study is sensitive to the ideas and concepts of the communities along the I-70, I-25 and secondary corridors and recognizes their needs for improved transportation, as well as their concerns about quality of service, system cost, the environment, and economic development. The aim of this process has been to ensure that the communities' voices are heard, and that the high-speed study is designed to maximize their interests. To meet this need the following outreach program was implemented. The outreach program is described more fully in Appendix M.

In each of the two primary corridors and secondary corridors specified previously, appropriate local government, MPO, Transportation Planning Regions (TPR), Transportation District or Authority, Public Land Agency, and the I-70 Coalition have been consulted regarding possible alignments (on-grade or aerial), station and vehicle support facility locations, and vehicle technologies. To do this, three Corridor Input Teams were formed: I-70 Corridor Input Team, Denver Metro Input Team, and I-25 Corridor Input Team. For each Input Team, a series of workshops were conducted. The Corridor Teams met three times:

- Scoping (September 2008) to gather data on local needs and desires.
- Alternatives Selection (December 2008) to help develop high-speed rail alternatives.
- Alternatives Analysis (April 2009) to gather data on the evaluation process and results.

These workshops explored the following:

- Identification of regional transport needs and the role of high-speed rail.
- Identification of potential station locations (note: the I-70 Coalition Land Use Planning Study provided proposed station locations and potential alignments for the I-70 corridor.)
- Identification of willingness of local governments to implement land use planning and zoning changes necessary to support the rail passenger alignment, location and development of rail stations and associated Transit Oriented Development, and vehicle support facilities.
- Identification of potential community, social and economic issues related to the development of high-speed passenger rail service.
- Identification of potential impacts to public lands.

Input relating to the rail system alternatives has been obtained from RMRA member jurisdictions (see Appendix A) and Colorado's general public and incorporated into the study. The study team has coordinated with business, non-profit and economic development organizations to develop a community partnership program. As part of this program, the study team has developed a series of communication tools including project website, community partnership program, media relations, and community presentations. These were used in providing communications updates for participating organizations to distribute to their members and other interested stakeholders across the diverse regions of the study area. The Business Plan identifies how the high-speed rail proposals meet areas of concern, identifies outstanding issues, and specifies critical travel needs assessed through this public outreach process.

1.4 Peer Review Process

A Peer Review Process has been implemented into the study plan.

- The initial set of meetings validated the study process and methodology including information on technology, engineering, and market alternatives.
- The second set of meetings provided review and comment on the study findings.

At each panel meeting, the study team made a PowerPoint presentation of its approach, assumptions, methodologies, findings and conclusions. The study team has coordinated its work with the Project Management Consultant (PMC) who organized and provided logistical support to the Peer Review Panel process. The study team worked with the PMC to define Peer Review Panel objectives and agendas, and to serve as a resource to the panel, providing requested information and meeting with the panel to review study information.

1.5 Study Process

For both the I-25 and I-70 corridors, this study evaluated a broad range of technologies ranging from a conventional 79-mph Amtrak service up to a 300-mph Transrapid maglev. Specific technologies and alignments are described in more detail in Chapter 4. These route and technology options were compared based on the costs and benefits of each technology (e.g., 110-mph diesel vs. 220-mph electric vs. 300-mph maglev) and alignment option (e.g., current rail rights-of-way vs. new greenfield alignments.)

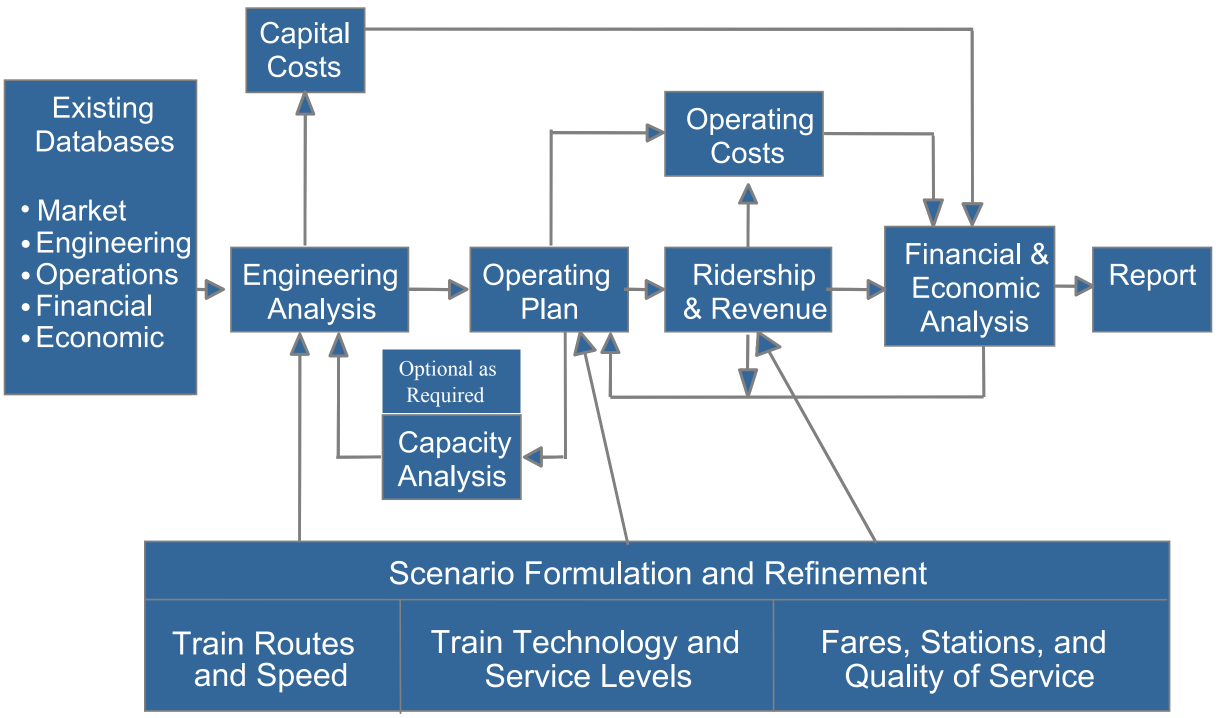
Evaluation of the route/technology options was based on the following objectives:

- Minimize travel time between major cities
- Maximize regional accessibility
- Minimize impact of topographical features on the route
- Minimize environmental constraints
- Minimize disruption to residential and commercial developments

The study entailed an interactive and quantitative evaluation, with regular feedback and adjustments between track/technology assessments and operating plan/demand assessments. It culminated in a financial and economic assessment of alternatives, with institutional issues addressed in a workshop with decision-makers and staff. Exhibit 1-3 illustrates the process that led up to the financial and economic analysis.

The study investigated the interaction between alignments and technologies to identify optimum trade-offs between capital investments in track, signals, other infrastructure improvements, and operating speed. The engineering assessment included aerial and/or ground inspections of significant portions of track and potential alignments, station evaluations, and identification of potential locations and required maintenance facility equipment for each option. *TRACKMAN*™ was used to catalog the base track infrastructure and improvements. *LOCOMOTION*™ was used to simulate various train technologies on the track at different levels of investment, using operating characteristics (train acceleration, curving and tilt capabilities, etc.) that were developed during the technology assessment. The study identified the infrastructure costs (on an itemized segment basis) necessary to achieve high levels of performance for the train technology options evaluated.

Exhibit 1-3: Interactive Analysis Process



A comprehensive travel demand model was developed using the latest socioeconomic, traffic volumes (air, bus, auto, and rail) and updated network data (e.g., gas prices) to test likely ridership response to service improvements over time. The ridership and revenue demand estimates, developed using the *COMPASS™* demand modeling system, are sensitive to trip purpose, service frequencies, travel times, fares, fuel prices, congestion and other trip attributes.

A detailed operating plan was developed and refined, applying train technologies and infrastructure improvements to evaluate travel times at different levels of infrastructure investment. Trip frequencies were tested and refined to support and complement the ridership demand forecasts and to estimate operating costs.

Financial and economic consequences were analyzed for each option over a 30-year horizon using FRA approved criteria. The analysis provided a summary of capital costs, revenues, and operating costs for the life of the project, and developed the Operating Ratio and Cost Benefit Ratio for each option.

1.6 Report Structure

The following is the report structure for the Rocky Mountain High-Speed Rail Feasibility Study.

Chapter 1: High-Speed Rail Planning Process

This chapter documents RMRA goals and objectives and the TEMS team response, including the Business Planning process. It includes a discussion of the following:

- Alternatives development process
- Public involvement process
- Peer Review Panel review process

Chapter 2: Target Markets

This chapter documents the character of travel in Colorado, in particular critical intercity travel from key locations such as the big cities (Denver and Colorado Springs), Denver International Airport (DIA), and the mountain resorts. Consideration is given regarding anticipated changes in markets over time.

Chapter 3: Infrastructure Needs

This chapter is divided into two sections. The first section defines potential routes in the I-25 and I-70 corridors, describing existing conditions and the ability to develop effective alignments along each corridor. The second part introduces basic engineering standards and infrastructure elements that are needed for developing an effective fixed guideway system. This chapter provides the background needed to understanding the route and technology options and operating plans that are presented in Chapters 4 and 5. The basis for the derivation of detailed capital cost estimates are presented in Chapter 8.

Chapter 4: Route and Technology Options

This chapter includes a review of existing technologies that might be used to provide service in the I-25 and I-70 corridors. It includes the rationale for defining equipment technology groupings, and the matching of specific technologies to route alignment options. Conventional rail technologies are limited in their ability to tackle heavy mountain gradients and have been restricted to grades of 4 percent or less. An "Unconstrained" network option, meaning that the alignment is allowed to deviate from the I-70 highway corridor, was developed for this evaluation. Newer high-speed rail or maglev technologies are able to cope with heavier gradients up to 7 percent on the existing I-70 highway alignment. A second "I-70 Right-of-Way" network option was developed for this evaluation.

Chapter 5: Operating Plans

This chapter describes the development of a range of alternative technology and route options in the I-25 and I-70 corridors. A critical element is the estimation of travel times and potential frequencies for each alternative.

Chapter 6: Travel Demand and Forecasting

This chapter describes the level of traffic and revenue generated by each alternative developed in Chapter 5 and its potential revenue. The detailed demand model and its calibration are described in Appendix B.

Chapter 7: Operating Costs

The character of the operation plan that optimizes each option is described together with its operating costs.

Chapter 8: Capital Costs

In this chapter, the infrastructure plan and capital costs for each route option are described. The chapter describes the capital cost development process and identifies the 2008 unit costs. The analysis provides capital costs on a segment basis; segmentation detail is provided in Appendix E and F.

Chapter 9: Evaluation of Alternatives

This chapter describes the financial and economic methodology used to evaluate and refine the proposed alternatives, and to identify the FRA Developed Option. The refinement process included "truncation" of weak segments, and the "mix and match" of both routes and technologies as appropriate.

Chapter 10: Implementation Plan for the FRA Developed Option and Risk Assessment

This chapter describes the implementation plan for the FRA Developed Option. It includes key milestones and phasing for the development of the system based on currently available information. For this option, a detailed financial plan and both sensitivity and a risk analysis is developed. The sensitivity analysis considers socioeconomic, transportation, operating and capital costs, and revenue ranges. The risk analysis considers "downside" factors and includes a quantitative analysis comparison of a totally non-freight railroad corridor compared to use of existing rail corridors. Funding options/strategies are defined.

Chapter 11: Funding Alternatives

This chapter describes the major funding sources for high-speed rail development, including the potential role of Federal, State, and local government. It also considers the opportunity for public-private partnerships, and the role that the private sector can play in operating and maintaining the trains and infrastructure, as well as in building stations through joint development partnerships.

Chapter 12: Conclusions and Next Steps

This chapter sets out the conclusions of the study, describing the key ridership, revenue, operating costs, capital costs and implementation results. It then describes steps needed to move the system forward, including requirements for PEIS, EIS, Design and Construction of both infrastructure and vehicles, and Funding.

2 Target Markets

2.1 Background

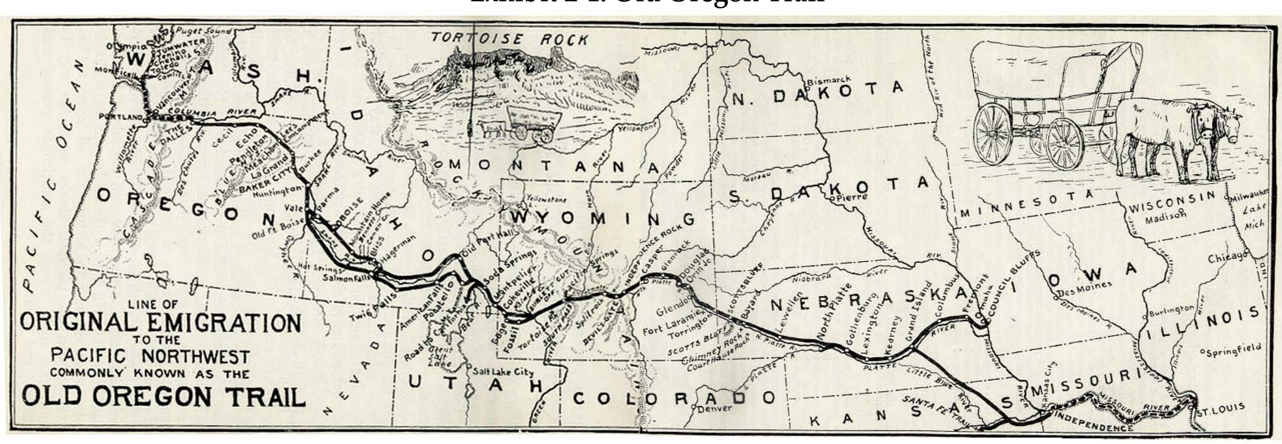
The state of Colorado represents the boundary between two of the most significant geographic regions of the U.S. Its eastern side reflects the western edge of the "great plains" with its "seas of grasslands," and its strong agricultural tradition for raising cattle and growing wheat, alfalfa and "cash" crops. The western side reflects the eastern edge of the Rocky Mountains or the eastern most fringe of the "Western Cordilleras".

In the opening up of the country (state), the Rockies had been a region to avoid, with westward bound wagon trains heading either north or south on the Oregon and Santa Fe trails, rather than trying to penetrate the high mountain ranges that suddenly arose in central Colorado. See Exhibits 2-1 and 2-2. The first transcontinental railroad was completed in 1869.

The Denver Pacific Railway completed a branch line from Cheyenne south to Denver the very next year, in 1870, the present-day Greeley subdivision. The Santa Fe Railroad laid track across Raton Pass in 1878, but extending a branch line to Denver by 1887. Interstate 25 follows that route today.

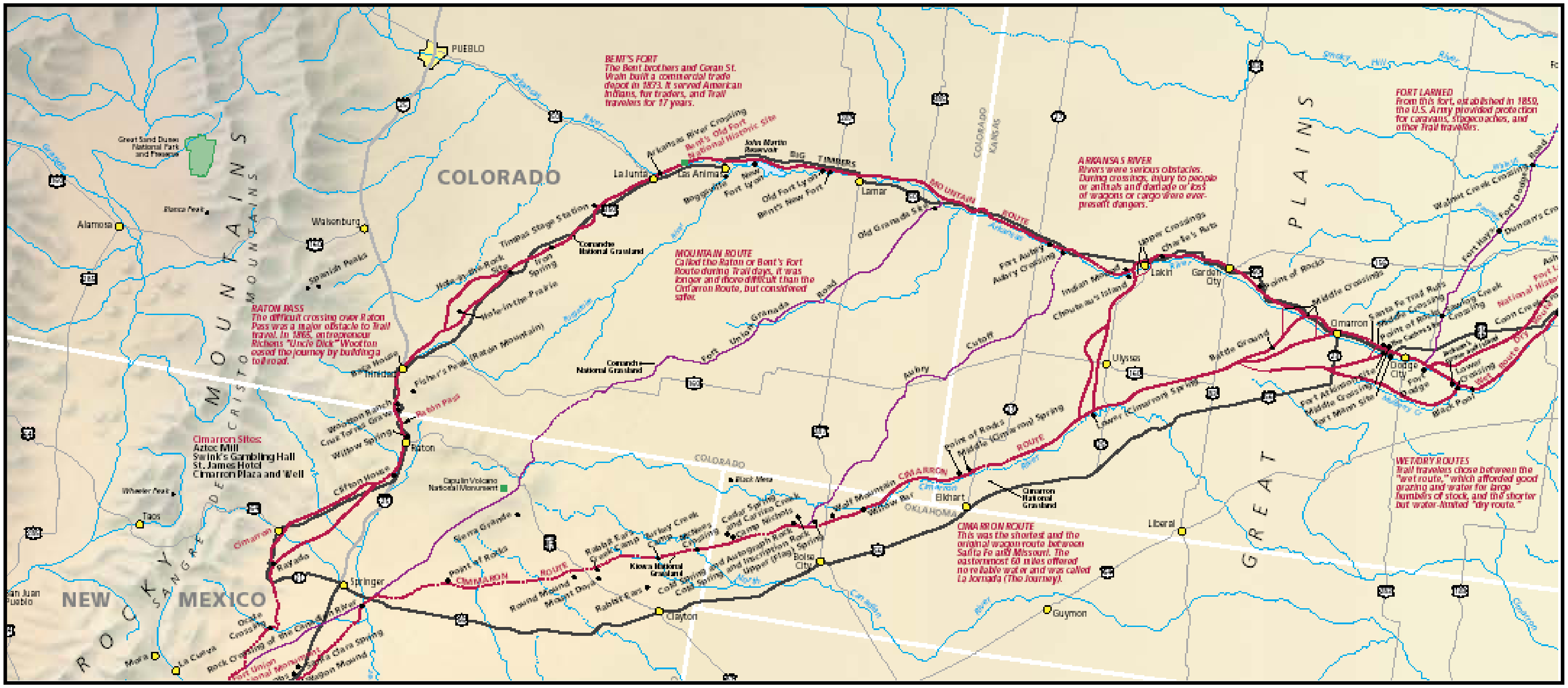
Both transcontinental rail lines bypassed Denver, following the routes of the original Oregon and Santa Fe trails.

Exhibit 2-1: Old Oregon Trail



Source: http://www.lib.utexas.edu/maps/historical/oregontrail_1907.jpg

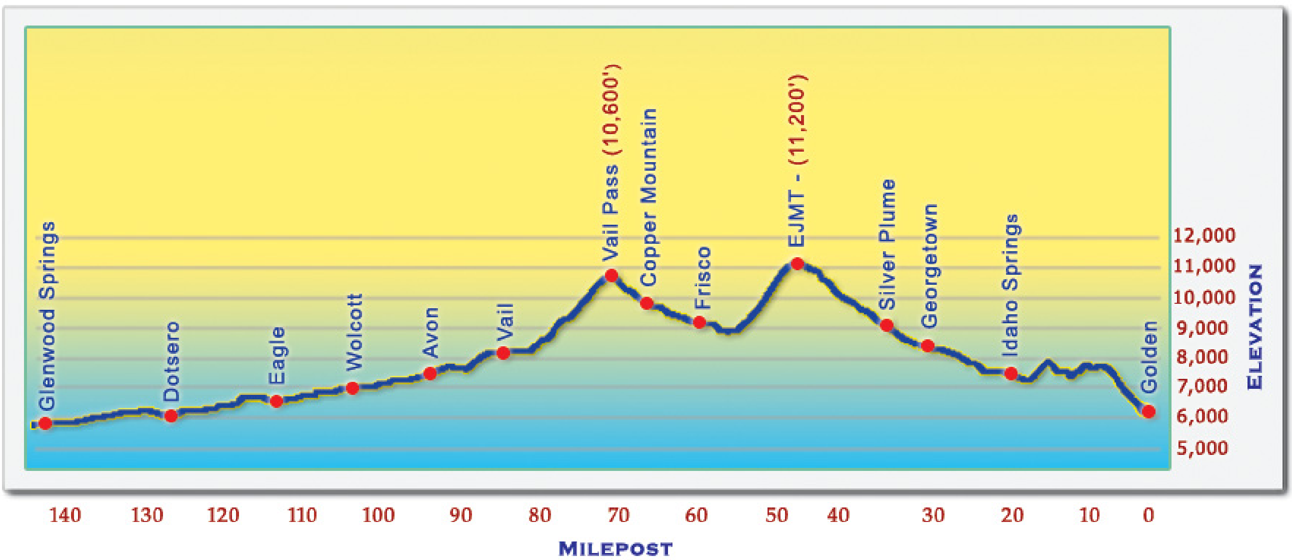
Exhibit 2-2: Santa Fe Trail



Source: http://www.santafetrailresearch.com/mileagecharts/santa-fe-trail-map-00.jpg

Even with the advent of the railroads and highways, the Rockies remained a barrier given the steepness of the gradients and the narrowness and curves of the canyons that have to be followed. These same problems face even the modern highway. It is only on reaching Glenwood Springs beyond the Glenwood Canyon that the I-70 corridor opens up as it falls to under 6,000 feet and follows the Colorado River west. See Exhibit 2-3.

Exhibit 2-3: I-70 Corridor Profile



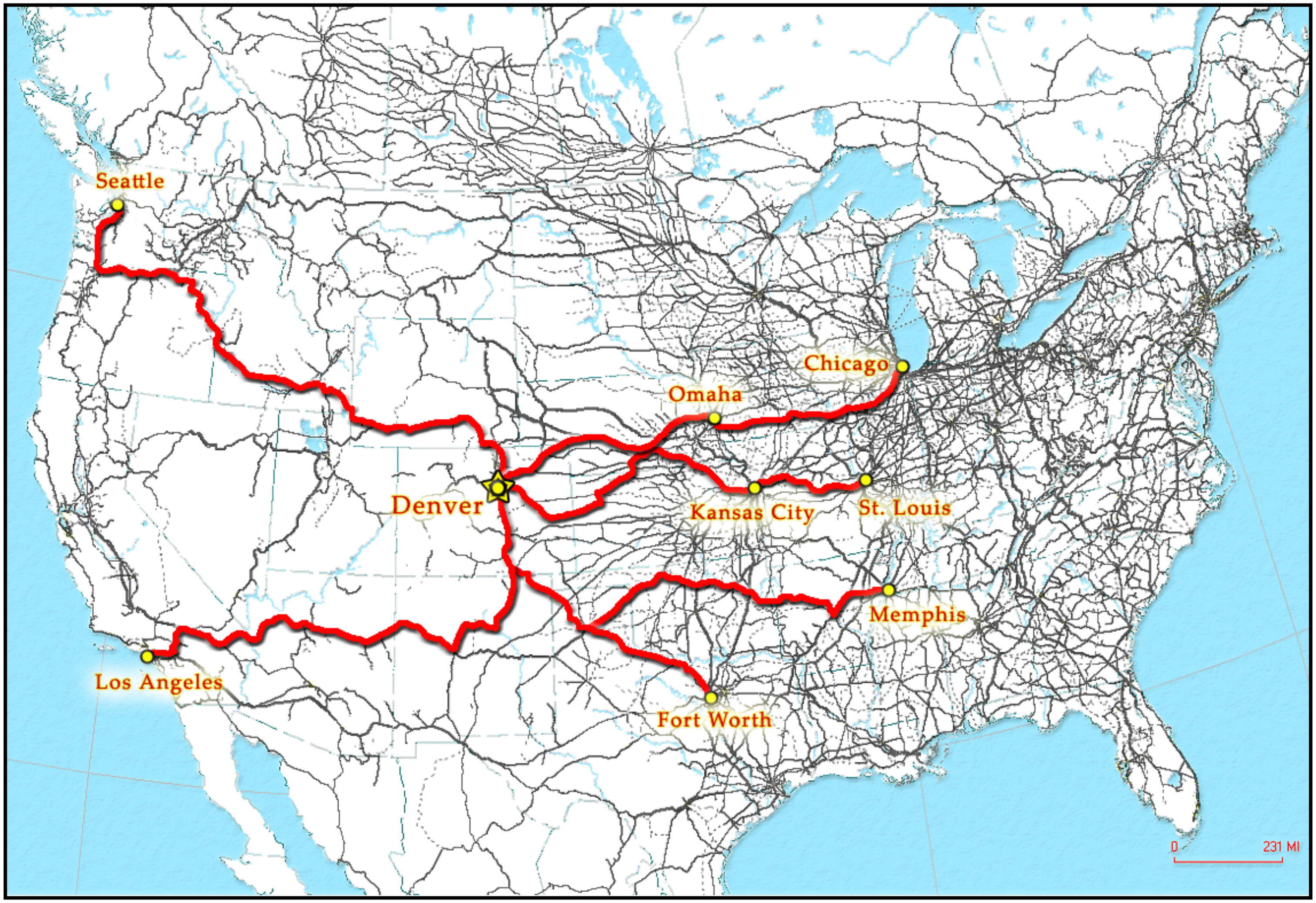
Source: TEMS, Inc., EJMY is the Eisenhower Johnson Memorial Tunnel under the Continental Divide.

As a result of its difficult terrain, the Rocky Mountain region was slow to develop. After an initial period as a fur and hunting area, it was the discovery of gold that finally attracted people to this mountainous region. Eventually, the region became famous for gold, silver, copper, and rare ores like zinc and molybdenum.

As a consequence, Denver and the Front Range cities became a staging center for mining activities in the Rockies, as well as an agricultural center for the eastern agricultural areas. This initially stimulated wagon trails, and as soon as the Denver Pacific reached Denver in 1870, narrow and standard gauge railroads started to be built into the Rockies. The original narrow gauge route up the Clear Creek canyon, for example, was built in 1871. That narrow gauge track bed has become the US-6 highway of today.

Finally, modern roads were constructed. Denver became a transportation, wholesaling and administrative center. By 1950, seven railroads converged on the city from Chicago, St. Louis, Kansas City, Memphis, and Fort Worth in the east, and from Los Angeles and Seattle on the Pacific Coast. See Exhibit 2-4. These railroads eventually merged into the UP and BNSF railroads that serve the region today. Denver also became a major transcontinental trucking center acting as a distribution center for goods arriving from Kansas City, Chicago and the West Coast ports. Most recently, its administrative and financing functions attracted public and private research and development functions to the city.

Exhibit 2-4: City of Denver's Connectivity to Markets and Ports

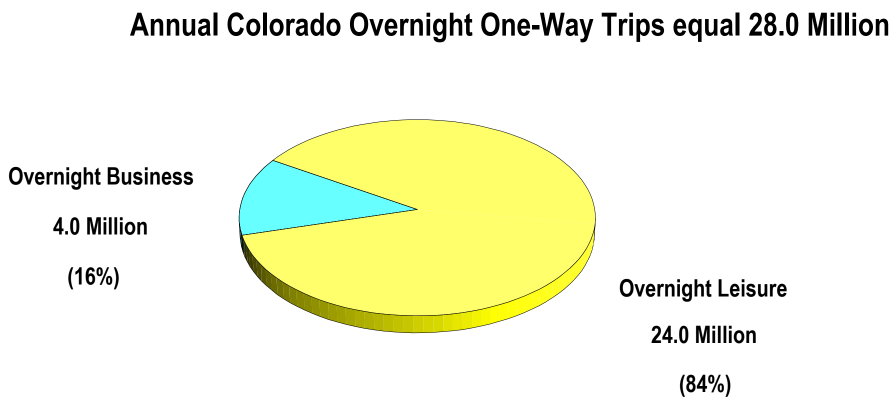


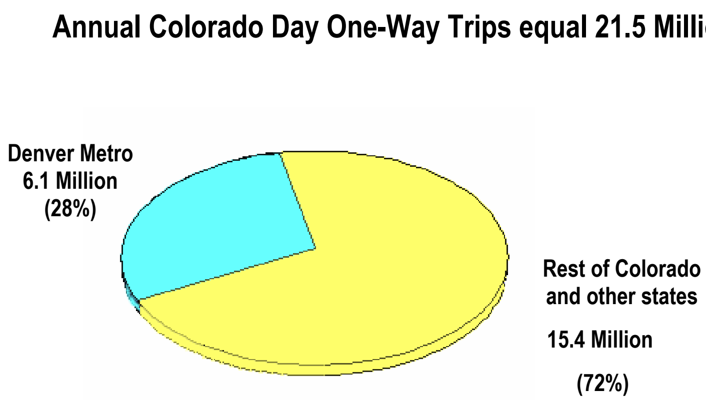
Source: TEMS, Inc.

While Colorado Springs with the lofty Pikes Peaks (14,000 ft.) and the Garden of Gods has long been an important tourist center, the opening of ski and summer resorts along the Continental Divide in the Rockies attracted a new type of tourist anxious to ski, mountain bike, hike, kayak, fish, and enjoy the local environment. While there were some limited Colorado ski resorts accessible by rail (such as Howelson Hill in Steamboat Springs, which opened in 1913, and was of interest primarily to local Colorado residents) after the 1960's the mountains that had provided such a barrier in the western part of the state began to develop into a significant economic engine. Two factors led to the advent of a world-class tourist industry: the opening of major resorts in Aspen and Vail, modeled after European ski towns, and development of the I-70 highway in the late 1960's and early 70's that provided easy access to these resorts, as well as to surrounding areas of national forest lands.

Today, the world-class recreational opportunities offered by the Colorado mountain region draw tourists from out of state as well as from in state. Tourists come from throughout the nation as well as internationally. Over 28 million overnight visitors and 21 million day trips are made to enjoy the state's amenities each year. See Exhibit 2-5.

Exhibit 2-5: Overnight and Day Trips to Colorado in 2007





Source: Longwoods International, Colorado Travel Year 2007

Of the 28 million overnight trips, only 33 percent were by Colorado residents, whereas Colorado residents make 81 percent of day trips. One of the key resident and tourist activities is skiing, and over 12.5 million skier visits are made each year to the over 28 ski resorts statewide. (A skier visit is defined as a skier skiing for one day in one area.) It is estimated[1] that 11 million ski trips (2-way) are made by local residents and 3.8 million trips (2-way) by visitors to Colorado, giving a total of nearly 15 million trips. See Exhibit 2-6.

Exhibit 2-6: Colorado Skier Visits

colorado
SKI COUNTRY USA

	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Destination Resorts										
Aspen Highlands	142,090	127,389	140,640	136,136	157,317	160,836	167,390	193,242	193,648	211,635
Aspen Mountain	334,536	331,121	319,343	310,381	315,130	298,830	304,495	324,465	328,002	337,774
Buttermilk	178,089	158,194	148,826	145,683	141,077	139,213	148,012	159,081	153,957	154,926
Crested Butte	462,478	414,642	367,263	336,483	342,416	333,011	375,936	411,729	366,765	416,009
Cuchara	21,678	32,154	DNO	DNO	DNO	DNO	DNO	DNO	DNO	DNO
Durango	304,735	235,000	321,600	250,500	263,712	268,486	278,767	211,003	251,794	278,994
Howelsen Hill	14,475	14,000	14,000	15,208	14,000	14,009	16,526	18,423	17,054	20,128
Silverton Mountain	DNO	DNO	DNO	DNO	2,382	3,600	3,683	3,900	5,589	6,000
Snowmass	777,140	707,600	740,241	676,505	669,701	724,752	747,293	768,007	770,407	771,455
Steamboat	1,013,254	1,024,832	1,003,317	1,001,003	1,001,020	1,002,821	971,770	1,046,650	1,071,786	1,022,193
Telluride	382,467	309,737	334,506	341,370	367,252	367,775	411,396	390,346	426,244	450,730
Wolf Creek	202,053	114,802	187,116	170,847	183,907	210,857	215,821	197,052	222,979	195,583
Total Destination	3,832,995	3,469,471	3,576,852	3,384,116	3,457,914	3,524,190	3,641,089	3,723,898	3,808,225	3,865,427
Front Range Destination										
Beaver Creek	614,549	586,004	676,528	657,956	718,353	768,542	815,350	875,455	889,812	917,863
Breckenridge	1,385,927	1,444,365	1,422,783	1,468,518	1,424,770	1,402,055	1,470,961	1,619,043	1,650,321	1,630,106
Copper Mountain	867,394	803,312	992,888	1,005,913	1,058,016	931,143	1,046,242	1,132,021	1,046,959	934,870
Keystone	1,253,192	1,192,198	1,230,100	1,069,111	1,038,942	944,433	1,021,069	1,093,939	1,170,710	1,129,608
Vail	1,334,939	1,371,702	1,645,902	1,536,024	1,610,961	1,555,513	1,568,192	1,676,119	1,608,204	1,569,788
Winter Park	980,408	902,827	978,539	975,256	998,772	955,615	990,837	1,077,001	1,007,582	1,000,221
Total Front Range Destination	6,436,409	6,300,408	6,946,740	6,712,778	6,849,814	6,557,301	6,912,651	7,473,578	7,373,588	7,182,456
Gems/Front Range Resorts										
Arapahoe Basin	267,406	220,945	240,406	151,678	317,401	275,428	328,892	326,428	360,247	430,897
Berthoud	20,101	16,870	20,160	DNO	DNO	DNO	DNO	DNO	DNO	DNO
Echo Mountain	DNO	DNO	DNO	DNO	DNO	DNO	DNO	3,238	18,758	23,073
Eldora	175,939	229,785	233,741	250,000	286,528	278,454	281,242	305,030	308,794	286,017
Loveland	230,333	225,896	209,757	199,781	244,621	203,916	240,961	245,610	263,163	280,683
Monarch	140,000	127,215	147,266	138,850	147,094	144,984	142,190	166,451	160,941	175,173
Powderhorn	55,613	71,941	70,118	76,456	79,624	82,948	81,893	79,103	70,714	83,014
Ski Cooper	62,145	60,171	66,225	68,893	64,499	58,408	57,389	64,751	56,669	61,394
SolVista	90,330	92,514	71,303	62,837	65,900	58,482	57,886	64,882	71,633	74,459
Sunlight	78,290	77,047	84,104	82,742	92,382	66,650	72,004	80,139	73,567	78,010
Total Gems/Front Range Destination	1,120,157	1,122,384	1,143,080	1,031,237	1,298,049	1,169,270	1,262,457	1,335,632	1,384,486	1,492,720
Total:	11,389,561	10,892,263	11,666,672	11,128,131	11,605,777	11,250,761	11,816,197	12,533,108	12,566,299	12,540,603
# Increase/Decrease	(590,158)	(497,298)	774,409	(538,541)	477,646	(355,016)	565,436	716,911	33,191	(25,696)
% Increase/Decrease	-4.93%	-4.37%	7.11%	-4.62%	4.29%	-3.06%	5.03%	6.07%	0.26%	-0.20%

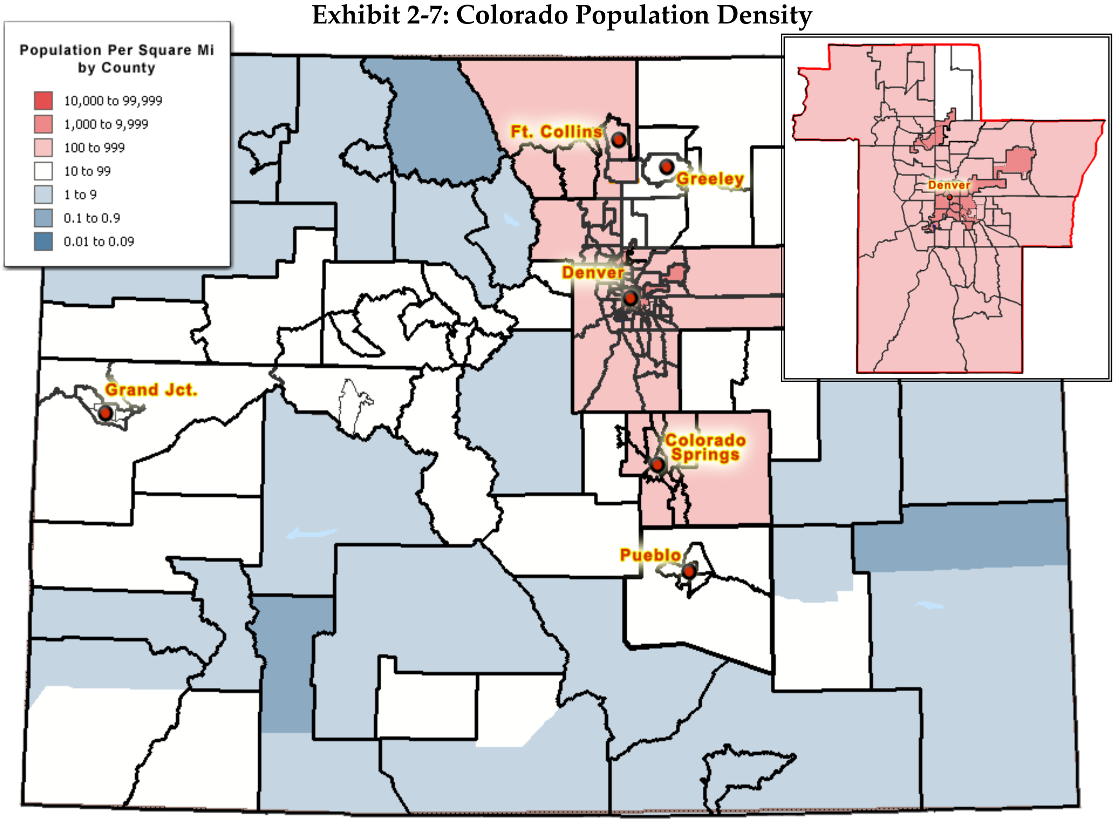
Source: Colorado Ski Country USA, http://media-coloradoski.com/cscfacts/skiervisits/

[1] Longwoods International, Colorado Travel Year 2007

2.2 Demographics and Settlement Pattern of Colorado

The demographics of Colorado are very much a reflection of its history. The eastern half of the state has an agricultural base focused on ranching and growing wheat, alfalfa hay, and other cash crops. As such, its population is widely spread with a low density per square mile. The western half of the state is even more sparsely populated, reflective of the difficult terrain of the Rockies, and the large proportion of western Colorado that is public land, either federal or state owned. See Exhibit 2-7.

Exhibit 2-7: Colorado Population Density



Source: Microsoft MS MapPoint 2006 demographic data provided by Applied Geographic Solutions

In this environment, it is not surprising that the state of Colorado has a very distinctive settlement pattern with major cities like Denver, Colorado Springs, Pueblo, and Fort Collins tucked up against the Front Range of the Rockies. These form a corridor from Cheyenne in the north to Trinidad in the south along which I-25 was built, and along which BNSF and UP have major rail routes.

Because of difficult topography, east-west transportation options remain more limited with only one major interstate (I-70), and four lesser routes; US-40, US-50, US-24 and US-285 penetrating the mountain region. Equally, there is only one active rail route (UP via Moffat Tunnel) and one inactive route (UP's Tennessee Pass route) penetrating the mountains to the Pacific coast. However, both of these rail and highway routes face problems with limited capacity, and with severe gradients and curvature that reduce their speed and raise operating costs. As a result, UP prefers its lower gradient and less curvaceous routes to the north and south. Even many truckers prefer to use I-80 through

Wyoming rather than I-70 through Colorado, because of I-70's tight curves, steep grades, difficult weather conditions and capacity limitations as it winds its way across the Continental Divide, Vail Pass, and through Glenwood Canyon.

At the base of the Rockies along the Front Range the need for market centers to support both the "mining" and "ranching" halves of the state resulted in the historical development of transportation, warehousing, and administrative towns and cities from Fort Collins in the north to Trinidad in the south. Cities like Denver and Colorado Springs became major urban areas initially to support the regional economies of the east and west, but now to an increasing degree support "new economy" service-sector business. The new economy includes high-tech service and manufacturing industry, technology firms such as the wind and solar energy industries that have increasingly developed in Colorado, and most importantly the tourist industry. The quality-of-life amenities offered by Colorado's generally mild climate coupled with convenient access to the mountain recreational area, have been key factors that make the Front Range region an attractive place to live, work, and do business.

The population of the state's largest urban areas is shown in Exhibit 2-8. These seven regions include the 12 largest cities of Colorado[2] with Denver, Aurora, Lakewood, Thornton, Highlands Ranch, Arvada, and Westminster being part of the Denver urban area or PMSA[3]. Grand Junction is an MSA[4], even though it is not one of the top 12 cities. These urban areas contain more than 85 percent of the total state population/employment.

Exhibit 2-8: Socioeconomic Data for Colorado Metropolitan Statistical Areas (2006)

#	Name	Population	Per Capita Personal Income	Employment	Unemployment Rate
1	Denver PMSA	2,411,836	$44,691	1,638,281	4.4%
2	Colorado Springs MSA	602,496	$34,255	375,799	4.7%
3	Boulder-Longmont PMSA	288,125	$49,628	232,336	3.8%
4	Fort Collins-Loveland MSA	281,620	$35,397	190,105	4.0%
5	Greeley PMSA	235,366	$26,002	115,822	4.7%
6	Pueblo MSA	152,081	$26,363	75,490	5.7%
7	Grand Junction MSA	134,061	$30,746	83,742	4.0%

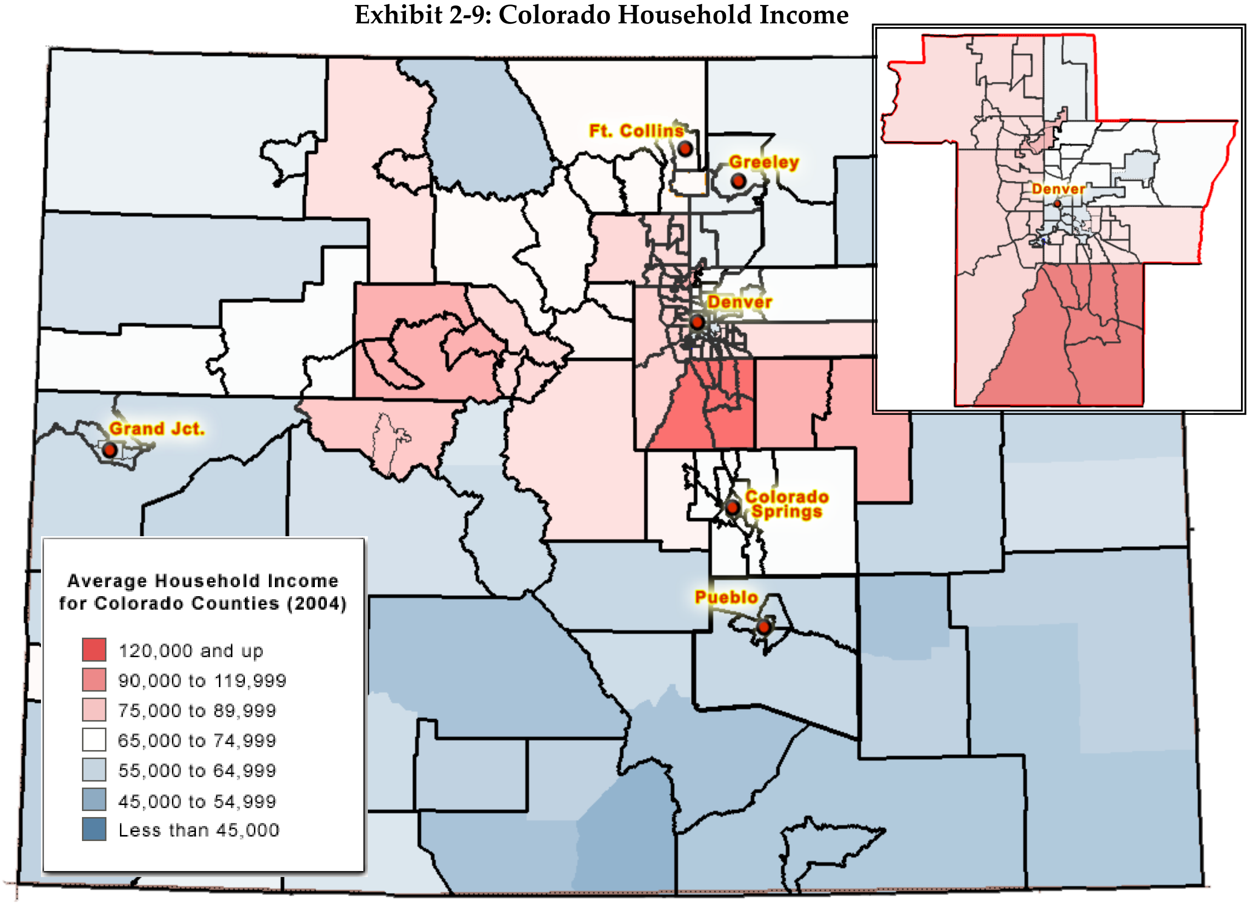
Source: Bureau of Economic Analysis, Regional Economic Accounts, http://www.bea.gov/bea/regional/ and Colorado Department of Labor and Employment, http://www.coworkforce.com/

As shown in Exhibit 2-8, employment was strong in 2006 in all the cities with unemployment rates at only around 4-5 percent. Pueblo's unemployment rate was highest at 5.7 percent. In terms of income, per capita income is highest in the Denver region with values of over $49,000 in Boulder-Longmont PMSA, and $44,000 in the Denver PMSA. Incomes are lower in Colorado Springs and the Fort Collins MSA, and fall further in Greeley, Pueblo, and Grand Junction. The overall distribution of household income is given in Exhibit 2-9. The areas with the highest household income are located

[2] Socioeconomic information can be found at www.city-data.com
[3] PMSA - Primary Metropolitan Statistical Area
[4] MSA - Metropolitan Statistical Area

along the I-70 and I-25 corridors with household incomes ranging from $65,000 to over $120,000. As in the case of per capita income, Boulder and Denver MSAs (Metropolitan Statistical Area) have the highest average household income in Colorado. The I-70 resort areas (Aspen, Vail, etc.) are second and are characterized by household incomes between $75,000 and $120,000. Away from the major urban areas and ski resorts, household incomes are lower with the lowest incomes being in the southeastern, eastern, and western parts of the state.

Exhibit 2-9: Colorado Household Income



Source: Microsoft MapPoint 2006 demographic data for the year 2004, provided by Applied Geographic Solutions.

2.2.1 Tourism and Mineral Development

While the Front-Range region served by I-25 can be characterized as a robust, traditional intercity corridor, the I-70 intercity travel market is strongly driven by tourism and natural resource development. These result in significant additional travel demand, over and above what might be forecasted by traditional demographics-based travel models. A key requirement for the study, therefore, has been to develop a means for appropriately representing and modeling the special characteristics of this highly unusual travel market.

The tourist industry, valued at $10.9 billion in 2007, now overlays the more traditional mining and foresting activities of the Rocky Mountain region. Today Colorado is the 17th largest tourist state in the U.S., and first in terms of overnight ski trips. According to the Colorado Data Book, the Rockies have over 20 winter recreational areas[5] with a large number on either side and close to I-70. The locations of some of these are shown in Exhibit 2-10. In the 1970's I-70 improved access to a 150-mile corridor of ski resorts and national forests that also have summer activities such as mountain biking, hiking, kayaking, and fishing, etc. In fact, approximately 60 percent of all visitor trips occur during the summer. Additionally, Colorado's gaming industry in Central City and Black Hawk is proximate to I-70. This in addition to Colorado Springs' historical attractions, which include Pikes Peak, the Garden of the Gods and the Royal Gorge farther south. These have turned Colorado into an economic powerhouse of the tourist industry. As a result, the entire Front Range region has developed extensive infrastructure and population to support the tourist industry.

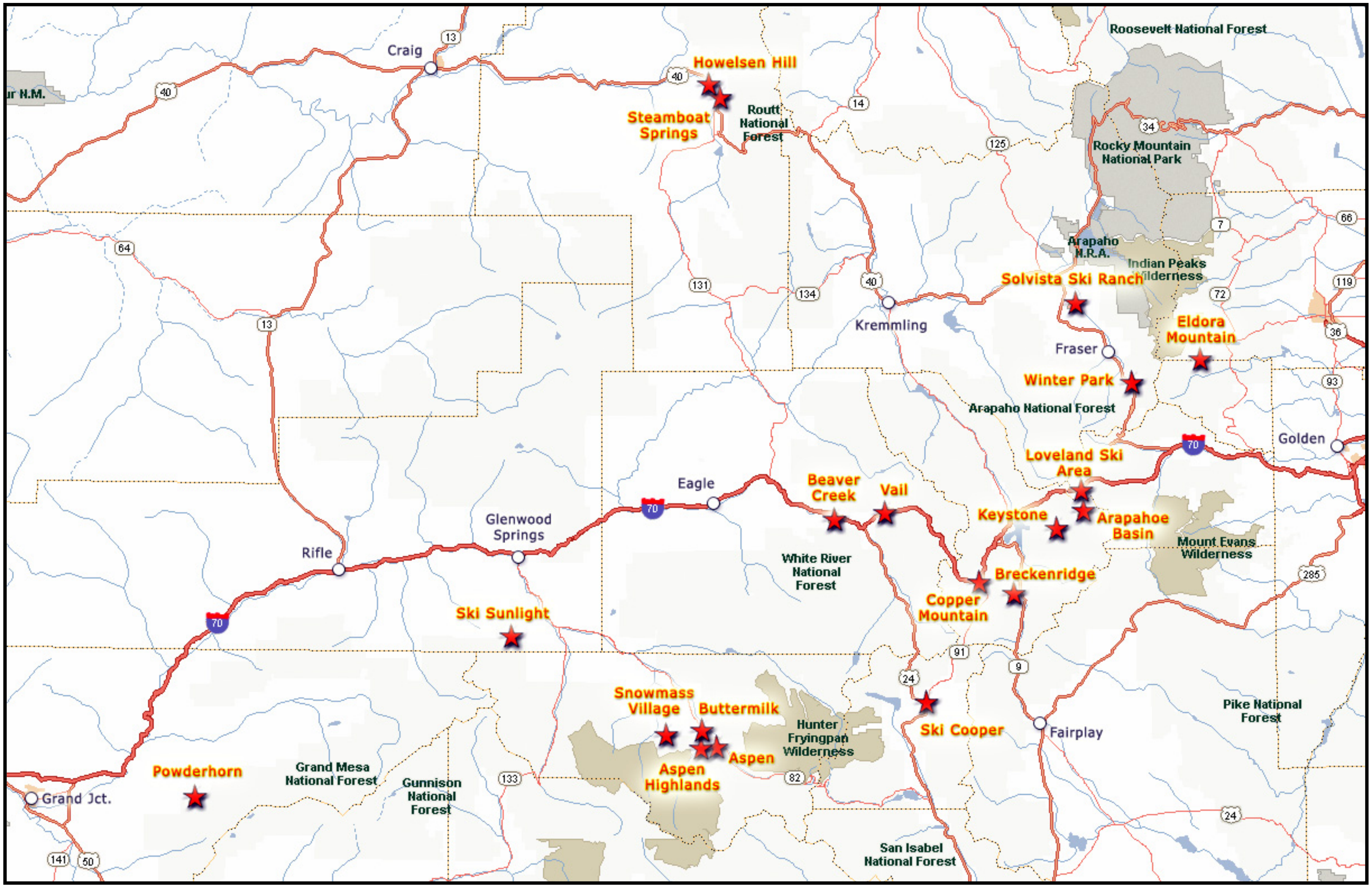
In addition to tourism and high tech manufacturing, the last several years have marked a renewed fossil fuel energy boom on the Western Slope. Because of a long-term structural trend of continually rising energy prices, development activities have continued in spite of the short-term volatility of energy and other commodity prices. This volatility however tends to result in a "boom or bust" development cycle for mineral resources that has characterized much of the Western Slope economy for many years. In addition to the continuation of coal mining and power production in several Western Slope areas (Routt, Moffat, Delta, and Garfield counties), new oil, gas and coal bed methane exploration, drilling, and production have increased dramatically on the Western Slope. These developments have had a major impact on I-70, US-40, and SH-13 and local roads/bridges, including congestion and road deterioration due to the large number of multiple axle vehicles. This development has also helped stimulate the growth of Yampa and Eagle County airports by augmenting tourism-based passenger traffic there.

Recent studies such as the ongoing I-70 PEIS, which evaluated the I-70 corridor from Golden C-470 to Glenwood Springs, show the dilemmas that will exist as traffic to the rapidly growing resort areas in the mountains continues to grow. These studies have shown that traffic has already reached capacity on I-70 at some critical locations. Investment in added transportation capacity will be expensive but critical in the tourist centered area from Golden to Vail, as well as in the energy development from Rifle to Parachute.

In the short term, these needs from Golden to Vail are being addressed by the Consensus Recommendation of the I-70 Collaborative Effort[6], which developed an approved list of highway improvements that will address the most critical and urgent concerns. For the longer term however, significant expansion to transportation capacity will be required to address the various costs associated with I-70 congestion. The question then, is what form this added capacity will take, whether in the form of added highway capacity or a potentially more environmentally benign mode like electric rail or maglev.

[5] Colorado Data Book. Colorado Office of Economic Development & International Trade. www.colorado.gov.
[6] See: http://www.co.clear-creek.co.us/Projects/I-70/Final CE AgreementincludingAddenda_June2608.pdf

Exhibit 2-10: Colorado Ski Resorts along the I-70 Corridor



Source: TEMS, Inc. and Colorado Ski Country USA.

2.3 Intercity Passenger Markets

2.3.1 Highway Travel

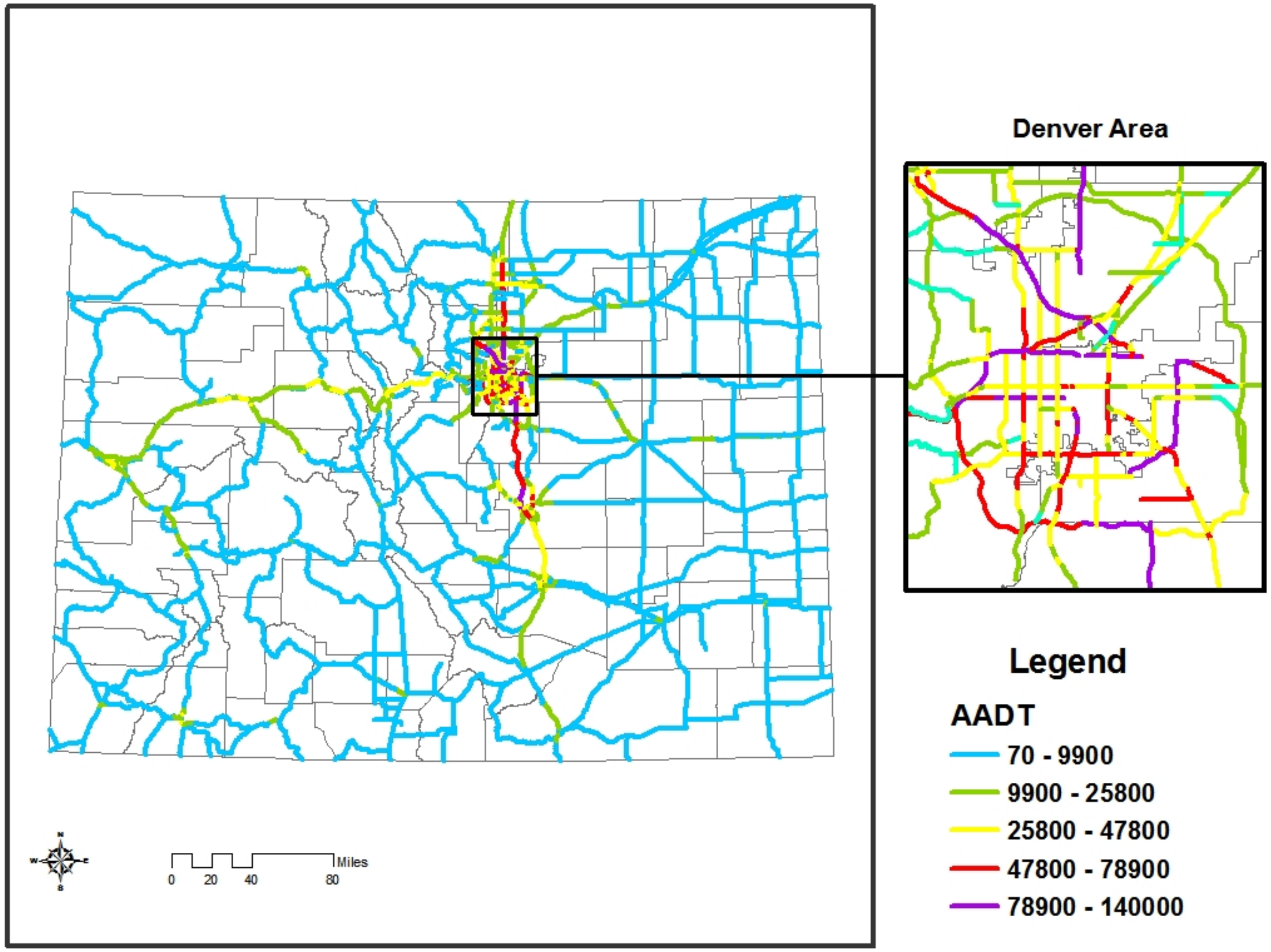
Intercity travel in Colorado is primarily focused into two key Interstate highway corridors, the I-25 Front Range and the I-70 Mountain corridor.

- The I-25 corridor reflects the initial need to avoid the mountains while connecting the Front Range cities along the I-25 from Denver to Trinidad in the south, and to Cheyenne in the north. Travel in the I-25 corridor mostly reflects the business and commercial travel that has long been a product of the transportation, warehousing, and administrative functions of the Front Range cities. Today this is supplemented by modern high tech research, development and production facilities, as well as finance and insurance.
- The I-70 corridor provides access to the Rocky Mountains and to the recreational opportunities they offer. I-70 traffic primarily consists of tourism, social and sports travel to and from the multiplicity of resort destinations along I-70.

Annual Average Daily Traffic (AADT) on I-25 range from 20,000-30,000 trips in rural areas, rising to 50,000-100,000 near major cities, and over 200,000 in Denver. See Exhibits 2-11, 2-12, and 2-13. This traffic reflects the normal five-day a week, work and business purpose of travel, as well as weekends. Weekend volumes on I-25 tend to be much lower than weekdays.

On I-70, traffic counts are highest in the east between Denver International Airport (DIA) and I-25 near downtown Denver, but then fall off as the road moves west from over 140,000 AADT (at C-470) on the western edge of Denver to 60,000 after Central City and Black Hawk a major gambling resort to 40,000 AADT near Silverthorne having passed Winter Park and Keystone ski and resort areas. The AADT falls again after Copper Mountain Ski and Resort area with AADT levels at 20-30,000 in the Vail Pass. West of Vail the addition of Route US-24 increases traffic for a short distance to 30-40,000 trips past Avon and Edwards. Beyond Edwards, traffic falls to around 20,000 as far as Grand Junction. Peak days on I-70 are on the weekend between Denver and Copper Mountain. Traffic is lower on weekdays, as there are not large numbers of recreational day trips made from the Front Range to I-70 destinations on weekends. This traffic pattern is highly unusual for any Interstate highway corridor. See Exhibit 2-14, which shows Year 2000 traffic volumes from the I-70 PEIS.

Exhibit 2-11: Statewide AADT Counts



Source: Colorado DOT, www.dot.state.co.us/App_DTS_DataAccess/index.ctm

Exhibit 2-12: AADT on I-25 and I-70 (2007)

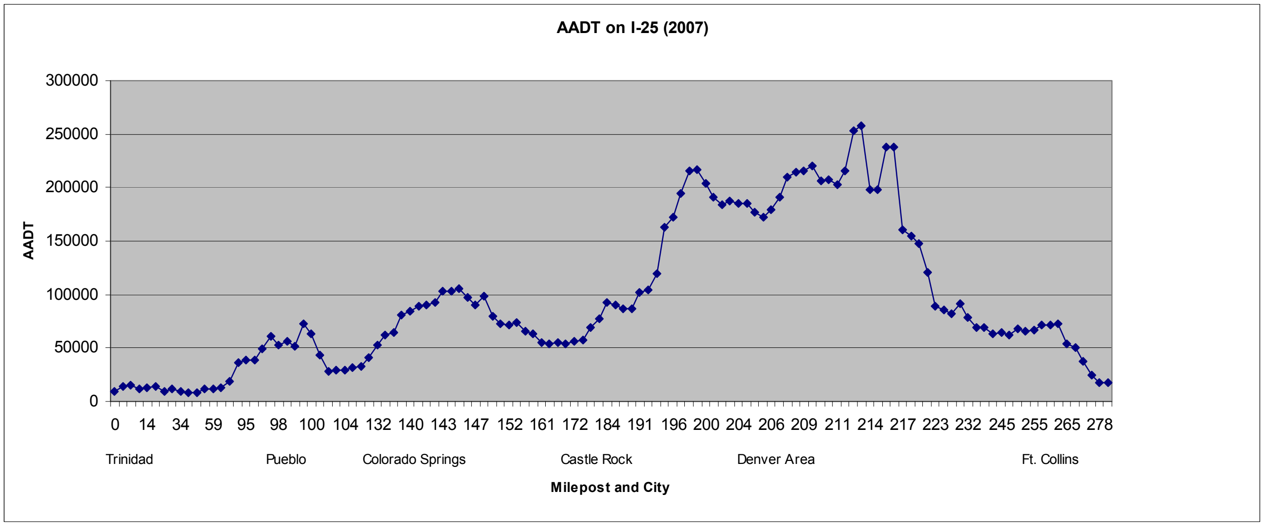
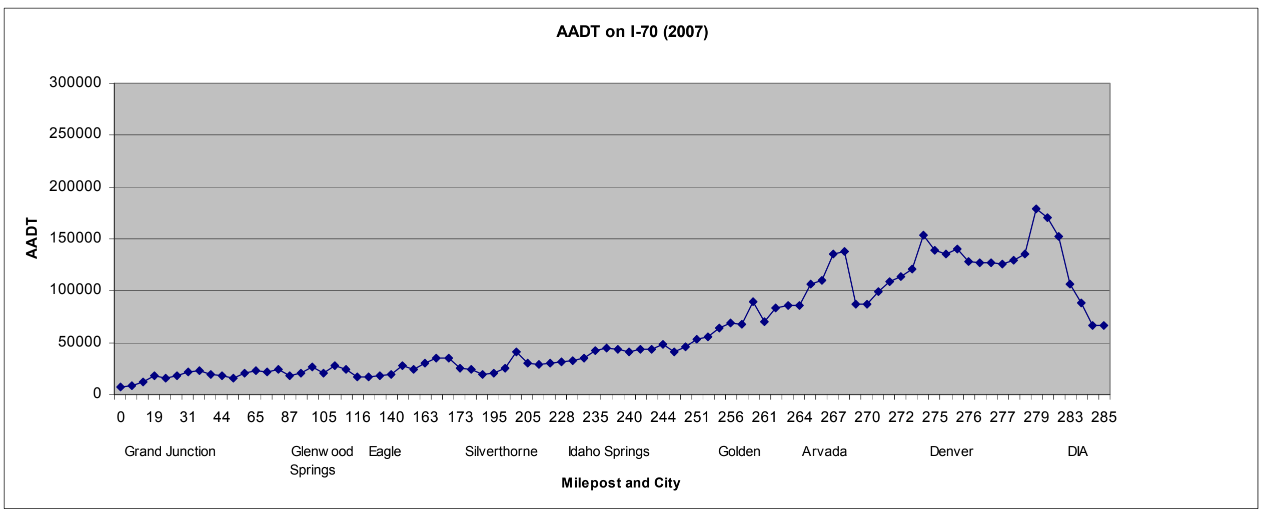
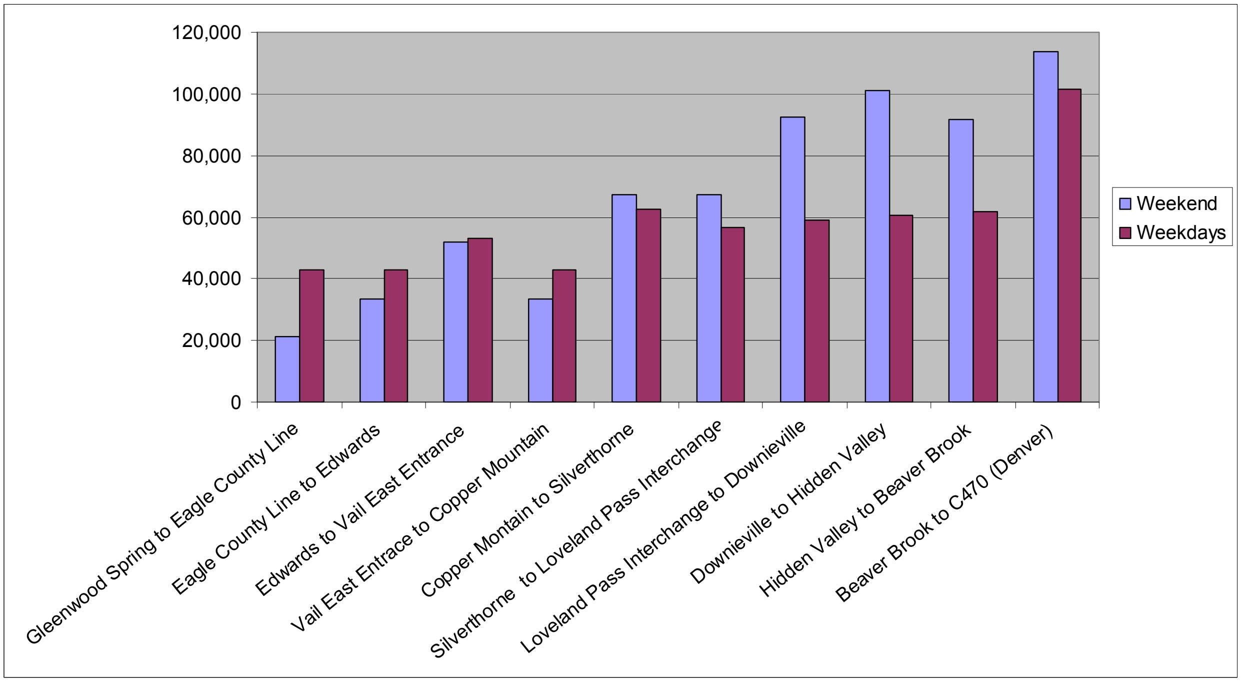


Exhibit 2-13: AADT on I-70 (2007)



Source: Colorado DOT, www.dot.state.co.us/App_DTS_DataAccess/index.ctm

Exhibit 2-14: I-70 Corridor Weekday and Weekend Daily Vehicle Trips (Year 2000)



Source: I-70 PEIS

2.3.2 Air Service

To support local business and tourist resorts Denver opened its new airport in the 1990's some 20 miles northeast of downtown Denver. (Although locally called "DIA" the airport retained the official "DEN" code that had been originally assigned to Stapleton.) In addition to serving local markets, the airport has developed into a major hub facility with over 40 million enplanements and deplanements per year, 55 percent of these for local travel, the remainder being connecting passengers. As a major "transfer hub", the airport attracts a substantially higher level of air service than the local market by itself would have been able to support. In addition, the airport itself has become a major employment center, and the city of Denver has rapidly expanded eastward toward the airport, which is a major economic development node for the city.

With respect to air service in the corridors, there are commercial flights in the I-25 corridor from Denver International Airport (DEN), Colorado Springs (COS), Pueblo Memorial (PUB), and Fort Collins and Loveland (FNL). The most important of these airports are Denver and Colorado Springs with 24 million[7] and 1.7 million passenger trips, respectively, to outside the state. (See Exhibit 2-15) The number of air trips in Exhibit 2-15 includes both commercial and general flights from Colorado

[7] Denver International Airport, as a hub for such major airlines as United, Frontier and Southwest, serves an additional 20 million connecting passengers each year, which are not included in Exhibit 2-15. Source: 2008 Colorado Airports Economic Impact Study, Colorado, DOT.

airports to the rest of the country. It is the lack of flights to the rest of the country that results in the small number of trips for the airports in Pueblo, Cortez, and Alamosa.

Exhibit 2-15: Annual Air Travel between Colorado and the Rest of the U.S. (2005)[8]

Airport	To Rest of the U.S.	From Rest of the U.S.
Denver (DEN)	12,055,139	12,028,078
Colorado Springs (COS)	847,182	849,023
Eagle (EGE)	165,879	166,786
Steamboat Springs (HDN)	87,588	86,856
Grand Junction (GJT)	82,861	81,977
Aspen (ASE)	53,065	53,816
Montrose/Delta (MTJ)	43,778	44,017
Durango (DRO)	34,655	34,667
Ft. Collins/Loveland (FNL)	25,510	27,953
Gunnison (GUC)	14,899	14,689
Telluride (TEX)	4,237	4,026
Pueblo (PUB)	1,301	1,302
Alamosa (ALS)	49	45
Cortez (CEZ)	12	4
Totals	13,416,155	13,393,239

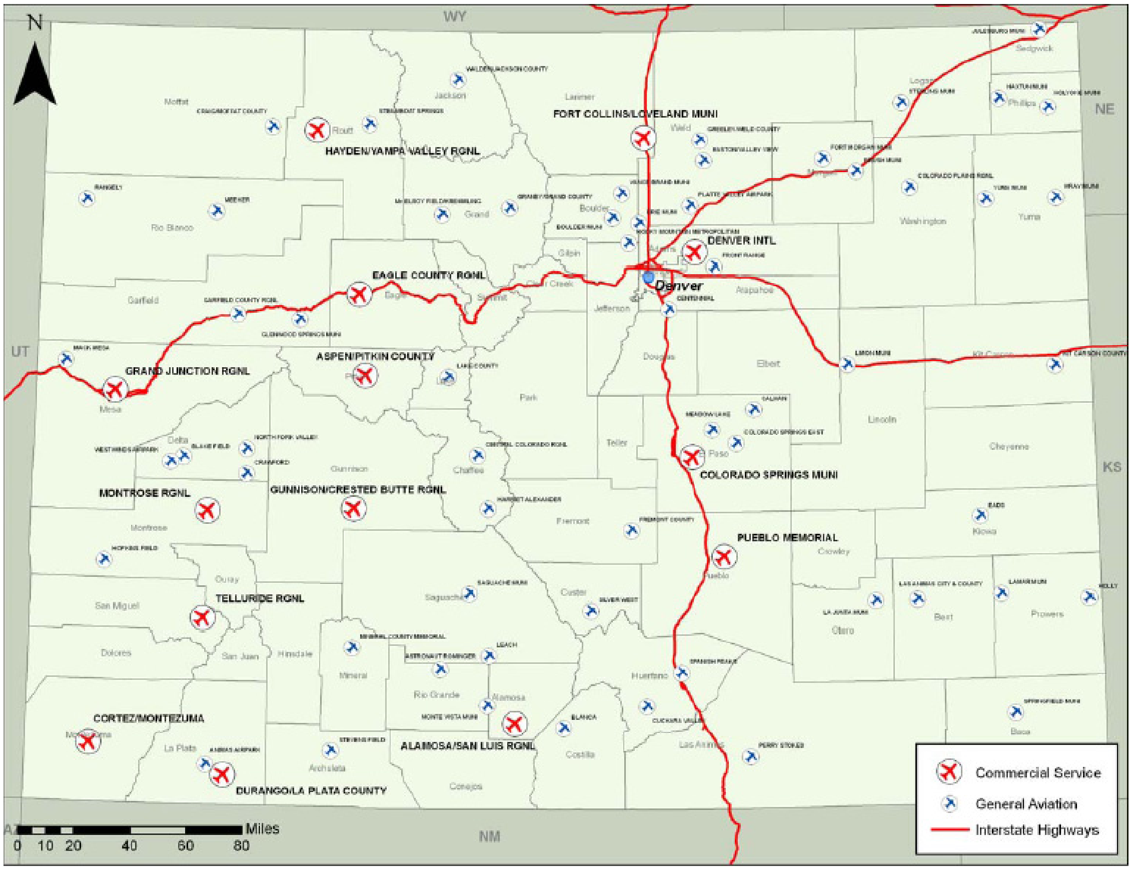
Source: Bureau of Transportation Statistics, www.bts.gov, Year 2005

In the I-70 corridor, key airports are Aspen and Pitken County (ASE), Eagle County (EGE), Grand Junction Regional (GJT), and Hayden/Yampa Valley Regional (HDN). See Exhibit 2-16. Flight information for travel between DIA and the other 13 commercial airports in Colorado is shown in Exhibit 2-17.[9] Flight time is about an hour and fares are very high. For example, Steamboat Springs, Colorado and Eagle to Denver are more than $3 per mile. However, air fares from Grand Junction, Pueblo and Durango, being longer-haul routes, are much more reasonable at about $1 to $2 per mile.

[8] According to the data from 2008 Colorado Airports Economic Impact Study, 45.2 percent of enplaned passengers in Denver are connecting passengers.

[9] Passenger counts in Exhibit 2-17 are only those trips beginning or ending at DIA, excluding connecting passengers who are traveling through Denver (e.g., Chicago through Denver to Aspen.) A 40-minute flight time from DIA to both Colorado Springs and Pueblo are based on published airline schedules, retrieved November 2008.

Exhibit 2-16: Colorado Airports



Source: 2008 Colorado Airports Economic Impact Study, Colorado DOT

Exhibit 2-17: Flight Information between DIA and 13 Commercial Airports in Colorado (2007)

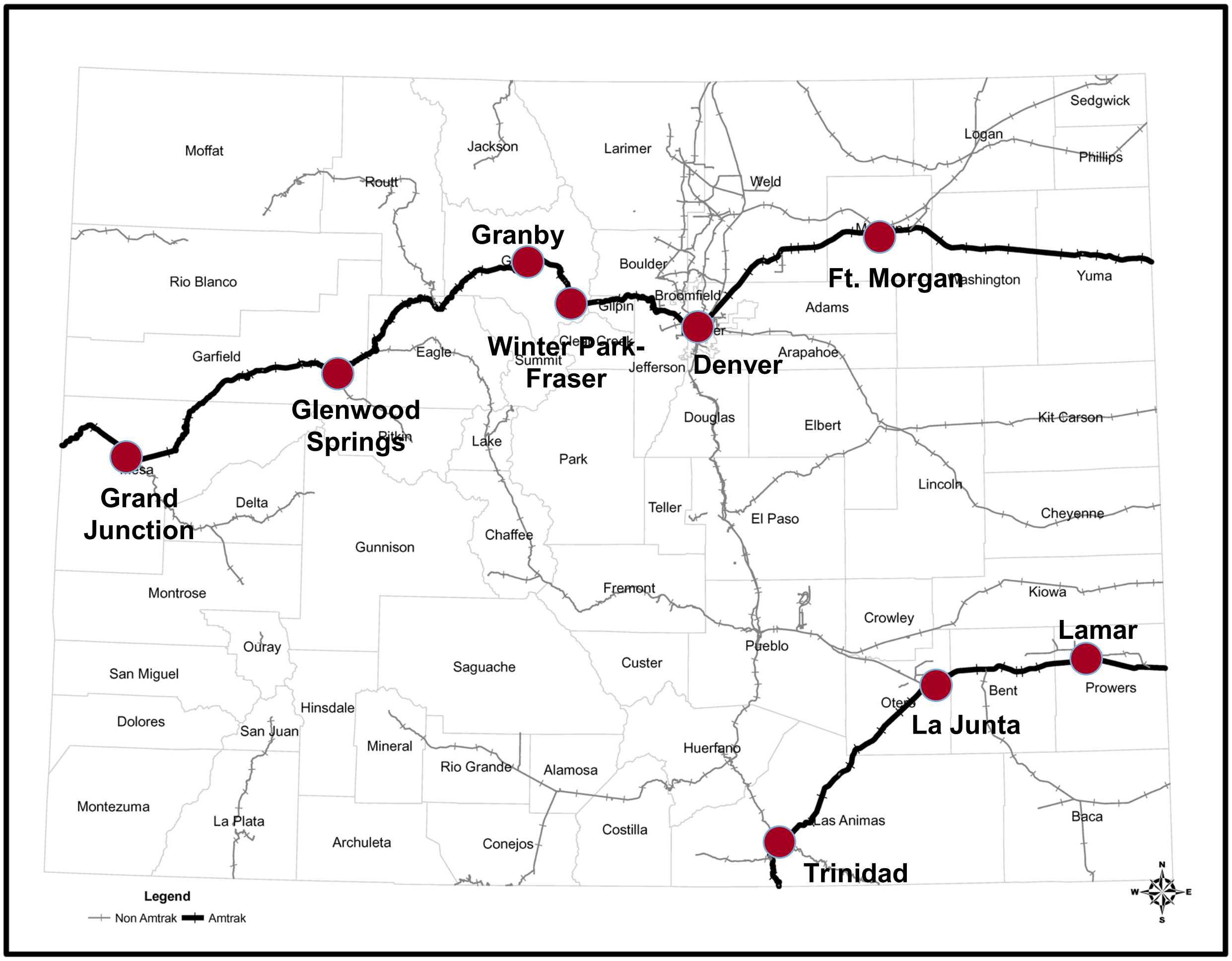
Airport	Frequency (flights per day)	Fare (one way)	Travel Time (min)	Passengers (per year)
Steamboat Springs (HDN)	4	$ 822	46	4,400
Ft. Collins/Loveland (FNL)	N/A	N/A	N/A	N/A
Eagle (EGE)	3	$776	54	2,826
Grand Junction (GJT)	10	$245	60	38,820
Aspen (ASE)	12	$305	55	27.165
Colorado Springs (COS)	12	$500	40	2,767
Montrose/Delta (MTJ)	4	$845	73	8,744
Gunnison (GUC)	2	$776	64	5,339
Pueblo (PUB)	2	$233	40	1,450
Telluride (TEX)	2	$486	70	8,584
Cortez (CEZ)	3	$341	80	11,277
Durango (DRO)	9	$251	80	33,336
Alamosa (ALS)	3	$253	58	5,795
TOTAL 13 Airports	66	-	-	123,365

Source: Bureau of Transportation Statistics,(www.bts.gov), Expedia (www.expedia.com), and Intrastate passenger counts furnished by DIA

2.3.3 Passenger Rail Service

Colorado is served by the Amtrak national passenger rail system (See Exhibit 2-18) with service provided by the California Zephyr linking Denver with Chicago and the California Bay Area, and the Southwest Chief connecting Trinidad, La Junta, and Lamar with Chicago and Kansas, as well as Albuquerque, New Mexico, and Los Angeles, California.

Exhibit 2-18: Colorado Amtrak Passenger Rail Map



Source: Colorado DOT website: http://www.dot.state.co.us/App_DTS_DataAccess/index.ctm

In fiscal year 2007, Amtrak had 208,552 boarding and alightings in the state of Colorado. See Exhibit 2-19. Rail ridership has increased significantly in recent years and between 2006 and 2007 ridership rose by over 7 percent. According to Amtrak travel data and results from the stated preference surveys conducted in Colorado, about half of these trips were intra-state trips, although they were not necessarily made by Colorado residents.

Exhibit 2-19: Amtrak FY2007 - Facts about Serving Colorado

City	Annual Boardings +Alightings
Denver	123,273
Fort Morgan	2,920
Glenwood Springs	32,697
Granby	3,508
Grand Junction	25,115
La Junta	6,556
Lamar	1,683
Trinidad	3,956
Winter Park-Fraser	8,844
Total Colorado Station Usage	**208,552**

Source: Amtrak, www.amtrak.com

Exhibits 2-20 to 2-23 give the fare and fare per mile of Amtrak in Colorado. It can be seen that the passengers are typically paying 15¢ to 30¢ per mile for Amtrak service.

Exhibit 2-20: Amtrak California Zephyr Fare in Colorado

Fare ($)	Fort Morgan	Denver	Fraser-Winter Park	Granby	Glenwood Springs	Grand Junction
Fort Morgan		$ 18	$ 27	$ 28	$ 48	$ 58
Denver			$ 26	$ 26	$ 48	$ 57
Fraser-Winter Park				$ 9	$ 36	$ 45
Granby					$ 31	$ 42
Glenwood Springs						$ 18
Grand Junction						

Exhibit 2-21: Amtrak California Zephyr Fare per Mile in Colorado

Fare/Mile	Fort Morgan	Denver	Fraser	Granby	Glenwood Springs	Grand Junction
Fort Morgan		$ 0.23	$ 0.19	$ 0.17	$ 0.17	$ 0.15
Denver			$ 0.41	$ 0.32	$ 0.24	$ 0.19
Fraser-Winter Park				$ 0.50	$ 0.26	$ 0.19
Granby					$ 0.26	$ 0.19
Glenwood Springs						$ 0.18
Grand Junction						

Exhibit 2-22: Amtrak Southwest Chief Fare in Colorado

Fare ($)	Lamar	La Junta	Trinidad
Lamar		$ 16	$ 35
La Junta			$ 24
Trinidad			

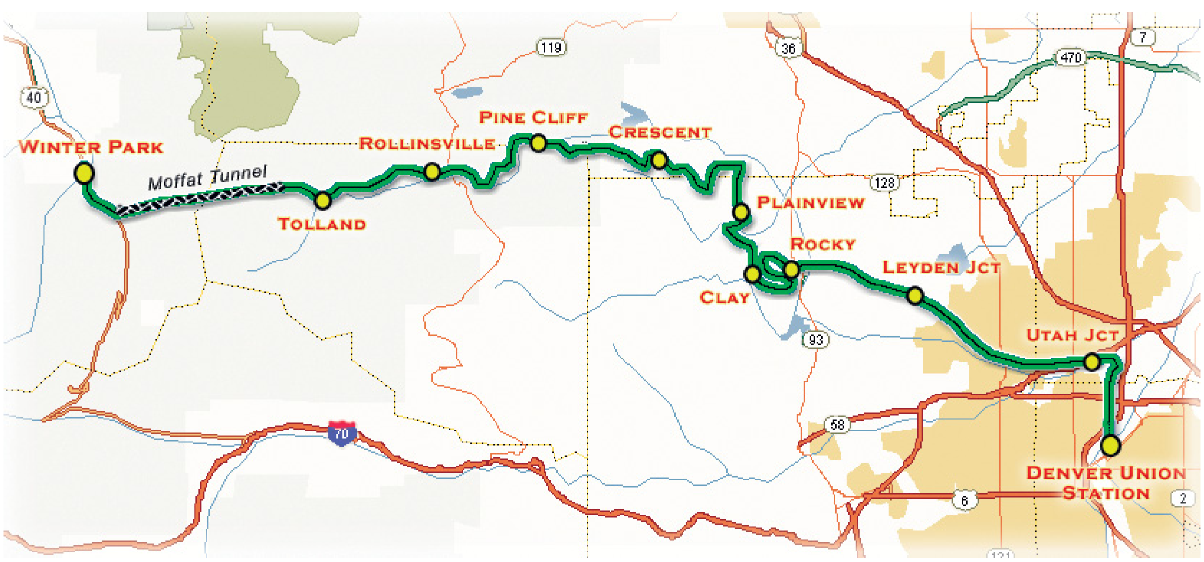
Exhibit 2-23: Amtrak Southwest Chief Fare per Mile in Colorado

Fare/Mile	Lamar	La Junta	Trinidad
Lamar		$ 0.24	$ 0.22
La Junta			$ 0.27
Trinidad			

Source: Amtrak, www.amtrak.com

In addition to Amtrak, until very recently the private sector offered summer and winter rail service in the form of the Ski Train. This service had been in operation for 69 years, offering travel from Denver Union Station to the Winter Park Ski Resort. About 1,200[10] people were transported each day the ski train operated. The train operated on Saturday and Sunday from January through March, with Thursday and Friday departures from mid-February through the end of March. In addition, the Ski Train operated a Saturday-only schedule in July and August. See Exhibit 2-24.

Exhibit 2-24: Ski Train Route



Source: www.skitrain.com

[10] The number is based on the assumption that the occupancy rate of the car is 80 percent.

This scenic route passed the Flat Irons, South Boulder Canyon, and crossed the Continental Divide. The trip took 2 ½ hours for the 57-mile trip, an average speed of 15.2 miles per hour. Round-trip coach fares ranged from $49-59, while the club fare was $85. This gives a cost per mile of 43-52¢ per mile for coach and 75¢ per mile for club. The ski train served largely a "novelty" market catering to group travel and special outings. Passengers considered their travel experience part of the outing and justified the cost primarily for recreational rather than transportation purposes[11]. However, citing difficulties with escalating costs: particularly liability coverage; operational conflicts with freight train traffic, substantial uncertainties posed by redevelopment of Denver's Union Station, as well as long-term impacts resulting from the nation's economic crisis - the Ski Train ended its operation in 2009.

2.3.4 Intercity Bus

The major areas for intercity bus are along the I-25 corridor to and from the city of Denver. Exhibit 2-25 shows that the highest level of service is Denver to Boulder (78 RTD buses per day in each direction) reflecting the high levels of commuting between these cities. Much of this traffic reflects the role of Boulder as a "suburb" of Denver. Levels of bus service is lower for other cities, the next highest being Colorado Springs with 23 FREX (FREX service is from 3:00am to 10:00pm) per day in each direction.

[11] Personal interviews, informal passenger surveys conducted February 2009.

Exhibit 2-25: Intercity Bus Service Frequency in the Corridors[12]

	Cheyenne	Ft Collins	Loveland	Greeley	Boulder	Denver	Colorado Springs	Pueblo	Walsenburg	Trinidad
	I-25 Corridor									
Cheyenne		2	-	2		2	2	2	1	
Ft Collins			12	2		2	3	3	1	1
Loveland				12						
Greeley						2	2	2	1	1
Boulder						78				
Denver							23	7	3	2
Colorado Springs								7	4	2
Pueblo									3	2
Walsenburg										1
Trinidad										
Central City										
Winter Park										
Vail										
Aspen										
Glenwood Springs										
Grand Junction										
Steamboat Springs										

	Central City	Winter Park	Vail	Aspen	Glenwood Springs	Grand Junction	Steamboat Springs
	I-70 Corridor						
Cheyenne			2		1	2	
Ft Collins			2		1	2	
Loveland							
Greeley			2		1	2	
Boulder							
Denver			3	3	4	4	5
Colorado Springs			3				
Pueblo			3		3	4	
Walsenburg			2				
Trinidad			2		2	2	
Central City							
Winter Park							
Vail				2	3	3	
Aspen					19		
Glenwood Springs						3	
Grand Junction							
Steamboat Springs							

Elsewhere service is low, 2 to 4 buses per day between paired cities (e.g., Greeley-Loveland has 12 buses per day) and key routes such as Glenwood Springs to Aspen, which has 19 buses per day in each direction. Fares and frequencies vary dramatically between subsidized commuter bus services such as Boulder to Denver at 10¢ per mile, and private bus service between Denver and Aspen at 60¢ per mile. See Exhibit 2-26. Average bus speeds are 30 to 50 miles per hour. Exhibit 2-27 shows the

[12] Exhibit 2-25 thru 2-27 are based on data from Regional Transportation District (www.rtd-denver.com), Greyhound (www.greyhound.com), Frex - FrontRange Express (www.frontrangeexpress.com), Black Hills Stage Lines (www.blackhillsstagelines.com), Colorado Mountain Express (www.ridecme.com), 34 Xpress (http://www.greeleygov.com/theBus/Documents/34-Xpress%20Bus%20Stop%20List.pdf), Roaring Fork Transportation Authority (www.rfta.com), and Alpine Taxi (www.alpinetaxi.com).

travel time of some bus services. Bus services such as Greeley-Loveland are based on institutional/county boundaries.

Exhibit 2-26: Intercity Bus Fares

Fare	Cheyenne	Ft Collins	Loveland	Greeley	Boulder	Denver	Colorado Springs	Pueblo	Walsenburg	Trinidad
	I-25 Corridor									
Cheyenne		$16.50		$19.30		$34.05	$40.00	$46.50	$57.50	
Ft Collins			$1.25	$14.20		$21.60	$33.00	$40.00	$51.50	$57.00
Loveland				$1.50						
Greeley						$19.30	$33.00	$36.00	$46.50	$57.50
Boulder						$4.00				
Denver							$9.00	$24.50	$36.00	$46.50
Colorado Springs								$12.25	$26.50	$33.00
Pueblo									$16.50	$23.50
Walsenburg										$11.75
Trinidad										
Central City										
Winter Park										
Vail										
Aspen										
Glenwood Springs										
Grand Junction										
Steamboat Springs										

Fare	Central City	Winter Park	Vail	Aspen	Glenwood Springs	Grand Junction	Steamboat Springs
	I-70 Corridor						
Cheyenne			$46.50		$62.50	$68.55	
Ft Collins			$36.00		$51.50	$48.50	
Loveland							
Greeley			$36.00		$46.50	$68.50	
Boulder							
Denver			$25.00	$104.00	$33.50	$48.50	$85.00
Colorado Springs			$40.00				
Pueblo			$46.50		$59.50	$59.00	
Walsenburg			$59.50				
Trinidad			$62.50		$150.00	$81.50	
Central City							
Winter Park							
Vail				$90.00	$20.50	$20.00	
Aspen					$6.00		
Glenwood Springs						$18.00	
Grand Junction							
Steamboat Springs							

Exhibit 2-27: Intercity Bus Travel Times

Travel Time (hour/min)	Cheyenne	Ft Collins	Loveland	Greeley	Boulder	Denver	Colorado Springs	Pueblo	Walsenburg	Trinidad
	I-25 Corridor									
Cheyenne		0:03		1:19		2:30	5:10	10:49	12:00	
Ft Collins			0:22	0:30		1:40	4:19	5:25	9:25	9:45
Loveland				1:16						
Greeley						1:10	3:49	9:00	10:40	17:00
Boulder						1:00				
Denver							1:45	2:19	3:25	3:45
Colorado Springs								0:45	1:55	2:04
Pueblo									0:55	1:10
Walsenburg										0:45
Trinidad										
Central City										
Winter Park										
Vail										
Aspen										
Glenwood Springs										
Grand Junction										
Steamboat Springs										

Travel Time (hour/min)	Central City	Winter Park	Vail	Aspen	Glenwood Springs	Grand Junction	Steamboat Springs
	I-70 Corridor						
Cheyenne			6:34		12:00	13:04	
Ft Collins			5:15		5:34	7:19	
Loveland							
Greeley			4:45		10:10	11:45	
Boulder							
Denver			2:04	5:15	3:15	5:00	4:15
Colorado Springs			4:15				
Pueblo			5:19		6:25	8:00	
Walsenburg			7:40				
Trinidad			9:25		5:19	9:55	
Central City							
Winter Park							
Vail				2:00	1:10	2:49	
Aspen					1:30		
Glenwood Springs						1:30	
Grand Junction							
Steamboat Springs							

While bus service south from Denver to Colorado Springs and Pueblo is strong and provided by both FREX and Greyhound, there is a major disconnect in the bus network serving the northern Front Range. The Denver RTD provides frequent service as far north as Longmont, and north of Loveland to Fort Collins and Greeley service is available. However, between Longmont and Loveland there is a gap between the bus service zone of the two regional transit agencies and it is difficult for riders to conveniently connect between the two transit systems.

Overall passenger counts and trip purposes, based on publicly available data for the Colorado regional transit systems are shown in Exhibit 2-28. It can be seen that Denver's RTD constitutes the majority of trips, but not all of the RTD trips would be considered intracity or intraregional trips for the purpose of this analysis.

Trip purpose data for RTD, FREX and Greyhound was summarized from the results of Stated Preference Surveys conducted in October 2008. This shows that the largest category of trips on FREX and RTD (urban transit systems) are for commuting whereas Social and Business comprised the main purpose for Greyhound trips.

Exhibit 2-28: Bus Ridership and Trip Purpose

Carrier Name	Carrier Operated By	Passenger Trips /Year		Annual Passenger Trips By Trip Purpose(5)			
		FR(1)	DR(2)	Business	Commuter	Vacation	Social
RTD	Public	81,988,863	425,726	7.3%	49.2%	19.8%	23.7%
Greyhound	Private	131,920		25.3%	4.0%	10.1%	60.6%
FREX(3)	Public	456,250		14.1%	76.1%	1.4%	8.5%
Mountain Express	Public	508,719		25.3%	4.0%	10.1%	60.6%
34 Xpress(4)	Public	471,921	26,765	7.3%	49.2%	19.8%	23.7%
Roaring Fork Transportation Authority	Public	3,567,921	3,518	7.3%	49.2%	19.8%	23.7%

(1) FR: Fixed Route

(2) DR: Demand Response

(3) based on 625 daily on-way passenger trips from FREX website, Source: www.frontrange express.com

(4) based on City of Greeley Transit

(5) the trip purpose percentage is estimated from survey data collected by TEMS

Source: Except FREX, all the ridership data are based on "2003 Colorado Transit Resource Directory."
FREX schedules were downloaded from the internet.

Finally, Exhibit 2-29 shows that usage of existing bus systems does vary by season, but the seasonal differences are not large, only in the order of approximately 10 percent. This pattern of course is different from that experienced on the I-70 corridor, which because of the largely discretionary trip purposes experience much larger swings than those encountered by typical bus or urban transit systems.

Exhibit 2-29: RTD Bus Ridership and Seasonality (in thousands trips)

2007 RTD Quarterly and Monthly Data(1)					
Quarter 1 Ridership	Avg Week Day (Quarterly)	**Jan**	**Feb**	**March**	**Total**
	198	4,790	4,621	5,407	14,817
Quarter 2 Ridership	Avg Week Day (Quarterly)	Apr	May	Jun	Total
	201	5,072	5,299	4,815	15,186
Quarter 3 Ridership	Avg Week Day (Quarterly)	Jul	Aug	Sep	Total
	208	4,875	5,404	5,337	15,616
Quarter 4 Ridership	Avg Week Day (Quarterly)	Oct	Nov	Dec	Total
	217	5,993	5,428	4,797	16,217

(1) Source: American Public Transportation Association (APTA) Ridership Reports Statistics, www.apta.com

2.4 Preliminary Intercity Travel Market

The character of the Colorado intercity market is influenced by two critical factors:

1. The day-to-day business and work environment that dominates the I-25 corridor, which provides the support and logistics for both the agricultural east and the tourist and mining west.
2. The tourist environment of the Rockies and the flows of traffic along I-70 from Denver and Denver International Airport.

Of the approximately 99 million annual intercity trips generated by overnight and day trips within the state, some 36.6 million (37 percent) are focused on the city of Denver, and 24 million (24 percent) are to or from Denver Airport[13]. Other I-25 cities have much lower levels of intercity traffic, such as Colorado Springs with 7.3 million trips, Fort Collins with 3.6 million trips, Boulder with 3.6 million trips, and Pueblo with 1.8 million trips. See Exhibit 2-30.

[13] DIA total 44 million trips: 24 million intercity passenger trips, an additional 20 million intracity trips by employees and travelers.

Exhibit 2-30: Preliminary Assessment of Major Production and Attraction Centers for Annual Intercity Trips

Key Locations for Intercity Trips	
Total Trips Colorado	99 million
Total Trips Colorado (overnight)	56 million trips
Total Trips Colorado (day)	43 million trips
Denver Airport	24 million trips
Denver	36.6 million trips
Colorado Springs	7.3 million trips
Fort Collins	3.6 million
Pueblo	1.8 million
Boulder	3.6 million
Black Hawk/Central City	12 million trips
Vail	7.9 million trips
Aspen	7.4 million trips
Breckenridge	8.2 million trips
Keystone	5.7 million trips
Copper Mountain	4.7 million trips
Steamboat Springs	5.1 million trips
Glenwood Springs	3.4 million trips
Avon	4.6 million trips
Grand Junction	4 million trips
Georgetown	1.5 million trips

Source: TEMS Analysis based on the data from Longwoods International, AADT flows, Denver Airport Master Plan, and Colorado Ski Country USA.

Perhaps more surprising is the volume of trips along I-70 with major attractors like Central City/Black Hawk, with 12 million trips; Vail, Aspen and Breckenridge with approximately 8 million annual trips each; Keystone, Copper Mountain, Steamboat with about 5 million trips each, and Grand Junction with 4 million trips. This shows that the recreational area resorts play the role of major traffic generators, capable of producing trips characteristic of cities many times their size on an equivalent population basis. In fact, the I-70 corridor markets generate more intercity travel demand than do the more traditional markets along I-25.

A significant challenge for serving I-70 markets is the largely social/recreational nature of the trip purposes, which is likely to depress the potential revenue yields available in this corridor, except for the DIA-related out-of-state travelers. As occasional users of the system, DIA riders are more likely to be willing to pay higher fares in return for a top-quality comfortable travel experience. Although these air connect riders may be willing to pay higher fares, stated preference work described later in this report has shown that they are extremely adverse to transfers and require a single-seat ride for any rail service to be competitive. In addition, DIA riders are sensitive to service frequency, requiring a high level of service from DIA up into the I-70 corridor as well as to I-25 destinations. This shows the critical importance of the ability to connect DIA directly into the I-70 corridor in order to maintain a reasonably high overall average revenue yield for the I-70 corridor.

2.5 Conclusion

The Colorado market for intrastate, intercity travel is very heavily focused in the I-25 and I-70 corridors, with significant numbers of trips now being made by private automobile, and air, Amtrak, and intercity bus playing a very minor role. The volume of travel in these corridors outside the urban areas has AADTs in the 30,000 - 60,000 range in the intercity sections of I-25, and in the 20,000 - 40,000 range along I-70.

These observed travel volumes in the I-70 and I-25 corridors are reflective of what might be expected in a "typical" high-speed rail corridor in much more densely populated regions of the country such as Ohio[14] or the Midwest[15]. It suggests that despite its low population, both the I-70 and I-25 corridors may have enough traffic density to be able to support a high-speed rail corridor. This will be especially true if the two corridors are interconnected and train service is interoperable, giving the ability to provide a single-seat ride not only to DIA but also to and from the I-70 to I-25 corridor population and attraction centers.

[14] Ohio Hub Study, TEMS/HNTB, July 2007
[15] Midwest Regional Rail Study, TEMS/HNTB, June 2004

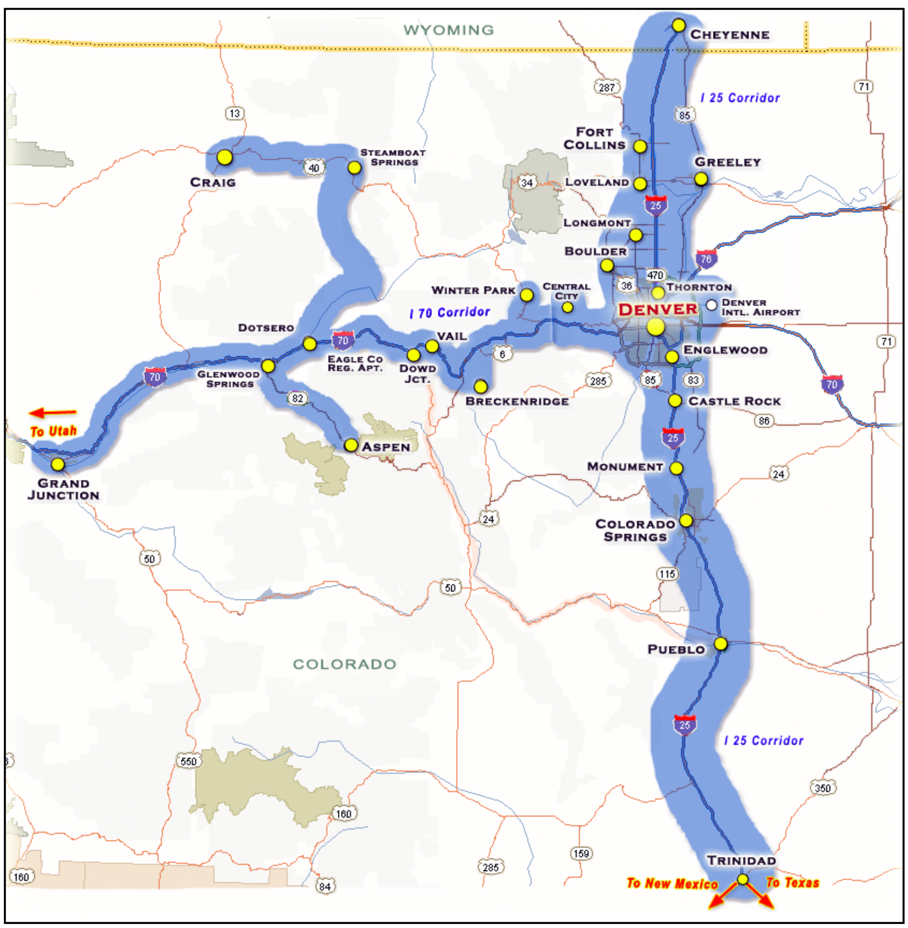
3 Infrastructure Needs

3.1 Introduction

The purpose of this chapter is to assess the level of infrastructure needed to support high-speed rail along the I-25 and I-70 corridors in Colorado. The study corridors are defined as two primary corridors and several secondary corridors as shown in Exhibit 3-1. The study corridors that were subject to engineering assessment include:

- **I-25 South:** Denver-Colorado Springs-Pueblo-Trinidad
- **I-25 North:** Denver-Fort Collins-Cheyenne (four alternate routes south of Fort Collins)
- **Denver to DIA:** downtown Denver to Denver International Airport (DIA)
- **I-70 West:** downtown Denver to Grand Junction
- **I-70 Secondary Corridors:** to Black Hawk, Winter Park, Breckenridge, Aspen and Craig

Exhibit 3-1: RMRA High-Speed Rail Feasibility Study Corridors



The infrastructure requirement was conceptually developed for "representative" routes in each study corridor, and the costs to build this infrastructure estimated. Infrastructure needs vary by alignment type and vehicle technology. In developing the representative routes for the I-25 and I-70 corridor, the following types of alignment are considered:

- **Existing rail** – a route using either the tracks or right-of-way of an existing rail corridor
- **Constrained/Highway Right-of-Way –** a route that is solely within or contiguous to the rights-of-way of the I-70 or I -25 highway
- **Unconstrained/Greenfield –** a route that is outside the I-70 and I-25 highway Rights-of-Way

Alignment variations for vehicle technology include:

- For speeds up to 110 mph in the I-25 corridor mph, use of existing rail rights-of-way owned by freight railroads has been considered. These options use diesel rail equipment.
- For speeds above 110 mph, a greenfield right-of-way option has also been developed for I-25. These options use electric rail or maglev equipment.
- For I-70 from Denver to Minturn, two different greenfield options have been developed: a low-gradient (4 percent) "Unconstrained" rail route that deviates from the I-70 highway right-of-way, and a high-gradient (7 percent) alignment within the I-70 Right- of-Way. The high-gradient route is the same one that was developed by the I-70 PEIS. While conventional trains could use the "unconstrained" 4 percent alignment, the high-gradient 7 percent alignment on I-70 is suitable only for maglev or Electric Multiple Unit (EMU, or self-propelled) rail vehicles.
- For I-70 west of Minturn, the evaluation focused on existing rail options, but short greenfield segments have also been considered from Gypsum to Mid-Valley (the "Cottonwood Pass" alternative) and from Wolcott to State Bridge (the "Route 131" option.)

This engineering assessment of the study corridors was conducted in cooperation with the RMRA, freight railroads, Colorado DOT and in coordination with both the FasTracks and Colorado Freight Rail relocations (R2C2) studies. The R2C2 study is developing an option for rerouting freight trains away from the Denver-Pueblo-Trinidad segment of the corridor by building a new north-south rail line in the eastern plains.

The engineering assessment entails a field inspection of the existing conditions within the study corridors, and a review of previous studies that were undertaken within the study corridors. Chapter 8 details the infrastructure plan and capital costs for each route considered for high-speed passenger rail service.

3.2 Engineering Assessment

An engineering assessment was prepared which provided an evaluation of the current condition of the proposed highway, greenfield, and railroad right-of-way; identified improvements to existing rail lines needed to support the 79-mph, 110-mph and 150-mph rail passenger service scenarios; and estimated civil engineering requirements for new greenfield routes for the 125-mph maglev, 220-mph rail and 300-mph maglev options.

The engineering assessment and its findings and recommendations relative to existing rail lines contained within this report are preliminary and were not developed in detail with the railroads. As discussed in earlier chapters, this study is at a feasibility level, the project to build a passenger rail system is un-funded and, therefore, formal negotiations with the railroads were not initiated. Future engineering assessments will require considerably more discussion to ensure railroad concurrence. Final design concepts and recommended capital plans will depend on detailed operations and capacity analyses, design coordination and in-depth discussions with the freight railroads. As the project moves beyond the feasibility phase, railroad involvement and coordination will become increasingly important.

A systematic engineering planning process was used to conduct the engineering assessment of the existing rail rights-of-way and potential greenfield routes within each study corridor, to quantify infrastructure needs and estimating the capital investment required for each route. As part of the engineering assessment the infrastructure needs were quantified by type of segment and by project element. The project elements that were assessed and quantified include:

- Guideway and track elements
- Structures
- Systems
- Crossings
- Stations/Maintenance facilities
- Special project elements

The engineering assessment of these elements was accomplished by conducting field inspections of each study corridor. A field inspection is a limited site verification without detailed surveys consisting of the sampling of critical sites along the track at crossings, bridges and stations. These field inspections were augmented by using satellite photography and GIS data to understand what lies between each view. At each location, engineering notes were compiled and the physical track conditions were compared with the latest track charts and other information provided by the railroads.

Field observations were conducted at highway/railroad crossings, overpasses and parallel roadways. The inspections focused on the condition of the track and the ability to accommodate joint freight and passenger train operations. The railroad right-of-way and highway corridors were examined for their ability to accommodate additional tracks for added capacity. Where possible, other existing facilities were observed, including bridge conditions, vertical/horizontal clearances, passenger train facilities, railroad yards and terminal operations. Photographic records were made at many locations.

As the study corridors were examined in the field, general concepts were developed and assumptions were made regarding the capacity and operational improvements needed to accommodate future passenger operations. The primary objective was to conceptualize infrastructure improvements that would improve fluidity and enhance the reliability of both passenger and freight rail operations.

During the field inspections, the condition of the right-of-way was noted and a determination was made relative to the improvements required to accommodate a specific train technology. The limited field inspections determined the existing track condition, assessed its suitability to accommodate joint rail freight and passenger operations, and gathered sufficient data to identify needed infrastructure improvements. For greenfield routes, the topographical features, waterways, and wetlands of the corridor were noted for future reference to other data sources such as GIS mapping, orthophotography and other available information.

The results of the field inspections were combined with data derived from GIS and railroad track charts to determine more precisely the recommended infrastructure improvements and to estimate capital costs. Cost estimates were then prepared through the application of appropriate unit costs and are presented in Chapter 8.

In order to ensure that the engineering assessment considered previous studies undertaken in Colorado, a review was made of the following:

- I-70 Programmatic Environmental Impact Statement and Collaborative Effort
- Colorado Railroad Relocation and Implementation Study
- FasTrack's various Environmental Studies
- Wyoming DOT Rail Feasibility Study
- Gaming EIS (Black Hawk and Central City)
- Colorado Maglev Study
- I-25 North Environmental Impact Statement
- Intermountain Connection Study, Phase 1 and 2

Information concerning this review of previous studies can be found in Appendix D of the *Existing Conditions Report*.[1]

3.3 Guidance from the Federal Railroad Administration (FRA)

For developing representative routes for the I-70 and I-25 corridors in Colorado, FRA guidelines for route development were used. FRA has produced a technical working paper: *Railroad Corridor Transportation Plans (RCTP), A Guidance Manual*[2]. Section II of this FRA manual provides practical suggestions and policy guidance to aid the selection of an appropriate route for high-speed rail. The five basic requirements are:

- Geometry (horizontal and vertical curves) that impacts speed and travel time
- Capacity of the route
- Proximity of route to population centers
- Proximity of route to intermodal sites
- Cost of improvements

An *Existing Conditions Report* was completed for this project and is available at the RMRA website. This technical report presents results of the field inspection in the form of a review of existing

[1] http://rockymountainrail.org/documents/FINAL_Existing_Conditions_Rpt.pdf
[2] See: http://www.fra.dot.gov/downloads/RRDev/corridor_planning.pdf

conditions in the I-25 North, I-25 South and I-70 study corridors, and also present observations concerning several potential greenfield routes.

This chapter provides an assessment of the development of representative routes based on the FRA *Guidance Manual*, and using the five route evaluation criteria described above. The criteria were applied through a qualitative assessment of the physical, demographic, and potential cost of any route option for a given technology.

3.4 Technology Considerations

The field inspection of the existing rail rights-of-way and potential high-speed rail greenfield routes within the study corridors was carried out considering the use of several potential technologies. Since the field inspection was undertaken in the early stages of the project, these technologies represent a wide cross section and were only used at this stage to draw conclusions as to infrastructure needs. The technologies considered at this stage are summarized as follows:

- Conventional steel wheel on steel rail, FRA compliant, diesel locomotive hauled coaches or DMU equipment limited in speed to 79 mph, without tilting capability, suitable for use on track shared with freight trains. The system will use existing and new track in existing rail corridors.
- Steel wheel on steel rail, FRA compliant, diesel locomotive hauled coaches, limited in speed to 110 mph, with tilting capability, suitable for use on existing rail corridors. In urban conditions where right-of-way is constrained, the system may share the track and/or right-of-way with freight and operate at restricted speeds.
- Steel wheel on steel rail, FRA compliant, electrified locomotive or EMU equipment, with tilting capability, suitable for use on dedicated track at speeds from 150 to 220 mph in new, fully grade separated corridors. In urban conditions where right-of-way is constrained, the system may share the right-of-way, but not track with freight and operate at restricted speeds
- High-speed magnetic levitation (LSM) technology, represented by the German TransRapid system with speeds from 250 to 300 mph. The system will be constructed in new fully grade separated corridors and will avoid the use of freight railroad right-of-way where possible.
- Urban magnetic levitation (LIM) technology, represented by Japanese HSST, with speeds up to 125 mph. The system will be constructed in new fully grade separated corridors, and will avoid the use of freight railroad right-of-way where possible.

This provides only a brief overview of the equipment options considered for this study. Chapter 4 of this report will be entirely devoted to a detailed examination of equipment technology issues, along with the specific route alignment options for which each technology has been evaluated.

3.5 Engineering Assessment: I-25 South Corridor - Denver to Trinidad

3.5.1 Existing Rail Rights-of-Way

In the late 1800's, the Denver & Rio Grande Railroad built a line from Denver Union Station south through Colorado Springs to Pueblo. Similarly, the Atchison, Topeka & Santa Fe extended their line north from La Junta through Pueblo and Colorado Springs to Denver on a parallel route. After a series of mergers and acquisitions, the current owners, Union Pacific Railroad and Burlington Northern Santa Fe, have come to share the corridor, generally operating southbound on the westernmost track and northbound on the easternmost track. In most locations between Denver and Pueblo, multiple tracks exist, except from Palmer Lake south to Crews. South of Pueblo, BNSF operates a single track to Trinidad. UPRR shares the right-of-way with BNSF south from Pueblo as far as Walsenburg, where its branch-line to Alamosa diverges west. The existing rail corridor is known as the Joint Line. Details of the field inspection of the existing rail rights-of-way are provided in the *Existing Conditions Report*.

I-25 south of Denver reflects significant operational challenges as a result of heavy freight traffic and complex operating arrangements on the existing "Joint Line" and "Consolidated Main Line" through Denver, continuing all the way south to Pueblo.

- The Joint Line (JL) begins at the South Denver interlocker, Milepost 0.0, approximately where I-25 crosses the rail corridor south of Denver – close to RTD's I-25 and Broadway Light Rail station – and continues to the Bragdon crossover switches, north of Pueblo. The United States Railroad Administration (USRA) established the Joint Line in 1918 during World War I. It consists of a combination of tracks originally built as two separate lines by the Denver & Rio Grande (DRGW, narrow gauge) in 1871 and by the Santa Fe (ATSF, standard gauge) in 1887.
- The Consolidated Main Line (CML) in contrast, extends from Sand Creek Junction to the South Denver interlocking at I-25, where the Joint Line officially begins. The CML resulted from abandonment of a portion of DRGW that formerly connected the Burnham yard complex to the south end of Denver Union Station (DUS). This abandonment left Burnham Yard, which was formerly on the DRGW mainline, on a looping branch line that is no longer used for through traffic, and left Union Station stub-ended. The former ATSF was double-tracked through downtown Denver to replace the capacity of the former DRGW line.

Some of the operational challenges associated with heavy Joint Line freight traffic may be mitigated by the freight rail relocation project being considered jointly by the Colorado Department of Transportation (CDOT) and the freight railroads. CDOT's Colorado Rail Relocation Implementation Study (January 2009), known as R2C2, has examined the feasibility of building a new north-south rail line in the eastern plains, to divert a significant share of through freight away from the corridor. Regardless of the specific means of capacity mitigation, because of the criticality of the Joint Line for freight, it is essential to ensure that any proposed passenger service does not adversely affect the ability of the freight railroads to efficiently move freight and grow their own capacity in the future.

The primary user of the Joint Line is BNSF who uses it as part of a through route from Wyoming to Texas. A significant share of BNSF traffic, primarily Powder River basin coal trains, could be diverted onto the proposed R2C2 bypass. However, UP also has significant operations serving power plants and other freight customers along the Joint Line. Because nearly all of UP's traffic is local, it is hard to divert any of UP's traffic. Therefore, the R2C2 project offers an opportunity to reduce, but not eliminate freight from the Joint Line. Any passenger plan must recognize the continued need for freight service, and provide a level of capacity that is appropriately matched to market needs.

3.5.2 Potential Greenfield Routes

High-speed passenger rail systems require long tangents and gradual curves to achieve high operating speeds. Grades may exceed those of freight trains, as the equipment is less massive and offers relatively high power to weight ratios. A possible solution is to depart from the existing rail right-of-way to establish new rail lines that are specifically designed for high-speed passenger service. Such lines can be constructed on entirely new alignments or greenfields with the option of using segments of existing highway right-of-way. In this report the term greenfield may be applied to any rail construction outside of existing rail right-of-way. In the I-25 South corridor, the Front Range from Denver to Pueblo, and the Eastern Plains from Pueblo to Trinidad were considered as potential greenfield routes.

For potential development of greenfield routes, the I-25 South highway corridor varies in width from Denver to Trinidad. However, it is difficult to utilize the I-25 corridor through Colorado Springs and Denver due to lack of sufficient right-of-way, and the presence of frequent overpass and underpass structures. South of Denver, instead of using I-25, a separate greenfield on new alignment has been proposed. A separate alignment offers better geometry than the highway alignment could, but the highway alignment offers direct service to downtown Monument and Colorado Springs.

North of Denver, the I-25 highway corridor is very straight and using it avoids rail construction impacts to built-up areas. So in the current feasibility study, the I-25 alignment has been used north of Denver, but not in the south. However, an option for using I-25 for rail in the southern corridor could be developed in the future.

3.5.3 Findings of Field Inspection and Selection of Representative Routes

The existing rail rights-of-way and potential high-speed rail greenfield routes between Denver Union Station and Trinidad were inspected during the period of June 11-13, 2008. The inspection included the historic rail corridors owned by BNSF and UPRR (the Joint Line), I-25 highway corridor and segments of the countryside to the east of the Front Range. The findings of the inspection and the relationship to the FRA basic requirements for an efficient high-speed rail route are as follows. (The relevant FRA guideline is listed in parenthesis following each bullet point):

- Access from the south does not exist at DUS. (Proximity of route to intermodal sites. Refer to section 3.5.5 for further explanation.)
- The Joint Line segment between Denver and C-470 is constrained by limited right-of-way and capacity issues. (Route capacity)

- The Joint Line segment through Castle Rock, Palmer Lake, and Colorado Springs has limited right-of-way that limits speed and impedes construction of improvements to mitigate capacity issues. (Route capacity)
- Many segments of the Joint Line contain limited right-of-way and abrupt curvature that result in slower speeds than desired for efficient passenger rail service (Geometry of route).
- The freight traffic on the Joint Line includes slow moving and frequent coal trains. (Route capacity)
- The existing Joint Line rail right-of-way, with improvements for curve easements, may be suitable for the construction of steel wheel/steel rail technologies with speeds up to 110 mph.
- The existing rail right-of-way, the I-25 highway corridor, and the Front Range and Eastern Plains provide good conditions for upgrading track or building a new right-of-way for various types of high-speed ground transportation. (Route geometry and Proximity to intermodal sites)
- The Front Range from Denver to Pueblo and the Eastern Plains from Pueblo to Trinidad are generally suitable for the construction of a full range of high-speed rail technologies. (Route geometry and Proximity to intermodal sites)
- The I-25 Highway corridor has constraints to the development of high-speed passenger rail service in that the geometric alignment has areas of curves and grades that are not conducive to efficient high-speed passenger rail operation. (Route geometry)

Exhibit 3-2 shows the two Representative Routes that were developed for evaluation in the I-25 South corridor. Please note that these routes are consistent with the Engineering assumptions that were used in development of the Costing Segments (see Appendix E) for initial option screening, and up through the initial development and assessment of the FRA Developed Option. The maps do not reflect changes in the Colorado Springs area or stations that were later developed as part of the Freight Rail Risk analysis (See section 10.6) and subsequently incorporated into the final FRA Developed Option maps.

The existing rail representative route south of Denver, as shown in Exhibit 3-3, include the Joint Line rights-of-way either owned by BNSF and UPRR from Denver to Trinidad (existing rail). Chapter 5 presents a more detailed analysis of the two existing rail tracks concluding in most places that the BNSF (former ATSF) alignment offers better geometry than does the UPRR (former DRGW) alignment.

The representative route for the greenfield option as originally conceived is shown in Exhibit 3-4. From Denver to Littleton, the existing rail alignment is used to gain access to downtown Denver. From Littleton the greenfield alignment proceeds to Lone Tree alongside the C-470, flying over the to east side of I-25 and then along a route contiguous to the I-25 highway to Castle Rock. From Castle Rock the route moves east where better geometry can be obtained. At the crossing of the former Rock Island right-of-way north of Colorado Springs, the route follows this mostly-abandoned rail corridor into downtown Colorado Springs. It uses a route either within or contiguous to the existing Joint Line rail right-of-way through Colorado Springs area; then proceeding into the Front Range from south of Colorado Springs to north of Pueblo onto a segment either within or contiguous to the existing railroad right-of-way into downtown Pueblo. South of

Pueblo the route enters onto the Eastern Plains to Walsenburg and onto Trinidad, entering Trinidad on or contiguous to the existing rail right-of-way.

Exhibit 3-2 shows the areas where the Existing Rail and Greenfield are on different alignments, as well as the common shared segments where the Greenfield uses the existing rail right-of-way in urban areas. It should be noted that both the Existing Rail and Greenfield options assumed the same stations in downtown Colorado Springs as well as a southern suburban station serving Fountain and Fort Carson. The existing rail line does not go past the Colorado Springs airport. The opportunity for adding a station at the airport arose during the freight rail Risk Assessment which occurred identified later in the study. The recommendation to add a station at Colorado Springs airport was subsequently incorporated into the FRA Developed Option after the freight rail Risk Assessment was completed. (See Appendix I)

It should be noted that the rail alignment on the I-25 Greenfield as originally conceived lies on the eastern plain, more than 10 miles east of the town of Monument. A sensitivity analysis was performed on the impact of including a Monument station on this alignment, but because the station lies so far east, the access time actually suggested that riders would generally prefer driving north on I-25 to Castle Rock rather than east on country roads to the place where a station would need to be. As such this station location on the original greenfield alignment was found ineffective, with an essentially neutral ridership impact. It is anticipated that this issue will be addressed in a future study by shifting the alignment farther west, following the recommendations of El Paso County, so that Monument can have an effective station. (See Appendix I)

Exhibit 3-2: Map of All Representative Routes in I-25 South Corridor

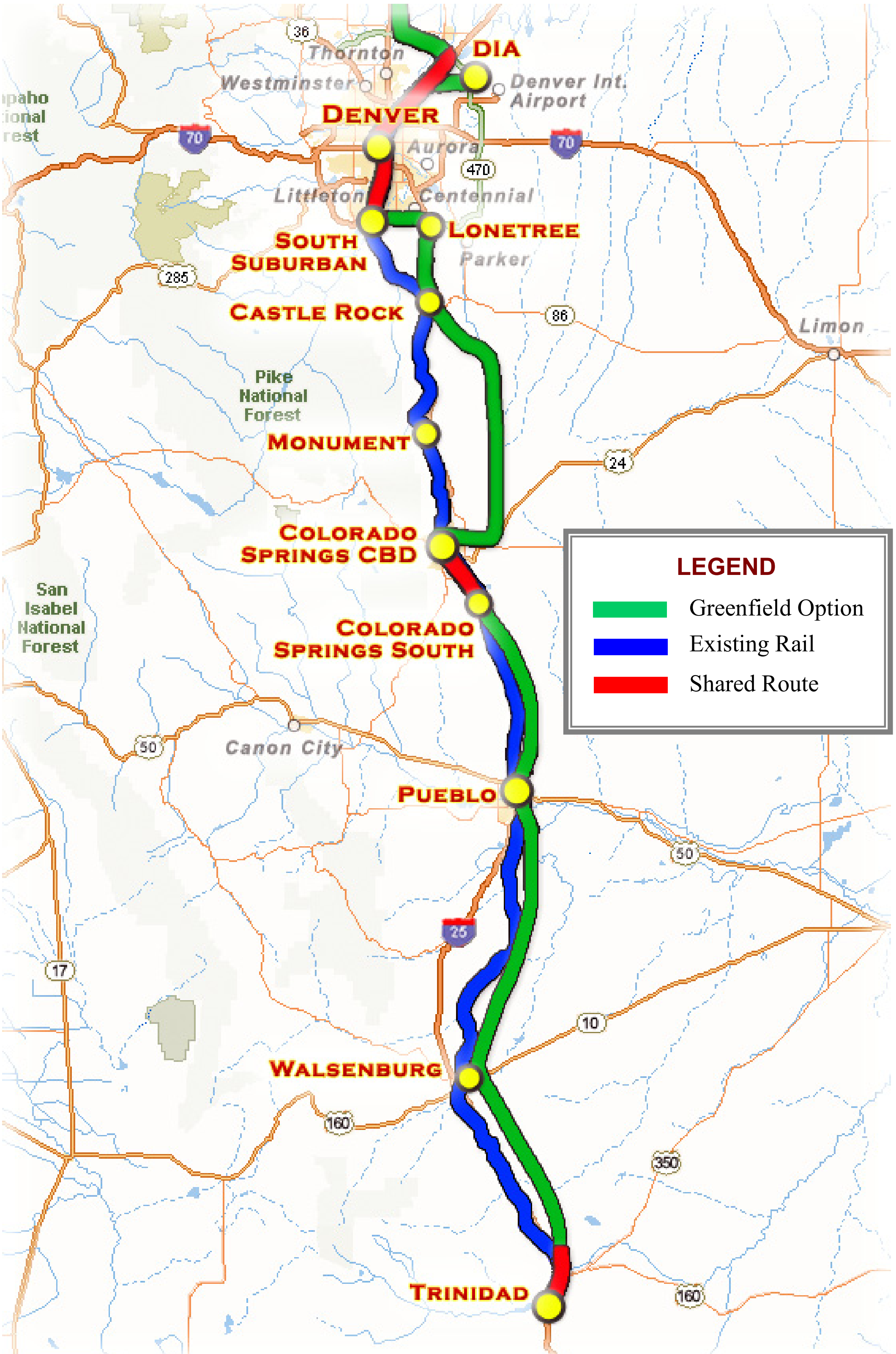


Exhibit 3-3: Map of Existing Rail Representative Route in I-25 South Corridor

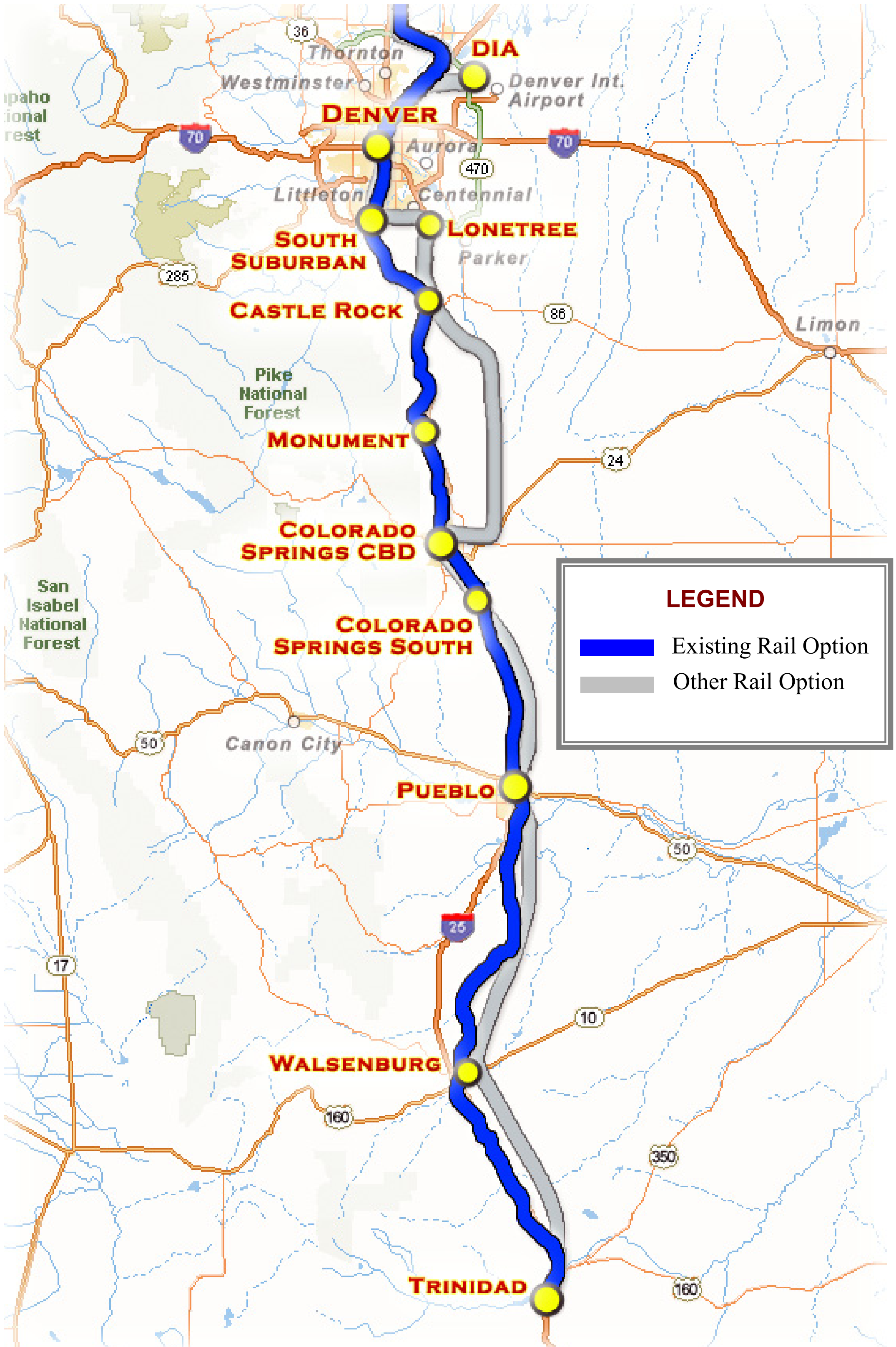
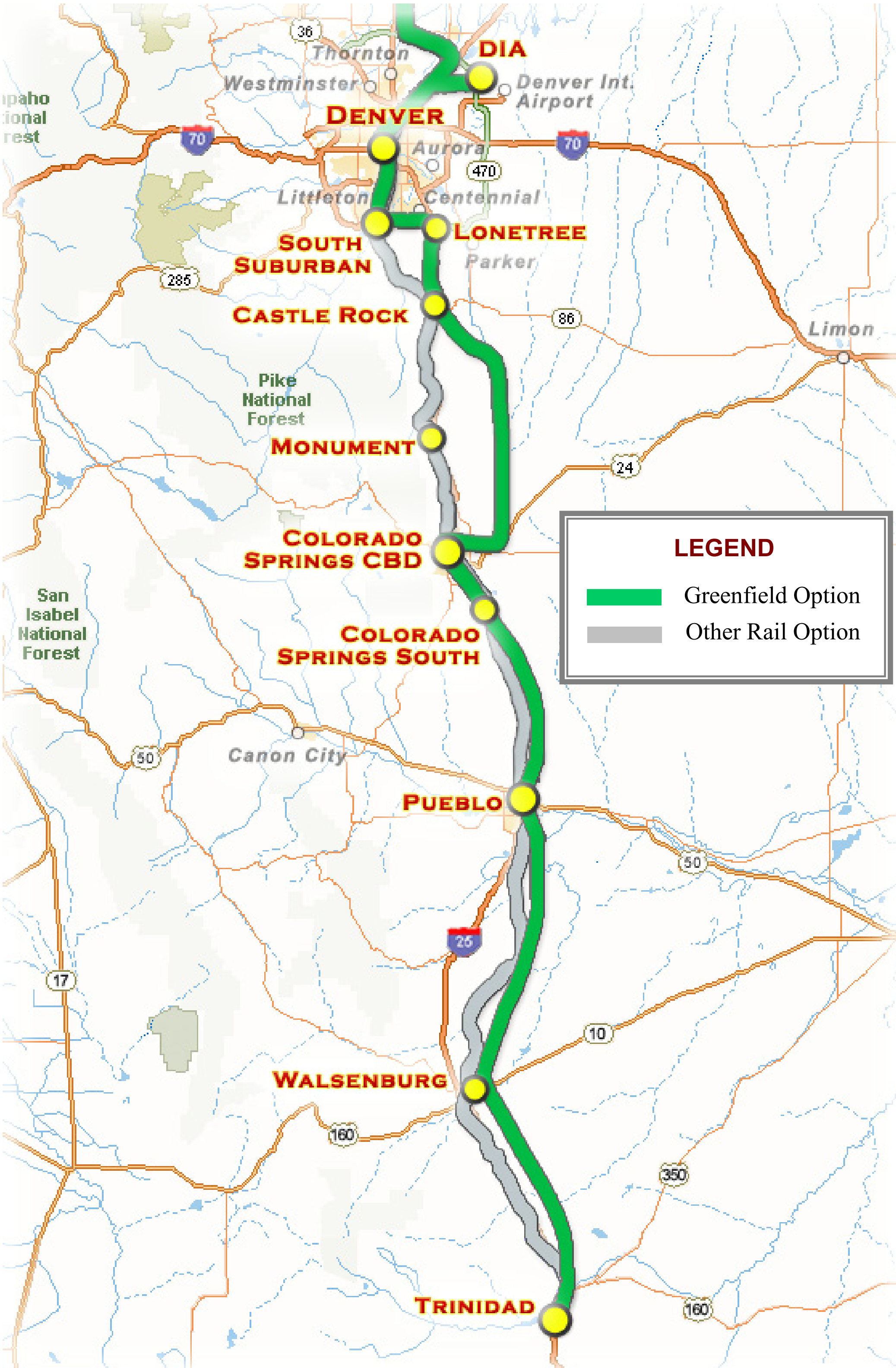


Exhibit 3-4: Map of Greenfield Representative Route in I-25 South Corridor



3.5.4 Proximity of Representative Routes to Intermodal Sites

Denver Union Station (DUS): DUS in downtown Denver is planned to serve as a key intermodal hub for FasTracks and other RTD rail and bus service. In the event that the proposed passenger service is implemented on the existing rail right-of-way, an intercity passenger rail station connected to DUS could be constructed contiguous to the Consolidated Main Line (CML). Since the current DUS station is a stub-end design allowing service only from the north, placing the intercity platform alongside the CML tracks would also allow for direct rail service from the south. The study assumes that a footprint for the necessary intercity rail platforms and tracks alongside the CML will be preserved in development plans for the site. To minimize platform space requirements at DUS, all operating plans developed in this study assume run-through service at DUS with no intercity trains originating or terminating there. The view south from DUS, showing the current Light Rail platform, is shown in Exhibit 3-5. It should be noted that this platform will be removed and relocated approximately 1,000 feet to the west, alongside the Consolidated Main Line, based on current redevelopment plans for the site. Exhibit 3-6 shows the area between DUS and the BNSF/UPRR Consolidated Main Line.

Exhibit 3-5: View showing commercial development constructed on the southern approach to DUS

Exhibit 3-6: Area between Denver Union Station and the BNSF/UPRR Joint Line (existing rail)

South Suburban Station: The South Suburban Station is proposed for a location near the intersection of the Joint Line with the C-470 highway. The location is contiguous to the existing rail route, and also accessible to the proposed greenfield route that proceeds from this intersection east along the right-of-way of C-470 to Lone Tree. The proposed South Suburban Station provides intermodal opportunities for highway users and users of the RTD system.

Lone Tree Station: On the greenfield corridor, the Lone Tree Station is proposed at a site near the intersection of I-25 South and C-470. The existing rail route does not serve this station. The greenfield route provides better access to intermodal sites than does the existing rail route, since it reaches into Lone Tree at the intersection of C-470 and I-25. For providing access to the Denver Tech Center, this location is near an existing, as well as proposed new RTD Southeast Light Rail station.

3.5.5 Proximity of Representative Routes to Population Centers

The representative existing rail and greenfield routes in the I-25 corridor, as shown in Exhibit 3-6, connect with major population centers. The only exception is that the greenfield route does not connect into downtown Castle Rock as currently envisioned. The proposed greenfield route leaves the I-25 corridor north of Castle Rock due to topographic conditions and development within and south of Castle Rock. A greenfield station site would have to be north of the city. The proposed greenfield route also misses Monument completely since it passes so far to the east. Alternative alignments that use portions of the existing rail or I-25 highway corridors to improve access to Castle Rock and Monument could be developed as part of the NEPA process.

3.5.6 Geometry of Representative Routes

The representative route using the existing freight rail corridor consists of two rail lines the former DRGW (Union Pacific) and the former ATSF (BNSF). The geometry of the Union Pacific alignment is not appropriate for high-speed rail operations in that the curves and grades are such that development of a curve easement program for this alignment would likely be very expensive. The BNSF alignment also has geometric constraints, but not as significant as the Union Pacific alignment. Because the BNSF alignment has fewer curves to begin with, fewer easements would be required to improve this alignment than the parallel UP track. Therefore, from Littleton to Pueblo the BNSF alignment is proposed for the passenger rail route. The Spanish Peaks section between Pueblo and Walsenburg is acceptable for passenger service, but there are significant curves on the segment from Walsenburg south to Pueblo.

The geometry of the existing rail alignment from Littleton to Trinidad is challenging. Many curves along the alignment need to be reduced or flattened in order to increase efficiency of operation. However, topographic constraints in several areas constrain the existing right-of-way making geometric changes very difficult, so it will not be possible at reasonable cost to ease all the curves. In general, the geometry of the existing rail right-of-way is less than optimum for efficient high-speed rail intercity passenger operation. However, the existing rail right-of-way does provide an opportunity to minimize both the capital costs and environmental impacts by utilizing the existing track infrastructure.

The greenfield route begins at the intersection of C-470 and the existing rail right-of-way (Joint Line) and proceeds within or contiguous to C-470 right-of-way to Lone Tree as shown in Exhibit 3-6. This greenfield route crosses over I-25 and proceeds on the east side of I-25 to a vicinity north of Castle Rock. The greenfield route then proceeds toward Colorado Springs and onward to Pueblo and south to Trinidad. Although the topography is challenging, geometry is conceptually developed with minimal horizontal and vertical curves allowing for efficient high-speed intercity rail service serving downtown Denver, Colorado Springs, Pueblo, and Trinidad with intermodal sites at optimal locations along the greenfield route.

As previously noted, geometry is directly related to speed and travel time. The geometry of the existing rail route is less than desirable, whereas, the geometry of a greenfield route can be developed for efficient high-speed rail and maglev operations that optimize speed and travel time.

However, the current greenfield alignment lies so far to the east that it misses many of the established intermediate population centers. The NEPA analysis for this corridor will undoubtedly have to develop the optimal tradeoff between geometry, which favors an eastern route, and market access, which favors a more westerly route through more difficult topography.

3.5.7 Capacity of Representative Routes

The Joint Line segment between Denver and C-470 is constrained by limited right-of-way and capacity issues. The Southwest Corridor Light Rail Transit (LRT) operates within this corridor from DUS to Mineral. A future Light Rail extension to C-470/Lucent Blvd has been proposed. The presence of the LRT combined with a limited right-of-way in the corridor restricts the opportunity to construct additional capacity at many locations along this segment, thereby presenting significant challenges to the implementation of passenger rail without either the construction of the R2C2 or the relocation of some Light Rail segments. Exhibit 3-7 shows the Littleton Trench, which is the most significant constraint to increasing capacity. It will be difficult to construct another track in this segment, without either elevating the new track or displacing the LRT line to a street-running alignment.

Exhibit 3-7: Littleton Trench on the BNSF/UPRR Joint Line between DUS and C-470

As noted, previously, the greenfield route in the I-25 South corridor currently requires the use of the existing rail right-of-way between Denver Union Station and C-470. Capacity issues discussed previously apply to this segment of greenfield route. The greenfield route exits the existing rail right-of-way at C-470. The greenfield route has no capacity issues except at Colorado Springs and Pueblo. In order to enter into these cities, the greenfield route needs to make use of the existing rail rights-of-way, thereby triggering capacity concerns. These concerns are mitigated by the proposed infrastructure improvements to the existing rail right-of-way.

Capacity for the existing rail route between Palmer Lake and Monument is a concern since the joint line in this section is limited to one track, and the BNSF portion of the Joint Line has been abandoned in this area. Exhibit 3-8 is a view south at Palmer Lake showing the abandonment of the old Santa Fe line on the east side of the lake and the construction of a park and residential area. The abandonment continues from Palmer Lake through Colorado Springs to Crews, presenting significant challenges to the construction of efficient high-speed rail service on the existing rail route. Exhibit 3-9 is a view north in Monument displaying the "New Santa Fe Trail." Possible options for dealing with these segment constraints will be discussed in Chapter 5.

The segment of existing rail route between Denver and Littleton has significant capacity issues that need solution with or without the construction of R2C2. This segment is common to both the existing rail and greenfield routes. The capacity issues on the existing rail route between Littleton and Denver are reduced by the construction of R2C2 but not fully alleviated.

Also, the section of existing rail between Palmer Lake and Crews provides challenges since the joint line only operates on the UP tracks since the BNSF property through Colorado Springs in this area has been abandoned. If the existing rail alignment is used, then consideration should still be given to development of a new greenfield alignment from Palmer Lake to Colorado Springs, to bypass the difficult geometry that exists on the current rail line on Monument Hill.

The greenfield route south of Littleton has no capacity issues except in Colorado Springs and Pueblo where the route leaves the greenfield and joins with the existing rail route to enter the urban areas. However, these capacity issues could be eliminated if Colorado Springs and Pueblo were served by suburban stations rather than following the current rail corridors downtown.

Exhibit 3-8: View south at Palmer Lake near MP 52.0 County Line Rd

Exhibit 3-9: View north at Route 105 of Abandoned BNSF in Monument

As can be seen in Exhibit 3-10, the topography of the Front Range and the Eastern Plains could allow for the development of a greenfield route with minimum horizontal and vertical curves. Exhibit 3-11 shows a site about 2 miles east of I-25 at Exit 91 south of Pueblo. As can be seen, the existing rail right-of-way and a proposed greenfield route are within a relatively flat, sparsely populated landscape. This situation permits optimum geometric design of a greenfield route, although it can be seen that the existing rail line in this area is fairly straight as well.

Exhibit 3-10: I-25 at MP 125 South of Colorado Springs, View North

Exhibit 3-11: BNSF at Lime Road View North

Exhibit 3-12 demonstrates the openness of the Eastern Plains and favorable topographic conditions for the development of a greenfield route. This site along the BNSF Spanish Peaks subdivision is approximately 10 miles north of Walsenburg and 5 miles east of I-25 in the Eastern Plains. The eastern plains are relatively flat with eroded waterways posing the only obstacle to rail construction. The population is very sparse except for occasional small towns between Pueblo and Trinidad.

Exhibit 3-12: BNSF Spanish Peaks Sub at County Rd 103 View North

3.6 Engineering Assessment: I-25 North Corridor – Denver to Cheyenne

3.6.1 Existing Rail Rights-of-Way

UPRR Greeley Subdivision

In 1868 the Denver Pacific Railway began construction of a rail line linking the City of Denver to the transcontinental line at Cheyenne, WY. The line followed the South Platte River through Greeley and was completed in 1870. In 1880, the railroad merged the Kansas Pacific and Union Pacific, eventually becoming a Union Pacific property. Currently, the line is operated as Union Pacific's Greeley Subdivision, serving as a freight line. Historically the route of Amtrak's Pioneer, no passenger service currently operates on the line.

Great Western Railway of Colorado (GWRCO) Greeley to Ft. Collins

In 1881, the Greeley, Salt Lake and Pacific Railway constructed a railroad between Greeley and Ft. Collins, connecting to the Denver Pacific Railway at Greeley. It is reported that the line was originally intended to become a southern branch of Union Pacific's transcontinental railroad operating through northern Colorado. In 1898, the line was incorporated in the Colorado and Southern Railway, eventually becoming part of the Chicago, Burlington and Quincy Railroad, predecessor to the BNSF. The BNSF sold the line to OmniTrax, which operates the property as a short line railroad, the Great Western Railway of Colorado.

BNSF Front Range Subdivision

BNSF's Front Range Subdivision runs north from the Denver Union Station (DUS) to Cheyenne, WY through Boulder, Longmont and Ft Collins, a distance of approximately 120 miles. The Denver RTD is planning to construct a new transit system segment from Denver to Longmont on the BNSF property employing DMU technology and sharing the track with the existing freight service. Generally, RTD will construct a second track adjacent to the existing track, except where constrained by very narrow right-of-way. RTD plans to operate up to 66 trains per day, making this a very busy corridor. This route has extremely poor geometry and urban speed restrictions south of Ft. Collins.

Milliken Line

The Union Pacific operates a branch line roughly paralleling the GWRCO line described above, but on a more southerly alignment. The line starts at LaSalle heading southwest to Dent, where it turns northwest to Fort Collins. For passenger service, only the Dent to Fort Collins segment has been evaluated, along with a proposed new greenfield segment that would connect from Dent to Platteville on the Greeley Subdivision. Although this alignment misses downtown Greeley, the potential North Front Range station at I-25 and US-34 would improve service to Loveland and south Fort Collins. The same North Front Range station location is also served by the proposed I-25 North greenfield alignment. The Milliken option is the one that was carried forward as the 110-mph representative route for existing rail on I-25.

3.6.2 Potential Greenfield Routes

The I-25 North highway corridor is wide from an area north of Denver to the Wyoming border, with the exception in urban areas south of the E-470. It is possible to construct a high-speed rail mode, either in the median or adjacent to the highway on either side. The I-25 North median is typically 40 feet in width, which satisfies the minimum requirement for constructing a passenger rail system.

3.6.3 Findings of Field Inspection and Selection of Representative Routes

The I-25 North Corridor was inspected between Denver and Cheyenne during the summer of 2008. The inspection included the rail corridors owned by BNSF, GWRCO and UPRR and the I-25 highway corridor. The inspection served to document the observed existing conditions and identify any significant challenges to the construction of new high-speed rail infrastructure. Specific photos and observations of the route from Denver Union Station north to Greeley and Cheyenne are included in the *Existing Conditions Report*. The findings of the field inspection and the relationship to the FRA basic requirements for a high-speed rail route are as follows:

- The BNSF route from Denver to Boulder and Longmont included a number of sharp curves, which will serve to limit the speed of passenger service. (Geometry of route)
- The Greeley route is very straight and wide, offering very good geometry for high-speed rail operations. (Geometry of route)
- The I-25 corridor offers a wide right-of-way, although reconstruction will be required of some grade separation structures. (Geometry and Capacity of route)

- Access to downtown Denver from the north is constrained by limited rail right-of-way and minimal availability of the median within the I-25 corridor. (Capacity of route)
- The existing rail right-of-way through Boulder, Longmont, and Loveland is limited (Capacity and Geometry of route)
- Commuter rail service is planned for the BNSF line to Boulder. (Capacity of route)
- The BNSF alignment through Fort Collins is "street running" which is not compatible with the needs of high-speed passenger rail service. (Capacity and Geometry of route)

Exhibit 3-13 shows the Representative Routes that were evaluated in the I-25 North corridor:

- The BNSF existing rail route consists of a route within or contiguous to the BNSF right-of-way through Boulder, Longmont, and Fort Collins to Cheyenne (existing rail). The portion of this route from Denver to Fort Collins was screened early on in the evaluation process as described in Chapter 5; however the northern portion from Fort Collins to Cheyenne is fairly straight and could serve as a viable route option for a possible service extension to Cheyenne. This is highlighted in Exhibit 3-14.
- The UP existing rail route consists of the Greeley subdivision from the Denver area to Greeley (existing rail). Three variants of the UP route option have been considered. The first option was to continue north from Greeley to Cheyenne. This route is fast but misses all the major markets, particularly in Fort Collins, that lie farther west. As a result, the use of the UP corridor north of Greeley was also screened early in the evaluation process. This is highlighted in Exhibit 3-15.
- A variant on the UP existing rail option would use the Great Western Railroad of Colorado (GWRCO) from Greeley to Fort Collins. This option was retained, but the Milliken line option was found to perform better. The GWRCO option is highlighted in Exhibit 3-16.
- A second variant on the UP existing rail option would use the UP Milliken line. This option would require a greenfield connector from Platteville to Dent, and then use the existing rail branch line on to Fort Collins. Either of the GWRCO or Milliken line options could continue north to Cheyenne over the BNSF railroad. Another variant that could be considered would be the use of the Milliken line to Fort Collins with a short branch line into downtown Greeley. The Milliken route is highlighted in Exhibit 3-17. The Milliken option is the one that was carried forward as the 110-mph representative route for existing rail on I-25.
- For access to DIA from downtown Denver, the representative route follows the BNSF Brush subdivision right-of-way (existing rail) to the north side of the Rocky Mountain Wildlife Refuge. It would then continue east on a greenfield alignment along the north side of the preserve to reach a station at DIA. This route was developed at the recommendation of the RTD because the narrow width of the East Line Corridor right-of-way would not accommodate the additional tracks needed to add express intercity rail service to the corridor. The DIA access route is highlighted in Exhibit 3-18.

- One greenfield option has also been developed for the I-25 North corridor. From downtown Denver, this route would share the BNSF Brush line route proposed for DIA access. Beyond the airport spur, the route would continue north along the Brush line to the E-470. At this point the alignment would leave the rail right-of-way and follow E-470 and I-25 to Fort Collins. The option that was developed for this study follows the highway right-of-way to fly over to the west side of I-25 at the E-470/I-25 junction. This greenfield route option is highlighted in Exhibit 3-19. However another option for connecting the alignment between the two highways would be to use a section of the Boulder Industrial Lead, which was just purchased from UP by RTD. This would allow a joint station with the proposed RTD North Metro corridor. This interconnection option is shown in Exhibit 3-20.

Exhibit 3-13: Potential Routes within the I-25 North Corridor

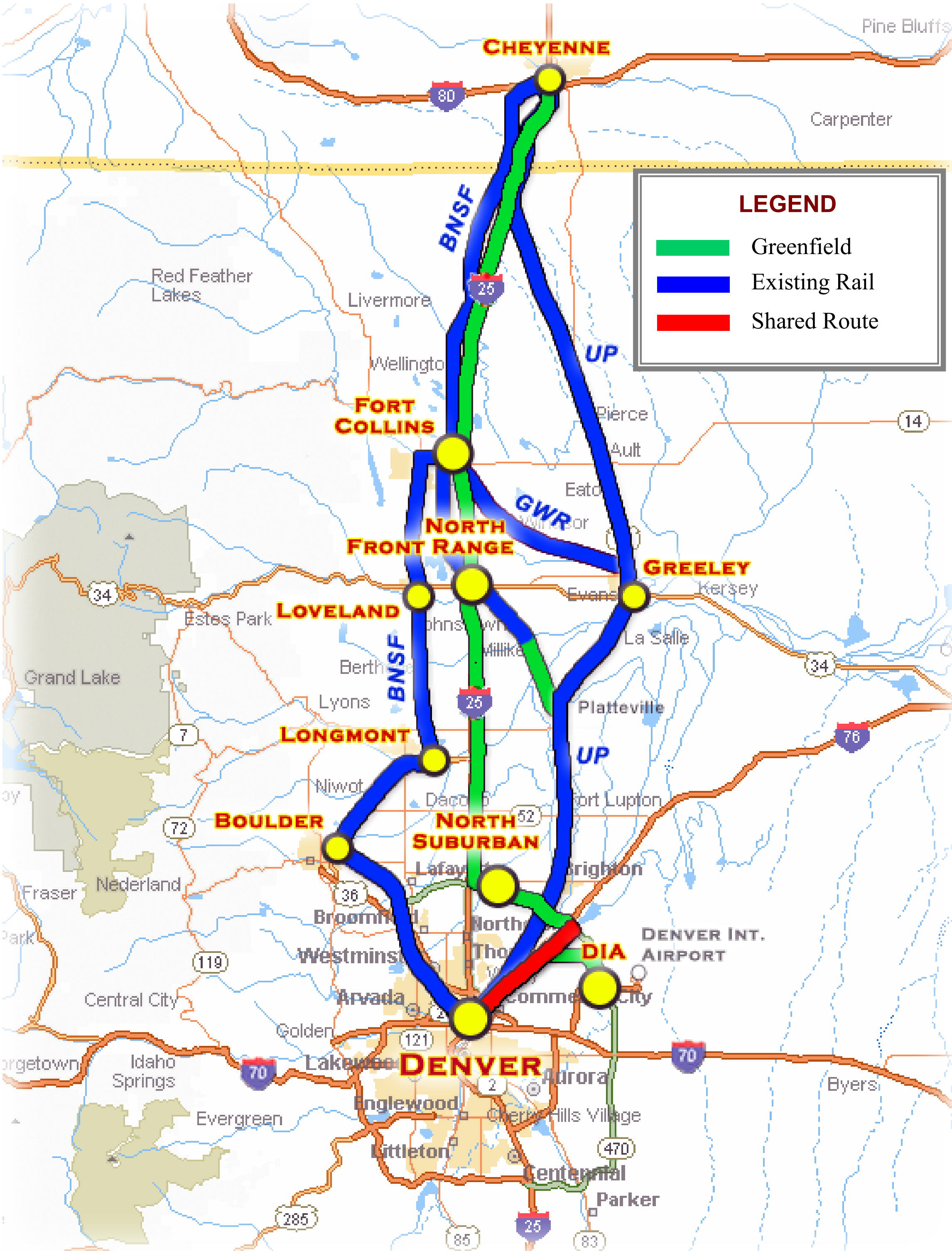


Exhibit 3-14: Screened Alternative, BNSF Route Denver to Cheyenne

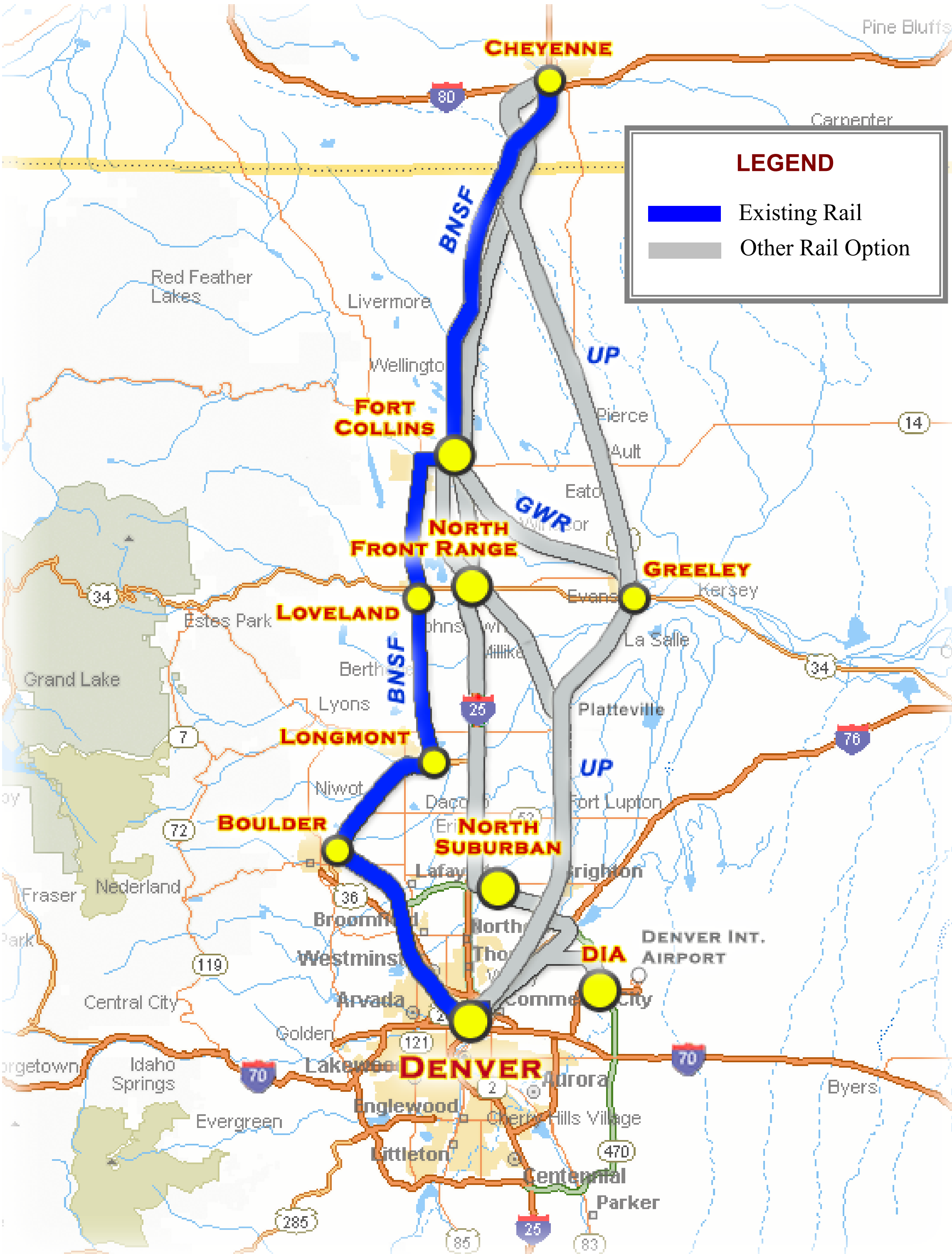


Exhibit 3-15: Screened Alternative, UP Route Denver to Cheyenne

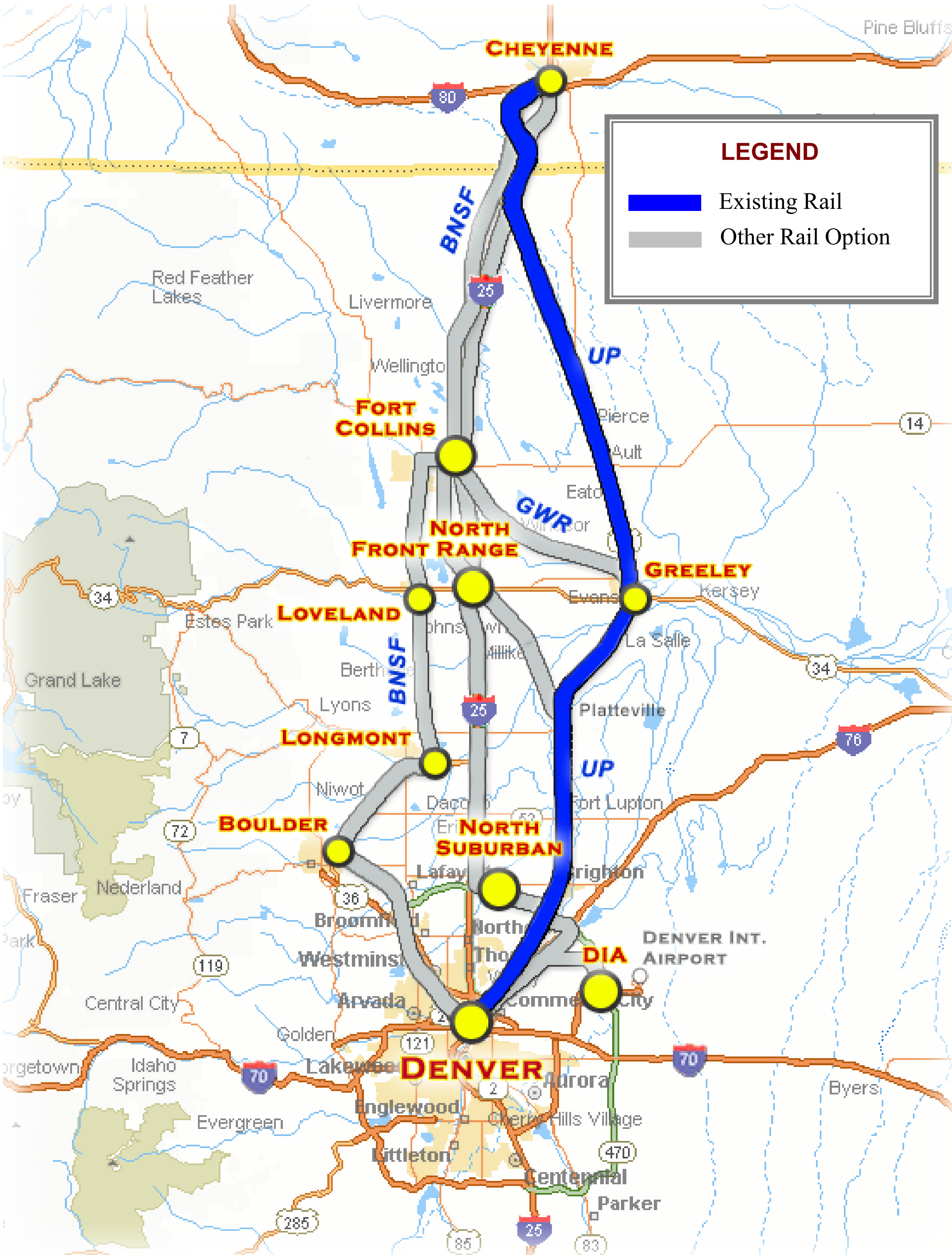


Exhibit 3-16: Retained Alternative, UP Route Denver to Fort Collins GWRCO Option

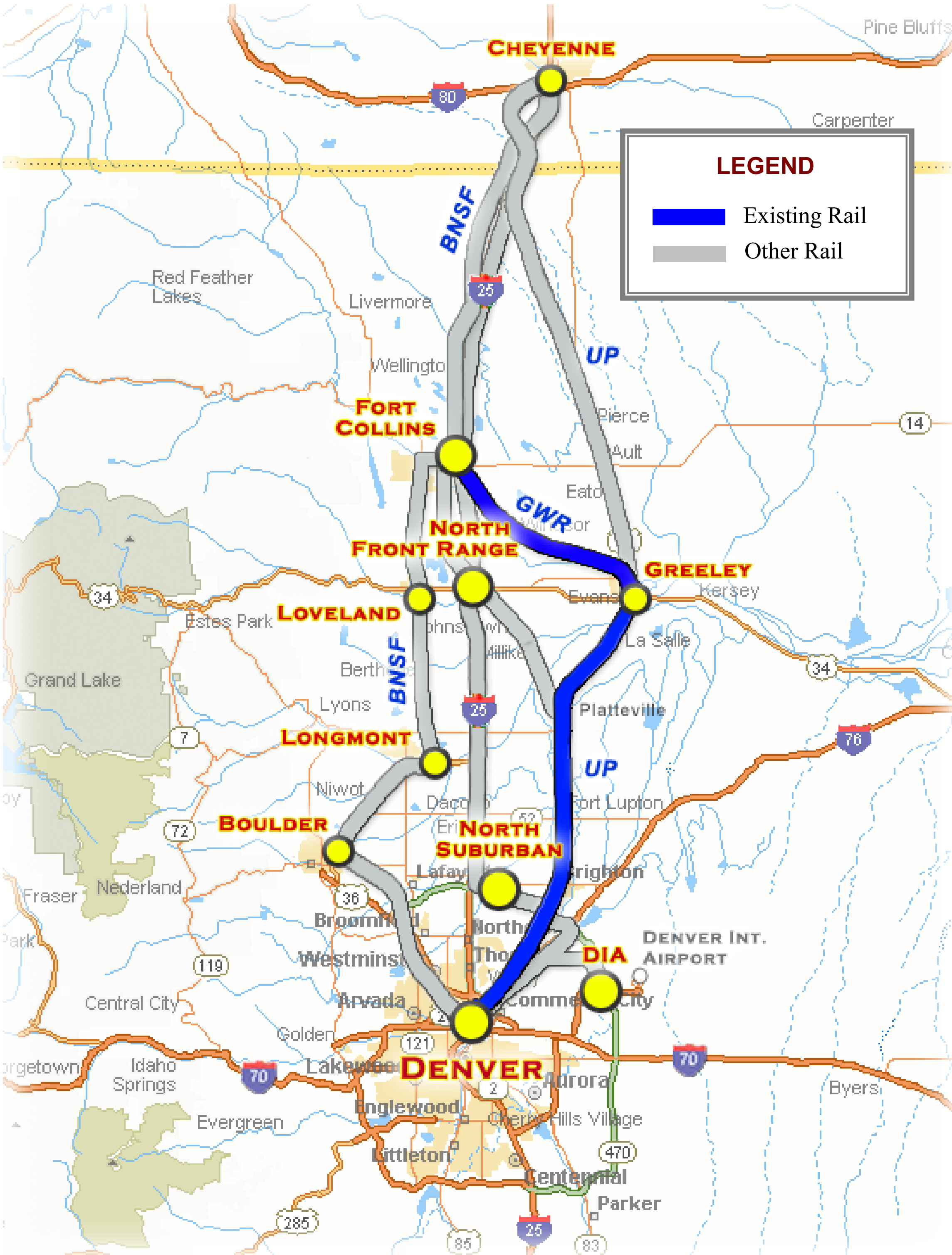


Exhibit 3-17: Representative Existing Rail, UP Route Denver to Fort Collins Milliken Option

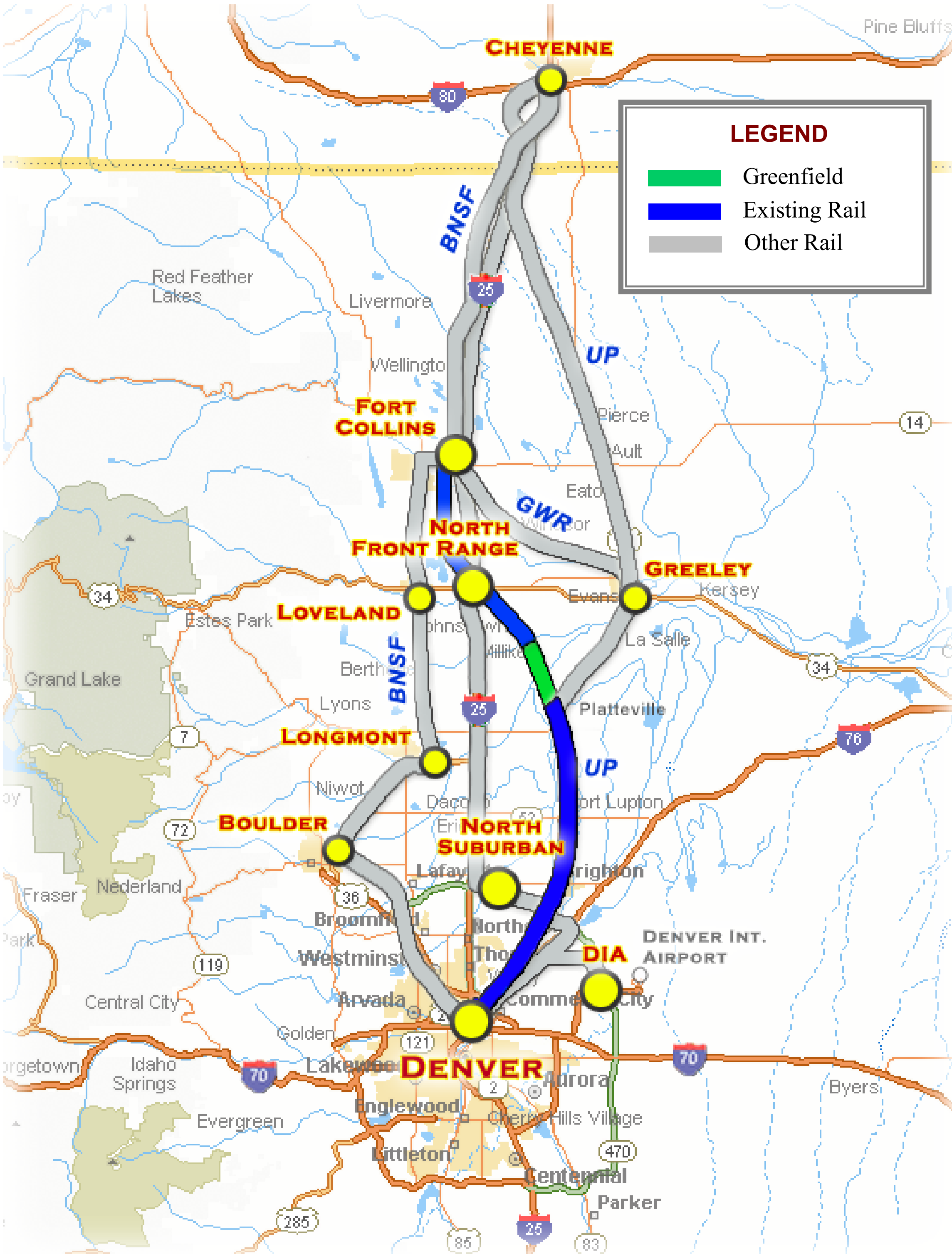


Exhibit 3-18: Airport Access route Denver to DIA

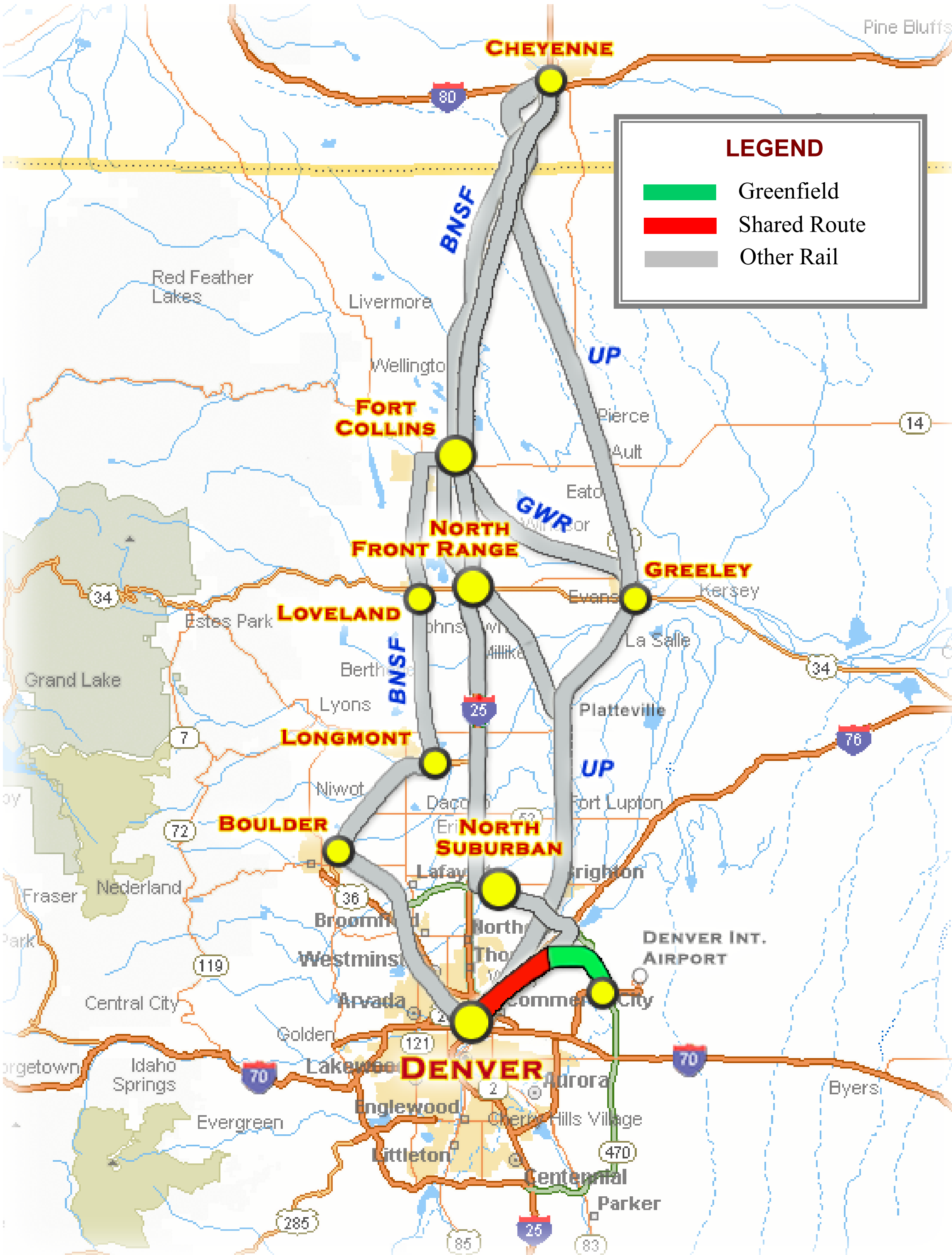


Exhibit 3-19: Greenfield Option following E-470 and I-25 Denver to Fort Collins

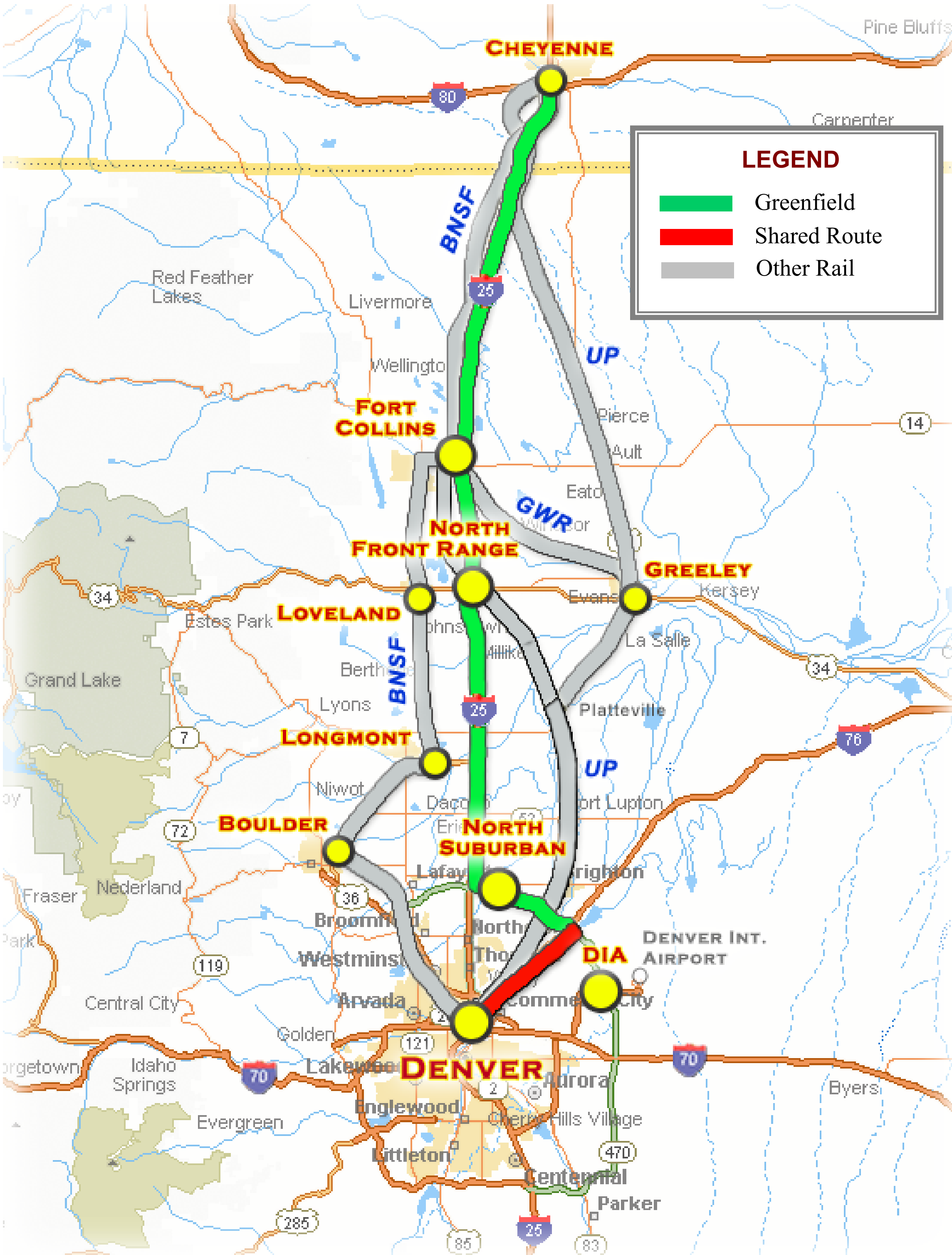
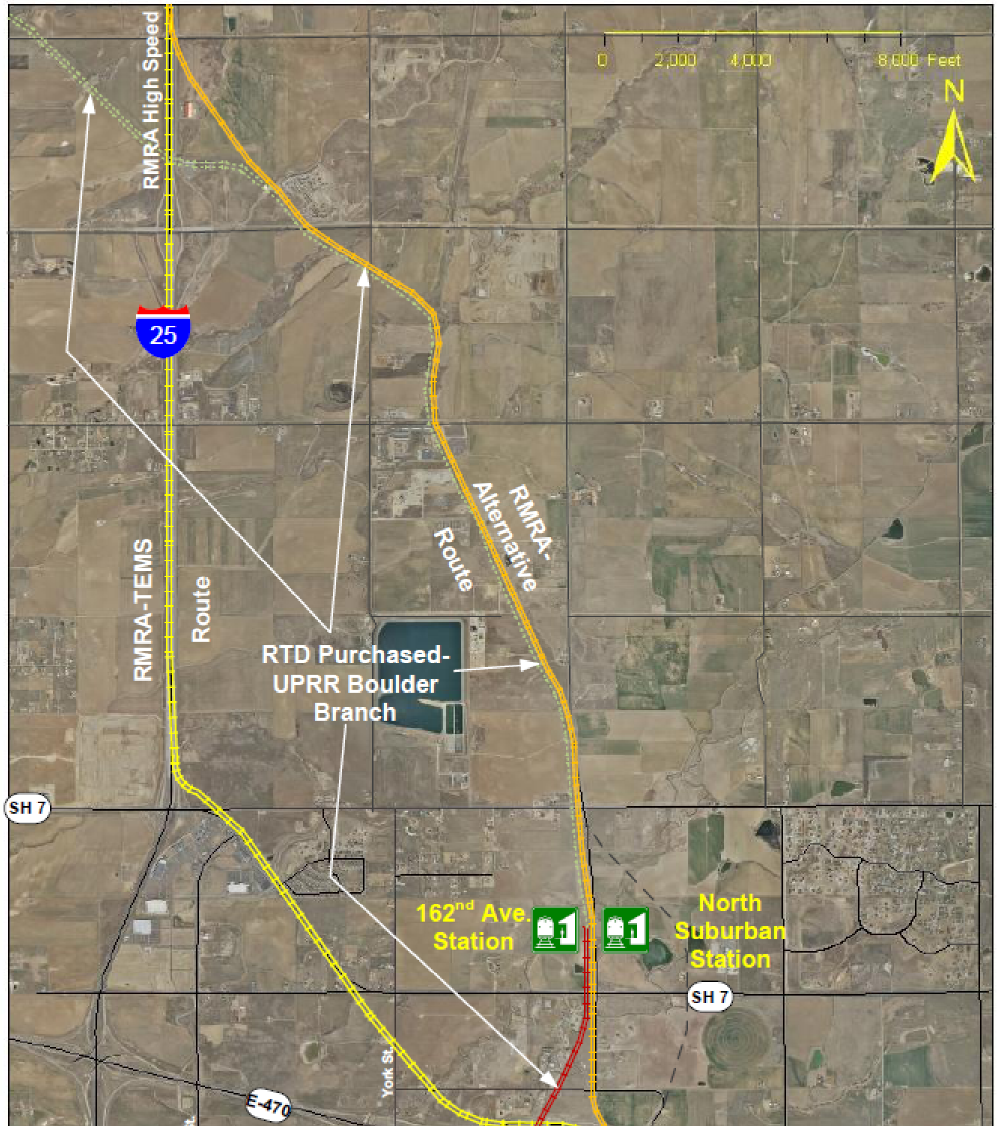


Exhibit 3-20: Greenfield Connection option using the Boulder Industrial Lead



Source: Gene Putman, P.E., Transportation Manager, City of Thornton

The I-25 corridor has been evaluated from Denver to Cheyenne as a potential corridor for High-Speed rail or maglev service. As can be seen in Exhibit 3-21, north of the E-470 the I-25 median for the most part provides sufficient width for installation of a guideway. However, on I-25 south of the E-470 this median has been taken or reserved for future highway expansion, and there are several complex interchanges crossing other interstate highway that form a barrier to rail development. For this reason the greenfield alignment follows the E-470 over to the BNSF Brush Line, which offers easier access to downtown Denver than would proceeding further south on I-25.

Exhibit 3-21: View north of I-25 North of State Highway 470

One issue for the utilization of any highway right-of-way is the occasional conflict with highway overpasses. If a pier in the median supports an overpass, the overpass may require reconstruction to remove the obstacle. However, most of the overpasses along I-25 do not appear to require reconstruction. Exhibit 3-22 shows a highway overpass that would *not* require reconstruction in order to install a high-speed rail alignment in the median. The existing overhead clearance of this overpass is sufficient for passenger trains on a dedicated alignment but it would not be sufficient for freight trains.

Exhibit 3-22: View north at I-25 MP 235 at State Highway 52 Overpass

3.6.4 Proximity of Representative Routes to Intermodal Sites

Three intermodal sites in the I-25 North Corridor are the North Suburban Station, the North Front Range station at I-25 and US-34, and the Fort Collins station, which can be located either downtown, or else on the I-25 highway along the proposed greenfield route. Only the Milliken Line existing rail route and the I-25 greenfield options serve the North Front Range station. Only the I-25 greenfield option could serve the North Suburban Station at the intersection of E-470 and I-25. Ridership modeling has shown that this highway interchange is close enough to Boulder and Longmont to attract some ridership from those cities. A North Suburban station could be provided on the existing rail option, but it would have to be located much farther east in the vicinity of the E-470 and US-85. This location is in a relatively depopulated area that is too far away to effectively serve the Boulder and Longmont areas. Accordingly, the I-25 greenfield option provides the best Intermodal connectivity and station site options, followed by the Milliken existing rail option. The GWRCO option has the weakest stations since it can only serve the Fort Collins market effectively, but misses the important Loveland, Longmont and Boulder markets farther south. This reflects in the ridership projections that have been developed for each of these route alternatives.

3.6.5 Proximity of Representative Routes to Population Centers

The existing rail right-of-way of the UPRR Greeley subdivision does not serve any major population centers with the exception of Greeley. From the Greeley line, use of either the Great Western or Milliken lines would be required to link to Fort Collins. The BNSF existing rail right-of-way connects with Boulder, Longmont, Loveland, and Fort Collins but has poor geometry and restricted speed. The I-25 greenfield route connects with major population centers in the I-25 corridor.

A brief review of the population centers north of Denver confirms the BNSF existing rail route serves more population than the UPRR existing rail routes. However as described previously, the I-25 greenfield also serves all population centers, and it could offer much better geometry for supporting high-speed operations than does the BNSF existing rail route.

3.6.7 Geometry of Representative Routes

The BNSF existing rail right-of-way from Denver to Boulder and Longmont has numerous sharp curves, which limit the speed of the passenger service. Therefore the BNSF existing rail right-of-way does not offer efficient high-speed rail service in the I-25 corridor, and this route was screened early in the evaluation process. The geometry of the Union Pacific existing rail rights-of-way is excellent. It would provide efficient high-speed rail service with the maximum speed of 110 mph but misses the main population centers. The proposed greenfield route in the I-25 corridor provides an opportunity to develop optimum geometry for efficient high-speed passenger rail service, as well as to effectively serve the entire population base of the north Front Range communities.

3.6.8 Capacity of Representative Routes

The BNSF Front Range subdivision existing rail right-of-way from Denver to Boulder to Fort Collins has significant capacity issues. Although the right-of-way in rural areas allows expansion of the track structure, the right-of-way is constrained in urban areas. Additionally, as shown in Exhibit 3-23 the right-of-way through Fort Collins is "street running" which would reduce capacity and the opportunity to add additional track. The length of this segment is approximately one mile. Also, RTD FasTracks is planning to implement commuter rail service on the BNSF right-of-way from Longmont to Denver, further reducing the available capacity of this corridor for intercity rail purposes

Exhibit 3-23: View north along Mason St in Fort Collins near MP 73.54 (BNSF Front Range Subdivision)

For access to DIA, several existing rail routes were considered including the UP Kansas Pacific subdivision between downtown Denver and Airport Boulevard. RTD has purchased 40 feet of the UP right-of-way in this subdivision and plans to construct an East Corridor service to DIA. However, UP is planning to add a second freight track to the remaining right-of-way. Therefore, the opportunity to utilize this existing rail route for high-speed passenger rail service to DIA is very limited.

As an alternative, the use of the BNSF Brush subdivision from DUS to Sand Creek Junction proceeding to 96th Avenue was considered. From 96th Street junction with BNSF to DIA, a greenfield route along the south side of 96th Avenue on the property of the Rocky Mountain Arsenal is considered as a reasonable route. Sufficient area exists to permit an at-grade guideway for rail or maglev technology as shown in Exhibit 3-24. This greenfield route connects to the BNSF Brush Line right-of-way (existing rail route) and parallels State Highway 2 (SH-2) along the BNSF right-of-way into DUS. Exhibit 3-25 shows the crossing of 96th Street with the existing rail route. Exhibit 3-26 shows the BNSF right-of-way on the east side with sufficient area to construct additional capacity as needed for passenger rail service.

Exhibit 3-24: View east toward DIA along 96th Street

Exhibit 3-25: View east toward DIA at crossing of BNSF existing route with 96th St

Exhibit 3-26: View south along SH-2 approaching 72nd St.

The capacity issue on both the UPRR right-of-way and the BNSF right-of-way from Denver Union Station to the Sand Creek Junction is a concern. RTD is planning to build the North Metro Corridor on the east side of the BNSF Brush Line tracks from Sand Creek to DUS further complicating capacity issues on this segment of track. The Sand Creek Junction offers a significant capacity challenge to the implementation of high-speed passenger rail service in that it is a potential bottleneck. Exhibit 3-27 shows that the UPRR Greeley Subdivision and BNSF Brush Subdivision cross at this point under the I-270 highway overpass proceeding into the Denver urban area. In addition, Sand Creek passes under the tracks in the same vicinity as the highway overpass. This makes it difficult to depress any of the tracks as an option for implementing grade separation. The capacity of the existing rail routes of UPRR and BNSF from Sand Creek to DUS needs to be increased by the addition of at-grade tracks or elevated structure to provide for efficient passenger rail operations.

Exhibit 3-27: View south at UPRR MP 5.0, Sand Creek Junction

From Sand Creek to the Wyoming border, sufficient land exists along UPRR rights-of-way to Fort Collins and BNSF right-of-way from Fort Collins to Cheyenne in the rural areas providing the opportunity to increase capacity of the route by the installation of additional tracks. Exhibit 3-28 displays that ample space is available within or contiguous to the UPRR Greeley subdivision in the vicinity of 120th Avenue, which is typical of existing conditions in rural areas. Exhibit 3-29 shows that similar conditions exist along the GRWCO between Greeley and Fort Collins. However, because of limiting constraints within urban areas along the existing rail routes, cooperation by the freight railroads is still needed to allow for efficient passenger rail service operations using the existing rail rights-of-way.

Exhibit 3-28: View south, UPRR Greeley sub MP 13.6 at 120th Ave.

Exhibit 3-29: View east along GRWCO MP 83.8 at County Road 13

The development of any greenfield route from Denver Union Station to the fringe of the Denver metropolitan area is challenging. Significant improvements to existing rail infrastructure and/or the construction of elevated guideways within the Denver metropolitan area will be needed to clear the metropolitan area of Denver. Once clear of the metropolitan area, there is sufficient land contiguous to or within the rights-of-way of E-470 and I-25 from outside the Denver metropolitan area to Wyoming.

3.7 Engineering Assessment: I-70 Corridor –Denver to Grand Junction

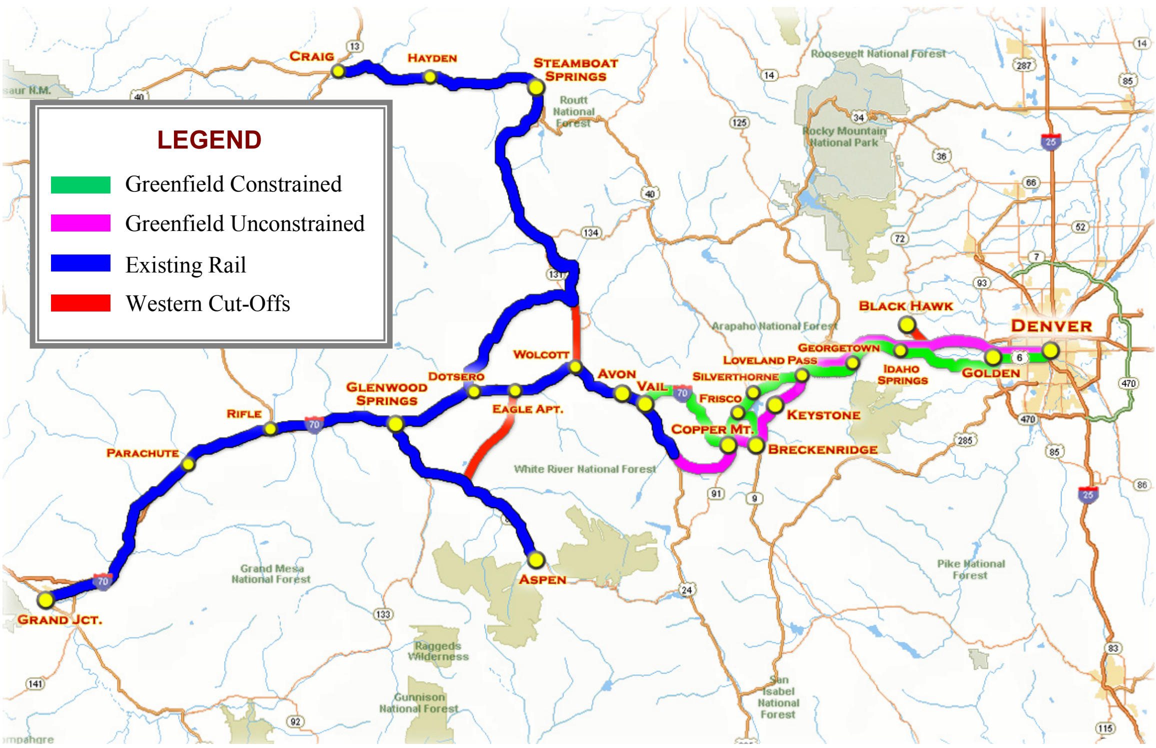
The existing and proposed greenfield right-of-way alternatives in the I-70 corridor, from Denver International Airport to Eagle Airport, and secondary route extensions to Craig, Aspen and Grand Junction. This section develops the I-70 options on a segment by segment basis. It is envisioned that a through rail service will be developed to allow a single-seat ride from DIA to I-70 destinations. Nonetheless from a physical infrastructure point of view, it made more sense to address DIA access as part of the I-25 North system so this segment has already been introduced. The presentation of I-70 segments will start in Denver and proceed west in three major sections, as follows:

- From Denver to Golden there are one existing rail option and several possible highway options. The US-6 highway option was preferred and used as the basis for this evaluation.
- From Golden to Minturn, west of Vail, no rail lines exist. Two greenfield route alternatives, one based on the existing I-70 highway right-of-way, the other independent of the highway, have been developed. This includes service to Breckenridge.

- From Minturn west to Grand Junction, Aspen and Craig, the existing rail options were evaluated, along with two "Cut off" options for shortening the routes to Aspen and Craig.

These segments are shown in the overall corridor map in Exhibit 3-30.

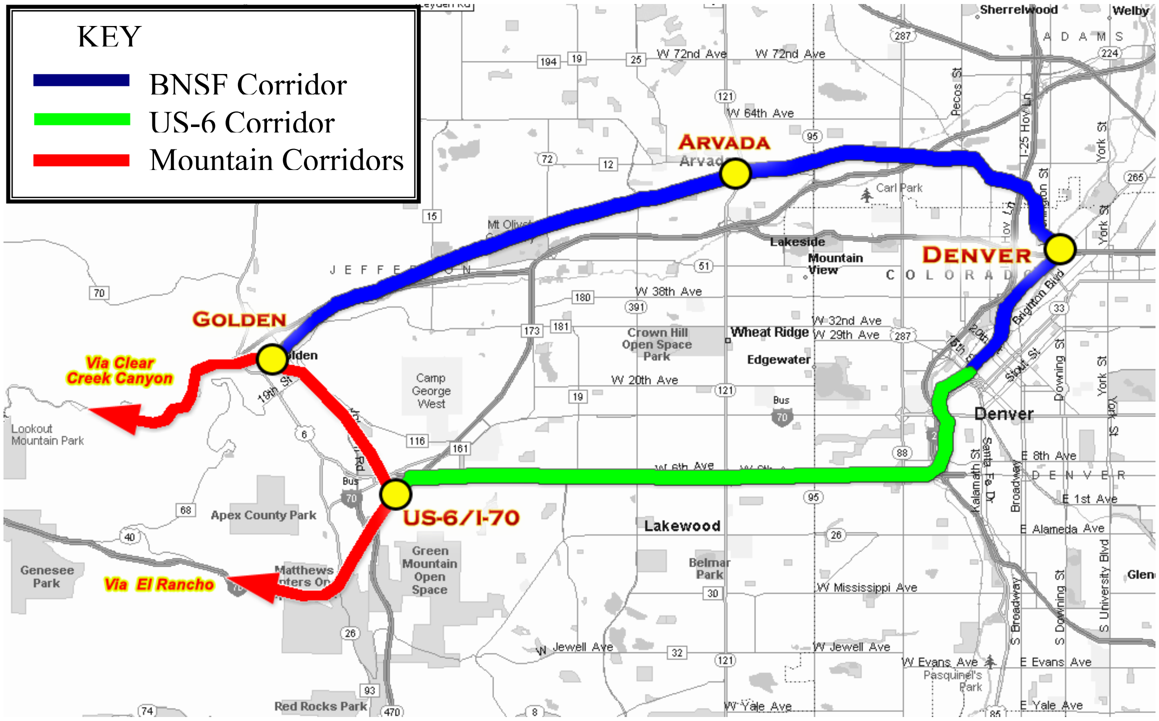
Exhibit 3-30: I-70 Corridor from Denver to Grand Junction, Aspen and Craig



3.7.1 Access to I-70 Corridor from Denver to Golden

The two options evaluated from Denver to Golden were the BNSF existing rail option using the BNSF Golden subdivision via Arvada and the US -6 greenfield alignment. I-70 and I-76 highway options were examined but were more circuitous than the US-6 option, rail access to the I-70 and I-76 corridors was more difficult than to US-6, and there were problems with geometry. In some cases sufficient median space or right-of-way for economical construction of a guideway was lacking. Accordingly the evaluation focused on the US-6 highway alternative from Denver to Golden which provides both a straight and direct means of linking to either the I-70 mountain corridor or the Clear Creek Canyon. Exhibit 3-31 shows these two options in more detail.

Exhibit 3-31: I-70 Corridor from Denver to Golden



US-6 Highway Corridor to Golden

To access the I-70 mountain corridor from downtown Denver, the proposed high-speed passenger rail service could use the existing rail Joint Line from DUS to the vicinity of the intersection of I-25 and US-6. This existing rail portion would be shared with the I-25 south corridor. From the junction of US-6, a new greenfield route would be developed that uses extensive elevated structure to take high-speed trains west to a Golden suburban station in the vicinity of the US-6/I-70/C-470 highway interchange. From here, routes could be developed either heading directly west up the I-70 corridor via El Rancho, or else linking over to a lower-gradient alignment option up the Clear Creek canyon.

Along US-6, Exhibit 3-32 shows that frontage roads are available for the construction of either at-grade or elevated guideways for passenger rail service. Exhibit 3-33 shows a very constrained area of US-6, which would require elevated guideways for passenger rail service. Furthermore, RTD has started construction of the West Corridor for Light Rail Transit service within the US-6 right-of-way near the Jefferson County Courthouse.

Exhibit 3-32: US-6 with frontage roadways on each side of the alignment

Exhibit 3-33: US-6 near Denver city limits in a very constrained area

BNSF Golden subdivision from Denver Union Station to Ford Street in Golden

The existing rail route of the BNSF Golden subdivision is also considered as a candidate route for passenger rail service from DUS to Ford St in Golden. Starting at DUS, the alignment follows the BNSF Front Range Subdivision (not the Brush Line) to Utah Junction, where it parallels the UP Moffat line for a short distance. The BNSF Golden Subdivision then diverges toward the south and west. The existing rail route passes through Arvada and ends at Ford Street in Golden. BNSF uses it to provide freight service to Coors Brewery as well as other local freight customers along the line. This existing rail route will also be used by the RTD FasTrack's planned Gold Line. Exhibit 3-34 is a view of the BNSF existing rail route near the Coors Brewery in Golden. However, the route through Arvada would require a tunnel or covered trench in order to mitigate concerns of local residents.

Exhibit 3-34: View west along BNSF Golden Subdivision near Golden

Beyond the end of existing track, a greenfield route would be required to connect the end of the BNSF Golden subdivision with the US-6 greenfield route up the Clear Creek canyon. The length of this connection is approximately 1 mile. Exhibit 3-35 shows the area that is traversed by the route.

Exhibit 3-35: View west in Golden from the intersection of SH-58 and Ford St

3.7.2 I-70 Corridor from Golden to Minturn

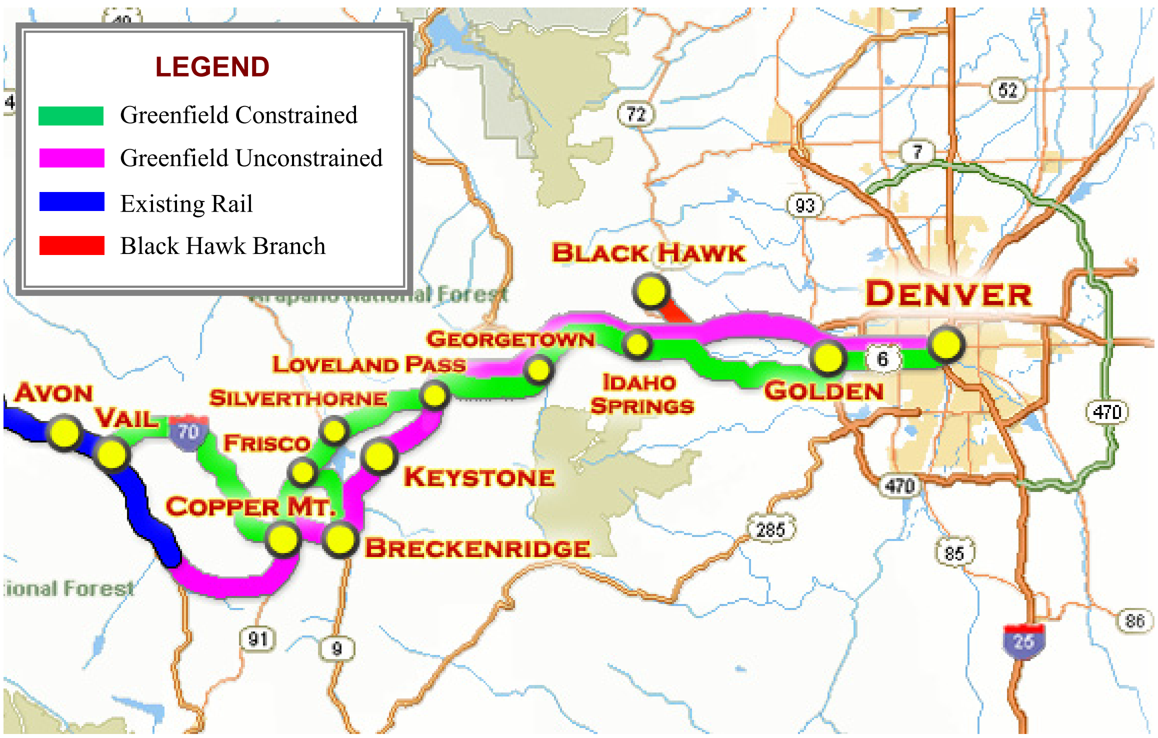
Whereas the I-25 South Corridor and I-25 North Corridor have existing rail rights-of-way, no rail lines exist from Golden to Minturn. As such, the development of a new greenfield route would be necessary.

The geometry of the I-70 highway is consistent with any highway through a mountainous area, consisting of numerous curves and gradients of up to 7 percent. This type of geometry is not ideally conducive to high-speed rail operations. In order to optimize the performance of high-speed rail in the I-70 corridor, two different options for development of a greenfield route have been developed by this study: both the use of the existing I-70 highway Right-of-Way, as well as routes that are off the I-70 right-of-way. The greenfield route that is within or contiguous to the I-70 right-of-way limits is defined as **constrained**. Any greenfield route that is not within the existing highway corridor of I-70 is defined as **unconstrained**. These two route options are shown in Exhibit 3-36, and described as follows:

- **The Constrained or I-70 Right-of-Way option** stays on the I-70 right-of-way the entire distance from the US-6/I-70 station, across El Rancho, past Georgetown and the Eisenhower Johnson Memorial Tunnel (EJMT), through Silverthorne, Frisco and Copper Mountain, across Vail Pass, through Vail to Minturn. However, a branch line was added from Silverthorne following US-6 back to Keystone, then tunneling under Swan Mountain south of Lake Dillon, and ending at Breckenridge. This allows the "Constrained" option the ability to serve these two important resorts directly.
- The intent of the unconstrained option is to minimize horizontal and vertical curves and maintain gradients at 4 percent or less. To comply with these geometric constraints, more tunnels are utilized as compared to the previous option. The alignment follows a connector line along US-6 up Clear Creek canyon to Floyd Hill.

This bypasses a severe segment of 7 percent gradient and also allows convenient access to Black Hawk just by continuing a branch line up the canyon. From Floyd Hill to Loveland Pass, the unconstrained alignment parallels I-70, but can be located anywhere in the valley to optimize route geometry and minimize cost. A tunnel is used from Georgetown to Silver Plume to reduce the gradient to 4 percent. From Loveland Pass the alignment tunnels directly to Keystone, then follows an alignment around the south end of Lake Dillon directly to Breckenridge. It then tunnels directly to Copper Mountain. From here, rather than going across Vail Pass, the route parallels State Route 91 south, to link up with the existing UP rail line at Pando.

Exhibit 3-36: I-70 Corridor from Golden to Avon showing two Greenfield Route Options



The earlier I-70 Mountain Corridor Programmatic Environmental Impact Statement[3] extensively researched the concept of implementing passenger rail service, either with steel wheel/steel rail technology or using an Advanced Guideway System based on urban magnetic levitation technology. The steel wheel steel rail technology considered in that study was an "on-grade electrified facility with elevated sections where needed for wildlife crossings and geologic hazards". The I-70 Mountain Corridor PEIS assumed that the infrastructure required for each technology would be constructed within the right-of-way limits of I-70 and was *constrained* by these limits. Information related to infrastructure needs and the capital cost estimates provided by this earlier study from C-470 to Vail were reviewed and used in this engineering assessment.

[3] I-70 Mountain Corridor, Tier 1 Draft PEIS, December 2004

As an alternative to 7 percent grades via El Rancho, a Clear Creek Canyon alternative was developed for the unconstrained alignment. Exhibit 3-37 shows the difficult geometry and terrain in Clear Creek Canyon. In order to minimize the geometric limitations of the route, ten tunnels are needed for nearly 40 percent of the entire length of this route. This allows an average train speed at about 60 mph through the canyon. The geometry of SH-119 continuing from US-6 to Black Hawk is similarly severe. If the I-70 Highway alignment via El Rancho were selected instead of the Clear Creek Canyon route, then a tunnel parallel to the proposed highway tunnel from Floyd Hill to SH-119 would provide an alternative means for linking to Black Hawk.

Exhibit 3-37: View west on US-6 in the Clear Creek Canyon

This RMRA Feasibility Study differs from the I-70 PEIS since it also considers an unconstrained option. The route studied between the US-6 Interchange at MP 244 and Loveland Pass Interchange at MP 216 considers the use of the entire I-70 corridor; i.e., land contiguous to the I-70 right-of-way limits. The engineering assessment of the contiguous portion of I-70 was undertaken for the purpose of determining the optimum route to select for high-speed passenger rail service using either steel wheel or maglev technology and also for the purpose of restricting the grade to 4 percent or less. Exhibit 3-38 shows a view west along I-70 highway and the potential for construction of a guideway within the right-of-way limits. Exhibit 3-39 shows a view of land contiguous to the I-70 right-of-way that could be utilized for the construction of a guideway. The corridor route developed in this segment includes an option for construction of the Georgetown Tunnel (14,000 ft.) in order to maintain a 4 percent grade. The gradient of I-70 at this location is greater than 6 percent.

Exhibit 3-38: View west in the vicinity of MP 230 approaching Georgetown

Exhibit 3-39: View of south of I-70 in vicinity of Georgetown

The unconstrained alignment leaves the I-70 corridor in the vicinity of the I-70/Loveland Pass interchange into the North Fork Tunnel (length of 30,000 ft) and proceeds to Keystone. From Keystone the greenfield route either reconnects to the I-70 corridor at Silverthorne or proceeds directly toward Breckenridge and SH-9 through a proposed Swan Mountain Tunnel (12,000 ft) to serve Breckenridge. The unconstrained route either enters the Breckenridge Tunnel (22,000 Ft.) directly to Copper Mountain or proceeds north to Frisco through the Frisco tunnel (6,000 ft.) to rejoin the I-70 corridor. Exhibit 3-40 shows the conditions along SH-9 between Frisco and Breckenridge and is also representative of the conditions along US-6 between Keystone and Silverthorne. These conditions permit the construction of a guideway that is contiguous to either US-6 or SH-9.

Exhibit 3-40: Typical condition of SH-9 and US-6 with space for guideway

Beyond Copper Mountain, the unconstrained route proceeds south along SH-91 and through the National Forest on a series of elevated structures, meeting with the UPRR Tennessee Pass subdivision (existing rail) at Pando. The route proceeds on existing rail to Minturn with a possible greenfield link to Vail. Further analysis of the route through the National Forest is needed to determine the optimum alignment and infrastructure to maintain a grade a 4 percent or less. Exhibit 3-41 shows area along SH-91 available for a guideway. Exhibit 3-42 shows the National Forest with mine tailing ponds where elevated structures and/or tunnels are likely needed to traverse this area.

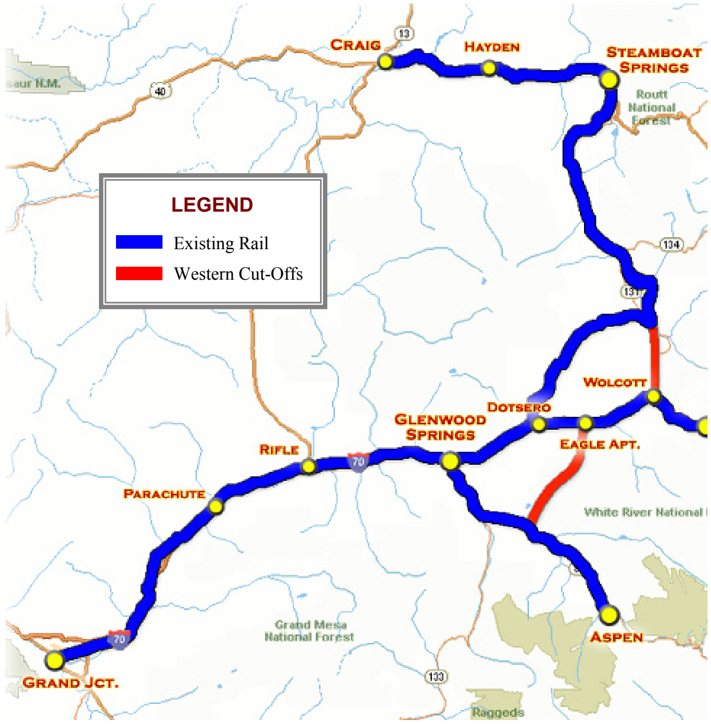
Exhibit 3-41: View north along SH-91 between Copper Mountain and Pando Junction

Exhibit 3-42: View west to National Park between SH-91 and Pando Junction

3.7.3 I-70 Corridor from Minturn to Grand Junction

West of Minturn to Grand Junction, Aspen and Craig, the evaluation primarily focused on existing rail options although two cutoffs, the "131 Option" from Wolcott to State Bridge, and the Aspen Tunnel option from Gypsum to Mid-Valley, were also evaluated as potential means for shortening the routes. Exhibit 3-43 shows the Existing Rail plus two greenfield cutoff options in more detail.

Exhibit 3-43: I-70 Corridor from Avon to Grand Junction



The UPRR Tennessee Pass Subdivision from Pando Junction and Minturn to Dotsero is considered as a candidate route for passenger rail service connecting the I-70 corridor with stations to the West. UPRR has suspended freight service on the Tennessee Pass existing route with the exception of minimal freight service from Dotsero to Gypsum. Exhibit 3-44 shows a typical view of the UPRR existing route.

Exhibit 3-44: Typical View of condition of UPRR Tennessee Pass Subdivision

Amtrak passenger rail service currently operates on right-of-way of UPRR from Dotsero to Grand Junction. Exhibit 3-45 shows the right-of-way of the UPRR on the south side of I-70 clinging to the Glenwood Canyon wall. At this point, there is approximately 7.5 miles of single-track rail line through very challenging terrain. As shown in Exhibit 3-46, consideration was also given to development of a greenfield route following I-70 through Glenwood Canyon to Grand Junction for potential use as a maglev guideway. This exhibit shows that the corridor within Glenwood Canyon is severely constrained by canyon walls. These constraints would present a severe challenge for construction of a guideway following the highway alignment through this area. It would be possible to close the 7.5 mile gap of single track rail line in the canyon by constructing a new rail alignment on an expensive combination of bridges and tunnels.

Exhibit 3-45: View west of UPRR and I-70 through Glenwood Canyon

Exhibit 3-46: View east along the I-70 corridor (MP 124) through Glenwood Canyon

The UPRR segment between Dotsero and Bond provides a possible connection for passenger rail service on a secondary corridor from the I-70 corridor to Steamboat Springs and Craig. This segment currently has Amtrak passenger service connecting to Denver and destinations to the East and Grand Junction and destinations to the West. This segment lies within challenging terrain as seen in Exhibit 3-47. Providing passenger service to Steamboat Springs and Craig would require the use of the Moffat and Craig Subdivisions. Although this existing rail route has freight service, the rail right-of-way, as shown in Exhibit 3-48, is in rural areas providing area for addition of track structure as required to add passenger service.

Exhibit 3-47: View west toward Dotsero along the UPRR

Exhibit 3-48: View south on the UP Branch line to Bond at CP 153 near Toponas

In 1997, the Roaring Fork Railroad Holding Authority purchased the Denver and Rio Grande Western Rail line between Glenwood Springs and Aspen to preserve the corridor for future rail and trail development. This right-of-way is considered as a route for passenger rail service. Exhibit 3-49 shows a bike trail along the right-of-way.

Exhibit 3-49: View north on the Rio Grande bike trail near Aspen

3.7.4 Findings of Field Inspection and Definition of Representative Routes

The I-70 corridor and its secondary corridors present major engineering challenges for the development of any high-speed fixed guideway system. While the topography of the Rockies present significant challenges, access to downtown Denver from the east and west is also difficult. As a result, defining an efficient passenger rail route in the I-70 corridor has the following challenges to overcome:

- Downtown Denver Access
- Access to Black Hawk and Central City
- Steep I-70 grade to El Rancho
- Georgetown to Silver Plume
- The Continental Divide
- Vail Pass
- Glenwood Canyon

The geological and environmental conditions in the mountains make any passenger rail route very expensive, particularly if a technology is limited to a maximum of 4 percent gradient, which requires a greater use of tunnels. As a result, a passenger rail route in the mountains needs several elevated and tunnel sections to provide efficient passenger rail service. For the secondary routes to Steamboat Springs/Craig and Aspen, as well as the main railroad corridor from Dotsero to Grand Junction, planning in coordination with the owners of the existing rail rights-of-way is critical to providing efficient passenger rail service at a reasonable capital cost.

Due to the extreme topography between Denver and Grand Junction, a series of new tunnels are needed to maintain the grade of the high-speed rail route to 4 percent or less. The constrained high-speed rail route within the I-70 rights-of-way has geometry similar to the highway geometry with abrupt curves and 7 percent grades

It should be noted that a branch line connecting from I-70 to Winter Park was considered, but screened very early in the analysis process. Such a line would have to either cross over or tunnel under Berthoud Pass, introducing a second major crossing of the Continental divide to serve only one ski resort. The cost of this could not possibly be economically supported. However, the development of the existing rail line via the Moffat Tunnel could provide a viable way to provide service not only to Winter Park, but also possibly to Steamboat Springs in the future. This should be evaluated in a future study.

Representative routes for the I-70 corridor have been defined as follows:

From downtown Denver to Golden, the main alternative proceeds south along the BNSF/UPRR joint line (existing rail) onto the US-6 corridor to vicinity of the I-70/C-470 intersection. An alternative representative route proceeds north from downtown Denver on the BNSF Golden subdivision through Arvada to its end at Ford St in Golden. This existing rail route connects with a greenfield route that parallels SH-58 to the Clear Creek Canyon entrance.

From Golden to Floyd Hill, the constrained alternative with 7 percent grades follows I-70 via the El Rancho area to the west intersection of I-70 and US-6. The unconstrained alternative with 4 percent grades follows the Clear Creek Canyon along US-6 to Floyd Hill. Both routes feature a connection to Black Hawk either along SH-119 from US-6 or a tunnel from I-70.

From the interchange of I-70 and US-6 at Floyd Hill, the representative route is either within or contiguous to the I-70 corridor through Idaho Springs and Georgetown. At Georgetown, the route continues either within the I-70 right-of-way or via a new tunnel on the south side of I-70 beginning at the western boundary of Georgetown and exiting on the south side of I-70 west of Silver Plume.

The route continues either within or contiguous to the I-70 corridor to east of the Eisenhower Johnson Memorial Tunnel near the Loveland Pass interchange. At this point, the constrained route continues through a new bore west within or contiguous to the I-70 Corridor to Silverthorne, while the unconstrained alignment would use a new North Fork Tunnel to the Keystone area, with a connecting line following US-6 back to Silverthorne and Dillon.

From the Keystone area the unconstrained route continues to the Breckenridge area south of Lake Dillon to SH-9 with a possible short branch line connection south to Breckenridge. From SH-9, the route either continues through a new Breckenridge tunnel to Copper Mountain or north to Frisco through a short tunnel and continues either within or contiguous to the I-70 corridor to Copper Mountain.

From Copper Mountain, the constrained route either is within or contiguous to the I-70 corridor to Vail, while the unconstrained route proceeds south along SH-91 with a segment through the National Forest to the UPRR Tennessee Pass subdivision at Pando. The route proceeds within or contiguous to the UPRR right-of-way (existing rail but currently not in use) north to Minturn with a branch connection to Vail. The route continues to Avon either within or contiguous to the UPRR right-of-way (lightly used existing rail).

West of Avon to Glenwood Springs and Grand Junction, the representative route includes a segment either within or contiguous to the UPRR right-of-way (existing rail corridor). The representative routes west of Avon also include a possible connection to Yampa, Steamboat Springs, and Craig either within or contiguous to the UPRR right-of-way (existing rail) from Dotsero to Bond to Craig. For this existing rail alternative, a new elevated structure is required at Bond to connect the Glenwood Springs subdivision from Dotsero onto the Moffat Line subdivision to Phippsburg. A potential greenfield alternative route, the “131 cutoff” would run from Wolcott to Bond either within or contiguous to SH-131.

These representative routes also include a segment to Aspen either using a long tunnel from the Gypsum area to the Basalt area connecting to the Roaring Fork Transit Authority (RFTA) right-of-way to Aspen, or the connection to the RFTA line to Aspen can be made by following the existing rail line through Glenwood Canyon to Glenwood Springs.

3.7.5 Proximity of Representative Routes to Intermodal Sites

The I-70 corridor serves Denver International Airport and downtown Denver. The proposed high-speed passenger rail service in the I-70 corridor west of Denver is planned to serve intermodal sites. Use of the BNSF Golden subdivision connecting to the greenfield route through Clear Creek Canyon misses an optimum location for an intermodal site at the C-470 interchange with I-70. Both the constrained I-70 route and the unconstrained route west of this interchange can be positioned near future intermodal sites by using the US-6 corridor west of Denver.

3.7.6 Proximity Representative Routes to Population Centers

The US-6 route from the Denver metropolitan area misses the center of Golden, but adds a valuable suburban stop. The only route that serves the center of Golden is the existing rail route of BNSF Golden subdivision. The constrained I-70 corridor route misses the important resort traffic generators of Keystone and Breckenridge. These areas could still be served by branch lines from I-70. Similarly, the unconstrained greenfield route through Keystone misses Silverthorne and Dillon and serves these communities with a branch line. Secondary corridors, or branch lines, are needed to serve Aspen, Steamboat Springs, Craig, and Black Hawk.

3.7.7 Geometry of Representative Routes

The geometry of the representative routes within the I-70 corridor is complex and challenging: the topographic conditions require numerous horizontal and vertical curves combined with grades up to 7 percent along the constrained alignment. While maglev trains could in theory handle the steep grades, their speed would still be restricted by sharp curves on the mountain corridor. In an attempt to optimize the operations as much as possible, unconstrained routes were developed to improve the geometry and hold the grades to 4 percent or less requiring the use of tunnels at strategic locations along the route.

3.7.8 Route Capacity

The capacity of the greenfield routes is not an issue since the routes are developed for the frequency of service necessary to serve the users, with the exception of the US-6 route between downtown Denver and the C-470 interchange with I-70. RTD proposes to implement light rail transit service that will occupy a portion of the US-6 right-of-way from the Government Center to the Jefferson County Courthouse. However it has been assumed that the construction of a double-tracked intercity rail alignment would still be feasible on this segment through use of elevated structures, if necessary.

The capacity of the existing rail routes is a concern. Both railroad companies need assurance that current and future freight operations will not be harmed by the introduction of passenger rail service. Furthermore, railroad companies have indicated objection to use of their rights-of-way for use by maglev service at grade level because of the use of FRA non-compliant vehicles.

The existing rail route using the BNSF Golden subdivision between downtown Denver and Golden has severe capacity issues from freight operations and the planned implementation of the Gold Line commuter rail service by FasTracks. Using the alignment of the BNSF Golden subdivision through Arvada would likely require the construction of a tunnel or covered trench to mitigate concerns expressed by the residents. Similarly, the existing rail route using the BNSF/UPRR Consolidated Main Line from downtown Denver connecting to the greenfield route on US-6 near the I-25 interchange is capacity constrained.

The existing rail route of UPRR between Dotsero and Grand Junction has capacity issues due to the volume of freight traffic and Amtrak service. Topographical features physically constrain the route from adding additional capacity without a huge cost for infrastructure improvements. The existing UPRR route between Dotsero and Bond is also constrained due to the topographical features of the route. Nonetheless a cost estimate has been prepared for adding an additional track to this segment. The UPRR route from Bond to Steamboat Springs and Craig has sufficient right-of-way to add track capacity needed for the introduction of passenger rail service.

The existing rail route from Pando to Minturn and west to Dotsero has no current capacity issues related to the introduction of passenger rail service with the exception of a small amount for freight traffic between Dotsero and Gypsum. However, this could change in the future. Capacity planning for this corridor must treat it as an active freight line.

3.8 Typical Infrastructure Needs for Steel Wheel/Steel Rail Technology

3.8.1 Trackwork Elements

Existing Rail Routes

Where passenger and freight are expected to share track, it is generally recommended that the existing track be improved with either a 33 percent or 66 percent tie replacement depending on the existing track condition and planned track speed. Where rail conditions are not suitable for passenger operations, the capital cost estimates provide for rail replacement with 136 lb continuous welded rail (CWR). For 110-mph rail operations in single-track territory, 10-mile long passenger sidings are provided at nominal 50 mile intervals to allow passenger and freight trains to pass. Additional freight sidings are provided between passenger sidings as needed to support whatever level of freight operations are anticipated for the corridor. Shared track is only assumed for adding passenger service to light-density branch lines such as the Milliken and GWRCO lines. On higher density freight main lines, passenger service may share the right-of-way but usually provides its own dedicated track.

A key engineering assumption adopted for this Study involves the centerline offset between an existing high density freight track and a new FRA Class 6, 110-mph track. Both UP and BNSF have requested that new tracks be constructed with a minimum 25-foot centerline offset from the adjacent track, where feasible. However, in order to accommodate possible future capacity expansion, especially in congested urban areas, the 25-foot offset will be increased to a 28-foot centerline offset. The 28-foot offset would allow a future siding with 14-foot track centers to be constructed between the new passenger track and the adjacent freight track. Based on the field reviews the costs

associated with the 28-foot offset will be estimated and included under the line item "High-Speed Rail (HSR) on New Roadbed and New Embankment."
Wherever the 28-foot centerline offset is not feasible due to inadequate right-of-way or other constraints, new track would be added at the standard 14-foot centerline offset from the adjacent freight track, but the proposed passenger train speed would be limited to 79 mph.

New turnouts and crossovers would be provided as necessary for operating the passenger service. Physical forces on the passengers, rolling stock and track serve to limit the speed at which a train can safely or comfortably operate through curves. The overall track standard for mixed freight operations is to increase super-elevation to as much as 4½ inches where necessary to achieve desired passenger speeds. For lines with very light freight operations or for high-speed intermodal trains, additional increases in super-elevation might be possible, but in no case will superelevation exceed the value that balances freight speed at 60 mph or be greater than 6 inches. Where heavy freight operations (e.g., slow coal trains) predominate, lower levels of super-elevation must be used. Because of the high density of freight operations on most Colorado rail lines, shared track is rarely feasible for this study, which has assumed practically all dedicated track.

Greenfield and Highway Routes

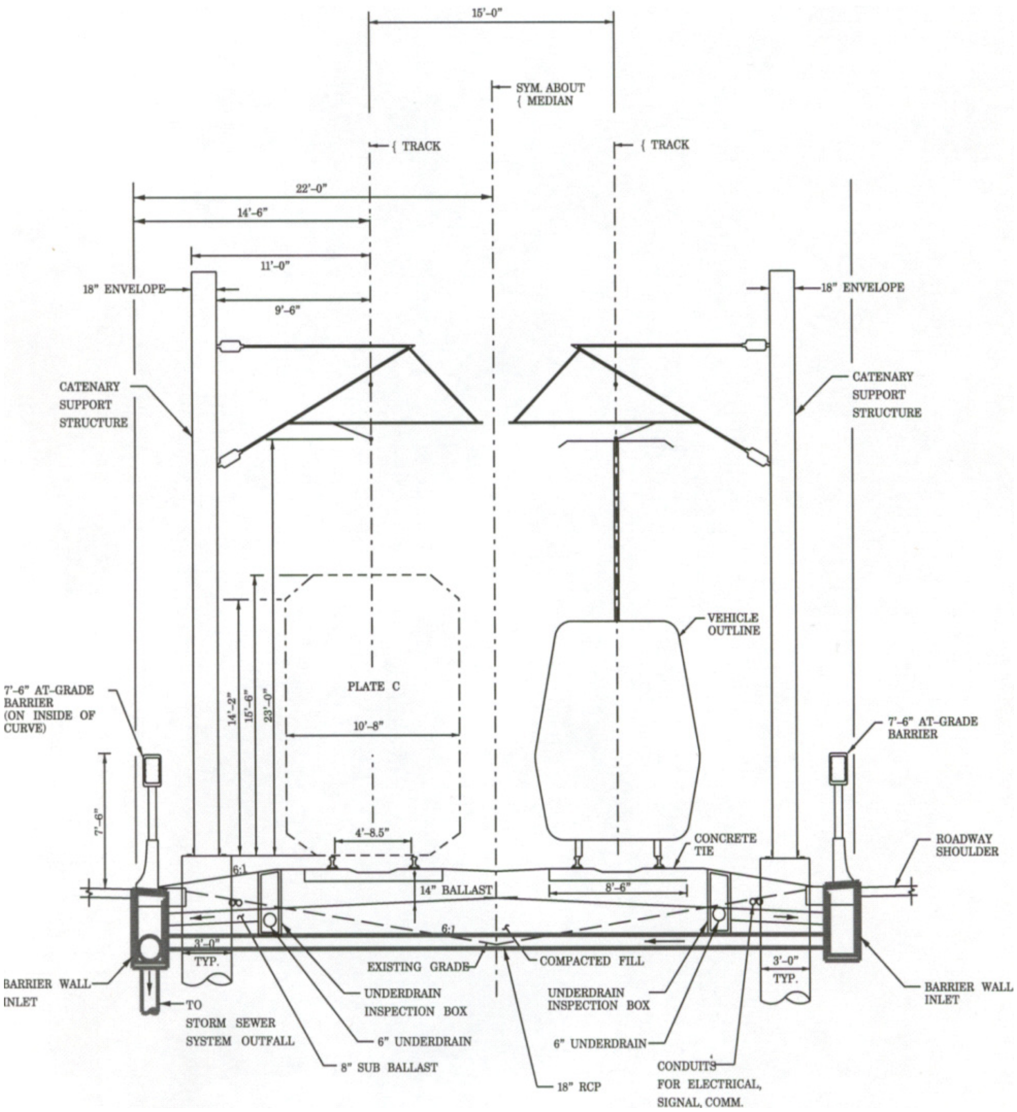
The I-70 and I-25 highway corridors (constrained) were examined to determine the feasibility of placing high-speed guideways within or near them. Unconstrained greenfield alignments were also developed for the assessing the feasibility of constructing high-speed guideways. The engineering assessment developed and plotted alignments on a scaled map to optimize the vertical and horizontal geometry needed to ensure efficient high-speed rail operation and to quantify infrastructure needs for determining the significant cost elements. Capital cost estimates are presented in Chapter 8.

Vertical geometry is an essential ingredient to maximizing speed, and the type of infrastructure section needed to obtain minimize vertical curves is directly related to the terrain. A rolling terrain may require elevated structures of several types to eliminate sudden dips or drop-offs. The profile of vertical alignment for high-speed rail must use smooth long vertical curves to ensure that the technology used can travel at its optimum speed. Other elements, such as roadway crossings, stations, and railroad bridges are specific to the greenfield and technology evaluated. The cost of many high-speed rail system components in greenfields is a direct function of the length (track, signals, communications, and electrification) and topography.

Track Work Typical Sections

Exhibit 3-50 is typical of the rail section that is required for a double track rail section. Unit costs will be presented in Chapter 8.

Exhibit 3-50: Rail Section: Double Track Electrified Rail Section; Signals, Communications & Dispatch



Source: Tampa to Miami Feasibility Study, Florida HSRA, March 2003.

Rail sections are constructed on embankment with the depth of embankment used to even a rolling terrain. Double track retained earth fill is used to even the gradient and build the alignment to the planned profile. For development of cost estimates, scaled topographical maps were used to quantify the need for retained earth fill along the greenfield routes. Exhibit 3-51 is a photograph of double track retained earth fill.

Exhibit 3-51: Double Track Retained Earth Fill

Source: Reinforced Earth Company

The medians of both the I-25 and I-70 corridors are considered for use as high-speed rail greenfield alignments. The Tampa–Orlando High-Speed Rail Study conducted in 2003 used the median of I-4. The Federal Highway Administration and Federal Railroad Administration mandated the use of Type 6 median barriers on curves between the highway and median in order to keep highway vehicles from entering onto the high-speed rail track structure. Exhibit 3-52 depicts an approved NCHRP Class 6 Barrier.

3.8.2 Structures –Approaches, Flyovers, Bridges, and Tunnels

Existing Rail Routes

A complete inventory of bridges was developed for each existing rail route from existing track charts. For estimating the quantity and costs of new structures along existing rail routes, conceptual engineering plans and per lineal foot cost estimates developed on previous studies were used.

Greenfield Routes

As noted in the trackwork section, maintaining an alignment with minimal vertical and horizontal curves is the key to operating an efficient high-speed rail service. Where the change in elevation between the planned profile and the ground exceeds 40 feet, the use of flyovers and bridges is necessary. The bridge approaches begin with retained earth fills up to 15 feet onto approach embankments. Exhibit 3-52 shows an example of an approach embankment on retained earth fill. If the difference between the alignment profile and the ground is greater than 40 feet then an elevated structure is required. Exhibit 3-53 is an example an elevated rail structure that can be used up to heights of 60 feet. For heights greater than 60 feet, a high level bridge structure is necessary, as shown in Exhibit 3-54.

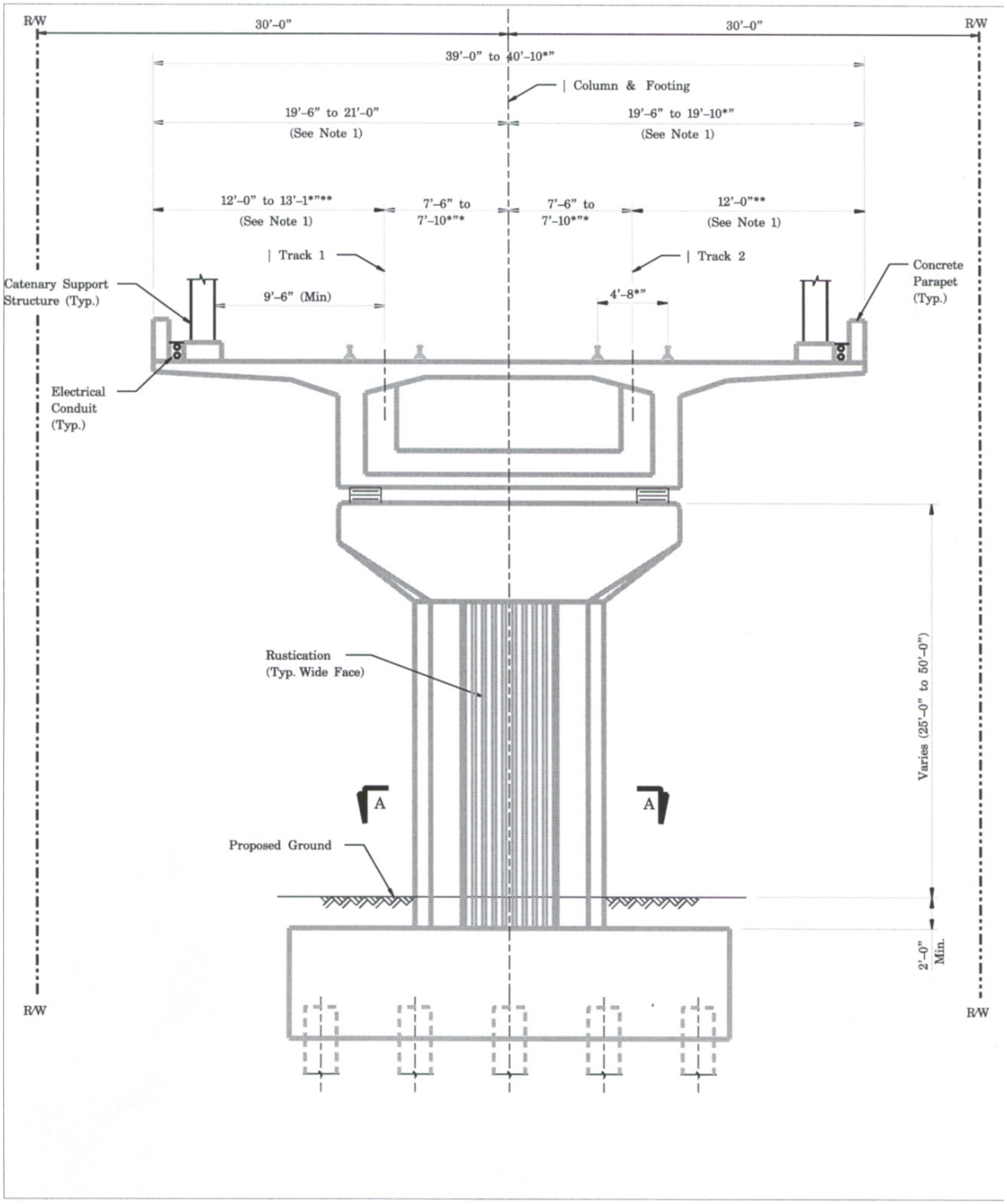
Exhibit 3-52: Example of Approach Embankment for Double Track

Source: Reinforced Earth Company

Exhibit 3-53: Example of Low Level Double Track Elevated Structure

Source: Reinforced Earth Company

Exhibit 3-54: Rail Section: High Level Structure for Double Track



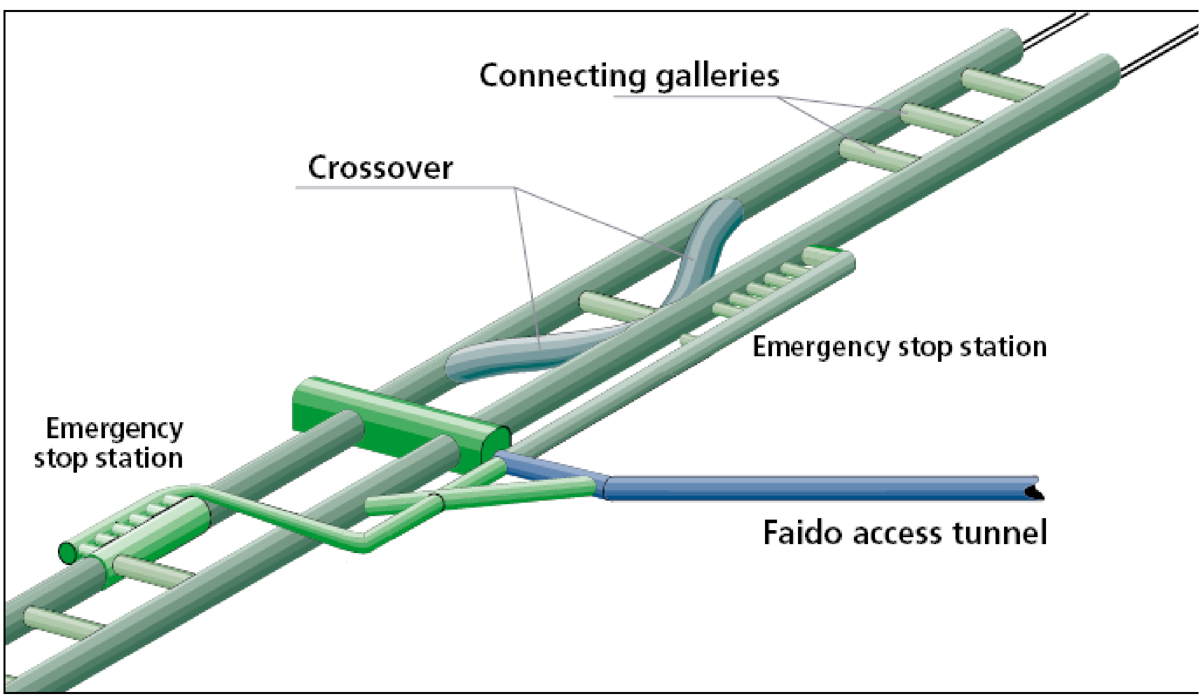
Source: Tampa to Miami Feasibility Study, Florida HSRA, March 2003

The representative greenfield routes would include tunnels to minimize grades or reduce distance between stations. Rail alignment alternatives through the Rocky Mountains would require a significant amount of tunneling to maintain operable and safe grades, avoid areas prone to rock falls and avalanches, and provide the shortest routes The recommended configuration for long term operations of high-speed system would dictate twin parallel tunnels, connected with cross-passages and bores large enough to provide safe egress and supply proper ventilation and ventilation controls in the event of a fire or mishap in the tunnels. Exhibit 3-55 shows a section of the Gotthard Base Tunnel in Switzerland and demonstrates the complexity of tunnels. Aside from the short tunnels proposed route on US-6 through Clear Creek Canyon, the major tunnels along the I-70 corridor and their proposed lengths are as follows:

- Black Hawk Tunnel 6,000 LF
- Georgetown Tunnel 14,000 LF
- North Fork Tunnel 30,000 LF
- Swan Mountain Tunnel 12,000 LF
- Frisco Tunnel 6,000 LF
- Breckenridge Tunnel 22,000 LF
- Aspen Tunnel 51,000 LF

A technical memorandum, *Rail Tunnel Evaluation for the Rocky Mountain High-Speed Rail Feasibility Study* prepared by Myers Bolke Enterprise, LLC is included in the Appendix G.

Exhibit 3-55: Tunnel section showing crossovers, connecting galleries, and emergency stations



Source: The New Gotthard Rail Link, AlpTransit Gotthard, LTD, November 2005

3.8.3 Systems

Modern train control and communication systems safely coordinate train operations to permit bi-directional use of a track network. On heavily used lines, railroads have installed Centralized Traffic Control (CTC) to maximize track capacity. CTC is system of signal blocks, track circuits, controlled switches, wayside signals (or cab signals), interlockings and communications to a central control facility that enable trains moving in a common direction to follow closely on a common main track or pass opposite direction traffic on siding tracks. Under CTC, a remotely located dispatcher can control train routing. However, train speeds are limited to 79 mph.

FRA regulations require that trains operating in excess of 79 mph employ advanced signal systems that provide cab signaling and automatic train protection or automatic train stop functions. Such track circuit based systems in use today are very expensive to construct and maintain. To develop a more cost effective technology, FRA and the rail industry have turned to Positive Train Control (PTC), a new communication based strategy that does not depend on track circuits to establish train location. Multiple research and development efforts in the United States are currently evaluating advanced train control systems:

- ITCS: The Michigan DOT, FRA, and Amtrak are advancing a project to implement an Incremental Train Control System (ITCS) in Michigan. The ITCS system, developed by General Electric Transportation Systems, is being tested on a 60-mile portion of the Chicago-Detroit High-Speed Rail Corridor between Kalamazoo and Niles, MI. The system has been in commercial operation since January 2002 and speeds have been gradually increased from 79 to 95 mph and are expected to reach 110 mph in January 2008.
- NAJPTC: The Illinois DOT, the Association of American Railroads (AAR), Union Pacific and FRA have tested a Positive Train Control project (PTC) on a 123-mile segment of the Chicago-St. Louis High-Speed Rail Corridor from Mazonia to Springfield, IL. The contractor, Lockheed Martin, successfully demonstrated 110-mph passenger operations in a field trial in 2002. The system has been removed from operation and transferred to AAR's Transportation Technology Center in Pueblo, CO for further development.
- BNSF, CSX and NS have developed systems independently to provide PTC functions, principally for freight applications.

The capital cost estimates used in Chapter 8 for this study will include costs to upgrade the train control and signal systems. Under the 79-mph scenario, capital costs will include the installation of CTC with interlockings and electric locks on industry turnouts and a PTC overlay system suitable for operation at that speed. Under the 110 mph or higher speed scenarios, the signal improvements include the added costs for a vital PTC system that can replace cab signal functionality.

The system element for magnetic levitation systems consist of propulsion, control, and communications systems including: civil structures for substations and cable trenches; propulsion blocks; propulsion equipment for low, medium, and high power; motor windings; wayside equipment; propulsion maintenance equipment; operation control subsystems for communication and data collection; and associated civil structures.

3.8.4 Curves

Track alignment curvature is normally expressed in degrees. Two measures can actually be used to determine the degree of curvature. The first is the number of degrees of rotation from a tangent or straight line that the track curves in 100 feet length. The second measure is the inches of variation on the outer rail from the center of a 60-foot chord stretched along the track. For the wide curves employed for fixed guideway systems, these two measures are essentially equal. Curves in a slow-speed yard environment may be as tight as 12 to 15 degrees, with 15 degrees representing the practical sharpest radius of curves used by modern heavy-duty freight locomotives. Many of the former narrow gauge lines in Colorado routinely used curves of 15 degrees or even more, some of those lines that were standard-gauged, such as sections of the UP Joint Line and Tennessee Pass route, are still in service today. Modern mainline track or Maglev guideway generally is laid at three degrees of curvature or less, in the interest of maximizing allowable speed and minimizing friction and drag. Exhibit 3-56 shows the relationship between the measurement of curvature in degrees, and the radius of the curve in feet.

Exhibit 3-56: Curve Degrees versus Radius

Degree	Radius
1	5,730 feet
2	2,865 feet
3	1,910 feet
4	1,433 feet
5	1,146 feet
6	955 feet

The very large difference in radius between a three degree and a one degree curve is about three-quarters of a mile. In most cases, if a restrictive curve on an existing rail or highway alignment were eased to a larger radius to increase running speeds, the new alignment would require the acquisition of an entirely new right-of-way.

An additional engineering feature of curves on high-speed track and gudeway is a spiral. This is simply a transition area coming into and out of a curve, so the curvature gradually increases in tightness and in super-elevation so that there is not a sudden lurch or sideways acceleration caused by an abrupt change. Properly designed spirals permit curves to be operated at maximum speed. Improperly designed spirals can cause a lurching effect as trains enter curves, degrading ride quality and possibly even limiting trains to slower speeds.

One method for increasing speed through curves is to cant or bank the track or guideway as on a highway curve or a speedway embankment. This is known as super-elevation. It is measured in inches of difference between the inner and outer rail, based on a level line across the rails or guideway, or in degrees of inclination, which turns out to be practically equivalent measures. The banking offsets the train's centrifugal force in the curve with an offset in the car's center of gravity. Significant speed improvements can result, especially for passenger equipment.

The stable characteristics of rail passenger equipment allow for under-balancing, which allows a train to go around a curve *faster* than its balancing speed. "Cant deficiency" is defined as the amount of additional track superelevation that would be needed to completely cancel out the sideways force in a curve. Riders on the train or maglev going faster than the balancing speed would then feel a centrifugal force towards the outside of the curve[4]. Heavy bulk freight rail lines use minimal super-elevation because of the relatively slow speed of the freight trains – often limited to one and one-half inches maximum super-elevation. Shared passenger and high-speed freight mains are often laid with four to five inches of super-elevation which is the commonly accepted limit for freight trains. However, dedicated passenger tracks can have six or even more inches of super-elevation.

- For rail equipment, tilt technology raises the allowable under balance (or cant deficiency) for passenger trains. For conventional non-tilting rail equipment, passenger comfort limits the allowable deficiency to four inches. (The train could safely go around the curve faster than this without jumping the track, but the sideways force could throw some passengers off their feet.) Tilting the vehicle allows trains to go around curves faster while still maintaining passenger comfort. Typically the sideways force is not completely cancelled, because leaving a small feeling of going around a curve helps prevent motion sickness. So instead of being limited to four inches of deficiency, passive tilt systems allow this to be increased to six or seven inches of deficiency with about four inches of tilt.[5] Some European trains with active tilting systems have utilized as much as twelve inches of cant deficiency with nine inches of tilt going around curves. This tilt works in addition to the amount of super-elevation that has been physically built into the tracks to ensure passenger comfort.

- Maglev performance is similarly affected by curves, since maglev vehicles, unlike rail, do not provide for any internal tilt mechanism. All superelevation for a maglev has to be provided by the guideway itself. Presently both the HSST and Transrapid maglev systems limit superelevation to 12 degrees, which provides essentially the same speed around curves as that of a tilting rail vehicle on conventional track.[6]

As a result, the curving performance of existing maglev and rail technologies are essentially the same. Some maglev advocates have suggested tilt capability greater than 12 degrees, but applying this level of super-elevation may start to give ride characteristics similar to that of an aircraft, which is allowed up to 20 degrees of superelevation. However, this imposes operating cost penalties in terms of having additional safety staff, seat belts, and seating requirements.

[4] However, on shared freight tracks as will likely occur in the I-25 corridor, excessive super-elevation can create a tipping force on slow freight trains towards the inside of the curve. This can lead to excessive wear on the inside rail and a shift in the rail and roadbed, where the inner rail sinks further because of loads and impacts, worsening the effect. In extreme cases, it could cause slow-speed derailments in the curve.

[5] The remaining uncompensated deficiency, which passengers feel as an outward force going around curves is about 3 inches, slightly *less* than the 4 inches they would have experienced on conventional non-tilting equipment. This is perceived as an improvement in ride quality.

[6] Six inches superelevation plus six inches of tilt on a rail vehicle produces the same lateral force as 12" of superelevation on a non-tilting maglev. By comparison, Amtrak's Acela's active tilting system can provide almost seven inches of tilt, so Acela already exceeds the curving capability of the maglev.

The following table illustrates the effect of varying applications of super-elevation on passenger train or maglev speeds. The speeds in the first part of Exhibit 3-57 are for conventional, non-tilting passenger trains. They allow the passenger train to go through a curve slightly faster than the actual balancing speed for the curve. For example a two-degree curve with four inches of super-elevation and 3.5 inches of under balance (or cant deficiency) produces an effective capability to go around the curve based on the equivalent balancing speed for 7.5 inches of superelevation. Higher speeds are attainable by a train that has a passive tilt system installed, like the Talgo T-21.

Exhibit 3-57: Passenger Reference Speeds*

	Passenger Reference Speeds (mph) with 3.5" Deficiency					
	Degree of Curve					
Superelevation (in.)	1	2	3	4	5	6
0	71	50	41	35	32	29
1	80	57	46	40	36	33
1.5	85	60	49	42	38	35
2	89	63	51	44	40	36
3	96	68	56	48	43	39
4	104	73	60	52	46	42
5	110	78	64	55	49	45
6	116	82	67	58	52	48

	Passenger Reference Speeds (mph) with 6.0" Deficiency					
	Degree of Curve					
Superelevation (in.)	1	2	3	4	5	6
0	93	65	53	46	41	38
1	100	71	58	50	45	41
1.5	104	73	60	52	46	42
2	107	76	62	53	48	44
3	113	80	65	57	51	46
4	120	85	69	60	53	49
5	125	89	72	63	56	51
6	131	93	76	65	59	53

*Note: Superelevation above is the "Actual Superelevation" and "Superelevation Under balance" or Cant Deficiency is assumed to be 3.5 inches and 6 inches

As a result, it can be seen that a two-degree curve for conventional equipment limits train or maglev speed to only 73 mph[7]. For tilting equipment on a dedicated track, this can be increased to 93 mph[8]. Curves greater than two degrees start to impose severe speed limits on operations. For example, a 3-degree curve pushes the speed down to only 56 mph.[9] A 6-degree curve, which is common along the I-70 alignment, would limit the speed of either a tilting train or maglev vehicle to just 53 mph[10]. A few isolated curves of this degree will not have that much impact on overall system performance but to the degree that the curves are closely spaced, the vehicle will not have the ability to accelerate back to high-speed before it has to start slowing down again for the next curve.

[7] Four inches of superelevation with 3.5 inches of cant deficiency
[8] Six inches of superelevation with 6 inches of cant deficiency
[9] Three inches of superelevation with 3.5 inches of cant deficiency
[10] Six inches of superelevation with 6 inches of cant deficiency

The conclusion is that it is practically necessary to limit curves to 2-degrees or less, except in special instances, to support 90-mph operation along the corridor. This is equally true for either rail or maglev technologies. The issue of curvature rather than gradient therefore, may in fact prove to be the most limiting factor for attaining high-speeds along the I-70 alignment. It is best dealt with by allowing the rail or maglev alignment to deviate from the existing highway alignment, where necessary and possible, by reducing the curvature to 2-degrees or less. For train performance evaluation in this study:

- Diesel-powered trains used for the 110-mph evaluation limit cant deficiency to 6" along with a maximum of 6" superelevation on dedicated tracks. This is consistent with the diesel tilting trains assumed in previous studies such as the Midwest and Ohio systems. It is also consistent with Exhibits 3-15 and 3-19, and with the capabilities of passive tilt trains such as the Talgo T-21.
- Electric-powered tilting trains assume a slightly higher level of 7" of cant deficiency along with a maximum of 6" superelevation on dedicated tracks. This is consistent with the tilting Acela electric train that utilizes an active (computer controlled) tilting system, and is currently certified by the FRA for operation in the Northeast Corridor at up to 7" of deficiency.

3.8.5 Highway Grade Crossings

The treatment of grade crossings to accommodate 110-mph operations is a major challenge to planning a high-speed rail system. Highway/railroad crossing safety will play a critical role in future project development phases and a variety of devices will be considered to improve safety, including roadway geometric improvements, median barriers, barrier gates, traffic channelization devices, wayside horns, fencing and the potential closure of crossings.

FRA guidelines require the use of four quadrant gates with constant warning time activation at public crossings for 110-mph passenger operations. Constant-warning time systems are essential to accommodate the large differential in speed between freight and passenger trains. The treatment and design of improved safety and warning devices will need further development to identify specifications and various approaches that may be advanced as part of an integrated program in Colorado.

There are numerous grade crossings through urban areas. For many of these, speed restrictions will be assumed, but there are others where high-speed operations are essential to the success of the rail system.

Grade crossing improvements are a significant component of the capital cost estimates for passenger rail service in this study. The following strategy has been employed to develop the cost estimates:

- Where passenger speeds are greater than 79 mph, 25 percent of the existing private crossings on the route will be closed.
- Where speeds do not exceed 79 mph, private crossings will not be affected.

- Where passenger speeds are greater than 79 mph, public crossings will be upgraded to four quadrant gates with constant warning time, and remaining private crossings will be upgraded to four quadrant gates.
- Where passenger speeds do not exceed 79 mph, public crossings warning systems will be upgraded to standard two quadrant gates, and flashers with constant warning time and remaining private crossings will be upgraded to standard two quadrant gates and flashers.
- Precast panels will be installed at all public crossings.
- Where new track and embankment are constructed, precast panels will be installed and roadway surfaces improved at public crossings.

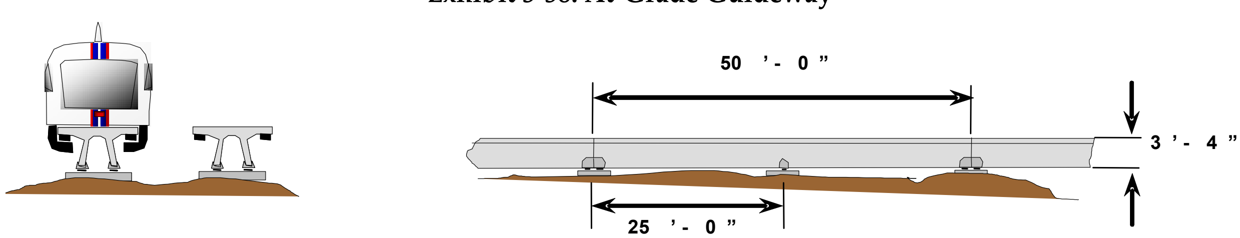
3.9 Infrastructure Needs for Maglev Technology

Maglev technologies have slightly different structural needs than do rail technologies. Maglev vehicles tend to be lighter, so somewhat lighter structures can often be employed. Even so the vehicle itself requires guideway support, which requires a beam structural element be provided even on level ground. Essentially the maglev guideway requires a continuous bridge structure although some cost savings are still possible if the beam can be brought down as close to ground level as possible. At-grade maglev systems of course, since the access to the right-of-way must be totally controlled, must have complete fencing to prevent any incursions on the right-of-way.

3.9.1 At-Grade Guideway

The at-grade maglev guideway section shown in Exhibit 3-58 was used in this study at locations allowing the guideway placement at or near ground level. The precast concrete or steel beams have typical spans of 25 feet. The section can be curved or superelevated to meet alignment requirements. At each support, grade beams serve as either pile caps or spread footings.

Exhibit 3-58: At-Grade Guideway

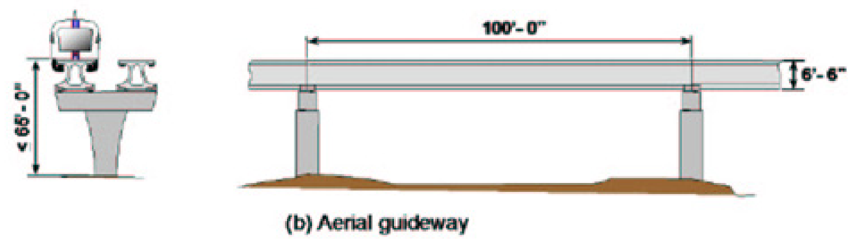


Aerial Guideway – Type A, Single Columns

Source: SANDAG Maglev Study Phase 1, Final Report

The aerial guideway section shown in Exhibit 3-59 was used in the constrained and unconstrained greenfield routes to maintain the planned profile in mountainous areas of I-70 and the rolling terrain of the Front Range and Eastern Plains of the I-25 corridor. This section was used when the difference between the planned profile and ground is less than 65 feet. The typical span is 100 feet. The structure is usually continuous over multiple spans but can be curved and super elevated to meet geometric and lateral acceleration requirements.

Exhibit 3-59: Aerial Guideway, Type A

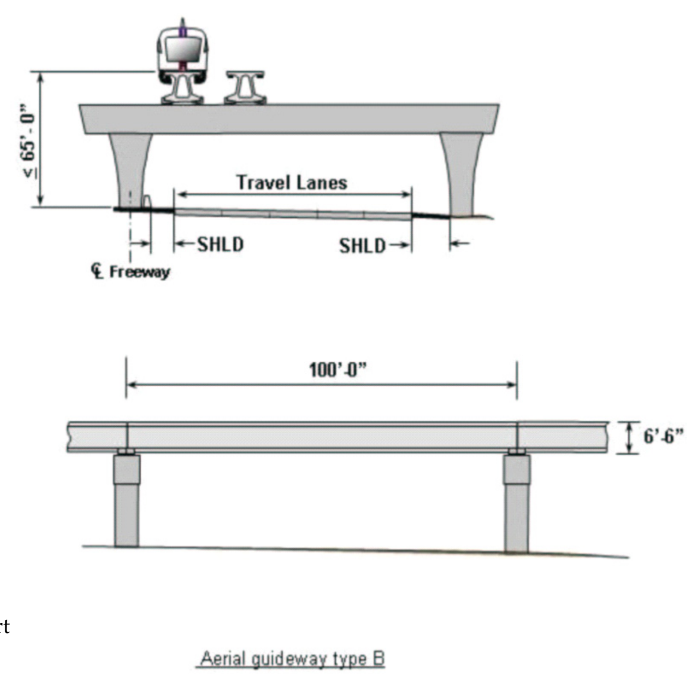


Source: SANDAG Maglev Study Phase 1, Final Report

3.9.2 Aerial Guideway – Type B, Straddle Bents

The constrained greenfield routes in the I-70 corridor have numerous horizontal curves. In order to minimize the curvature, the geometric alignment crosses over I-70 several times making it impossible to use the Type A section. Therefore, a straddle bent was used to laterally span the travel lanes of I-70. Exhibit 3-60 depicts the straddle bent.

Exhibit 3-60: Straddle Bent over Highway Lanes

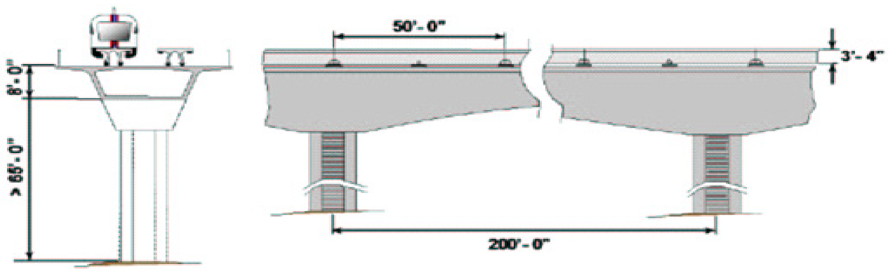


Source: SANDAG Maglev Study Phase 1, Final Report

3.9.3 Bridge Structures

Bridge structures for maglev are required for spans exceeding 100 feet or column heights greater than 65 feet. Since these limits are exceeded primarily in remote mountainous terrain, precast concrete segmental structures constructed using the balanced cantilever method was assumed. In order to minimize deflection, the spans are limited to 200 feet. The bridge structure supports at grade girders that are mounted to the deck of the bridge with small pedestals. Exhibit 3-61 depicts this bridge structure

Exhibit 3-61: Bridge Structure, SANDAG Maglev Study Phase 1, Final Report



(c) Bridge structure

Note: Guideway beams from *ZEVrail Glasers Annals – Special Issue Transrapid 2004.*

3.9.4 Tunnels

In order to improve maglev operations in mountainous areas, tunnels are necessary to reduce unreasonable grades and maintain a smooth profile with long vertical curves. Two types of tunnels were considered in this study. Type A, as shown in Exhibit 3-62, is a two bore tunnel for use in shallow or short tunnels. Type B, as shown in Exhibit 3-63, is a two bore tunnel with a third bore for service and relief for use in deep or long tunnels. Within the tunnel, girders are still required to support the train and associated propulsion system. Each bore requires separate 37 ft. diameter tunnel due to the high train speeds. For long Type B tunnels, an additional 20 ft. diameter ventilation shaft with ducts periodically connects to the riding tunnels for pressure equalization.

Exhibit 3-62: Type A Shallow or Short Maglev Tunnel

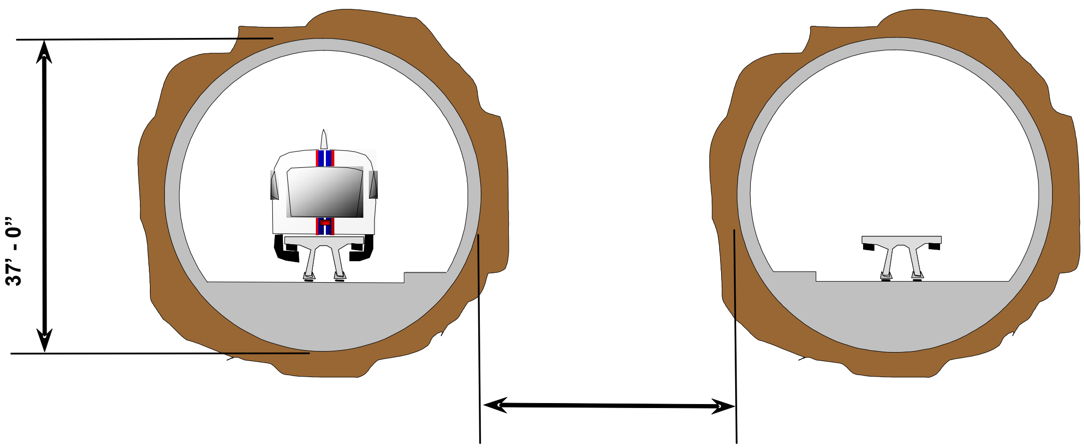
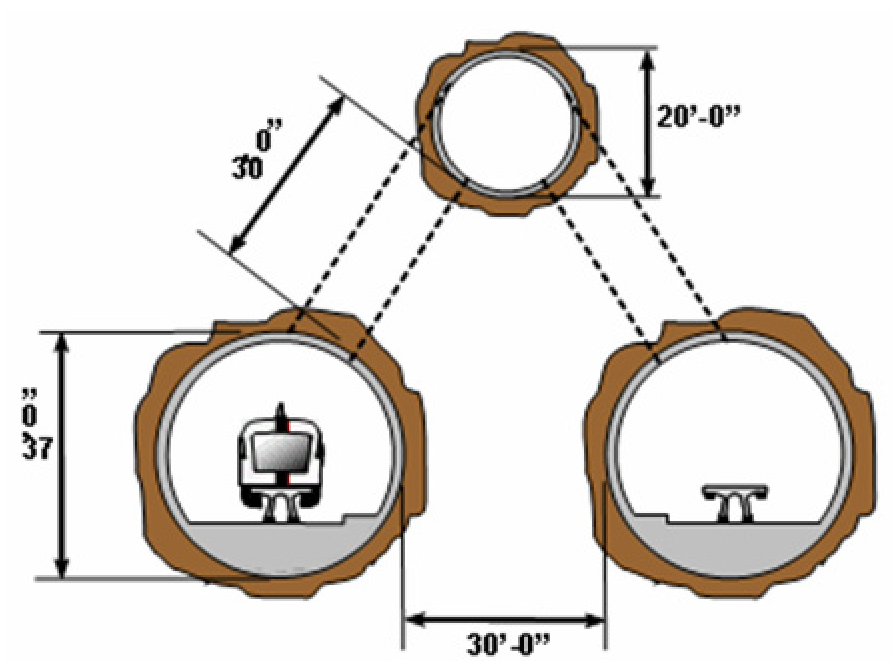


Exhibit 3-63: Type B Deep or Long Tunnel



Source: SANDAG Maglev Study Phase 1, Final Report

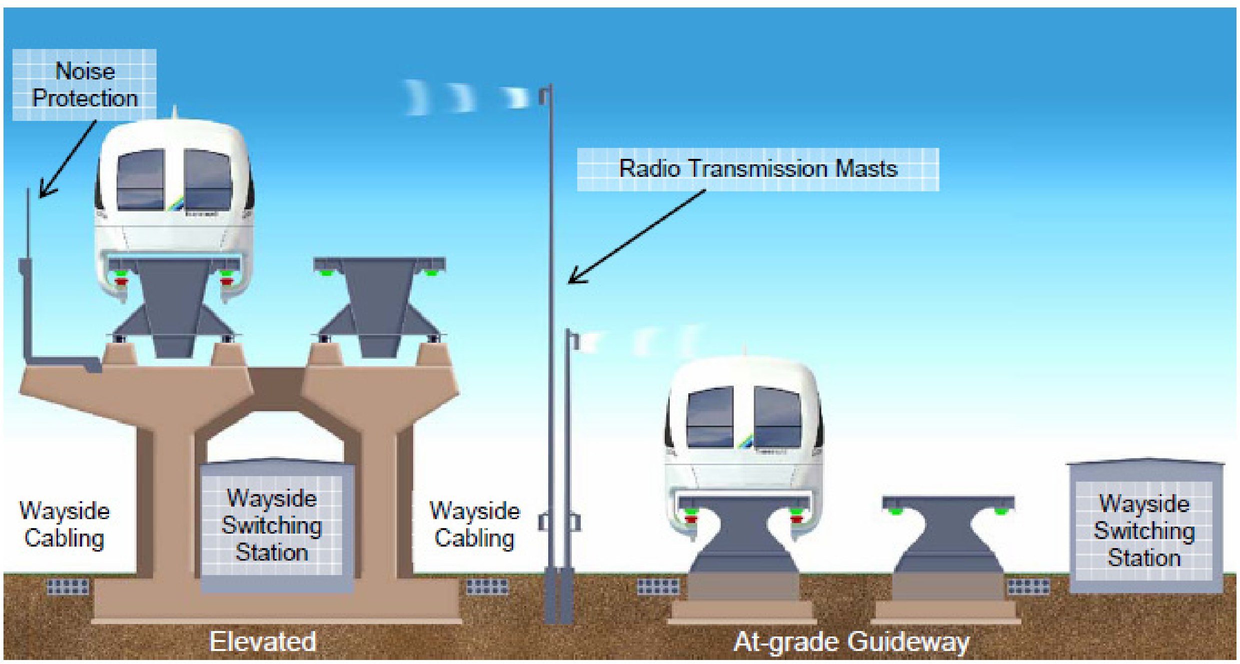
3.9.5 Maglev Propulsion, Communication and Controls

Wayside components are needed in the right-of-way to provide basic operations of the maglev system and are of five distinct types, each with its own size/space requirements and specialized technical functions. These types include:

- Propulsion system switching stations
- Transformer stations
- Radio transmission masts/transceivers
- Guideway switch stations
- Cable routes/trenches[11]

Exhibit 3-64 shows the components that comprise wayside equipment for maglev operations under both elevated and surface conditions.

Exhibit 3-64: Maglev Propulsion, Communication and Controls



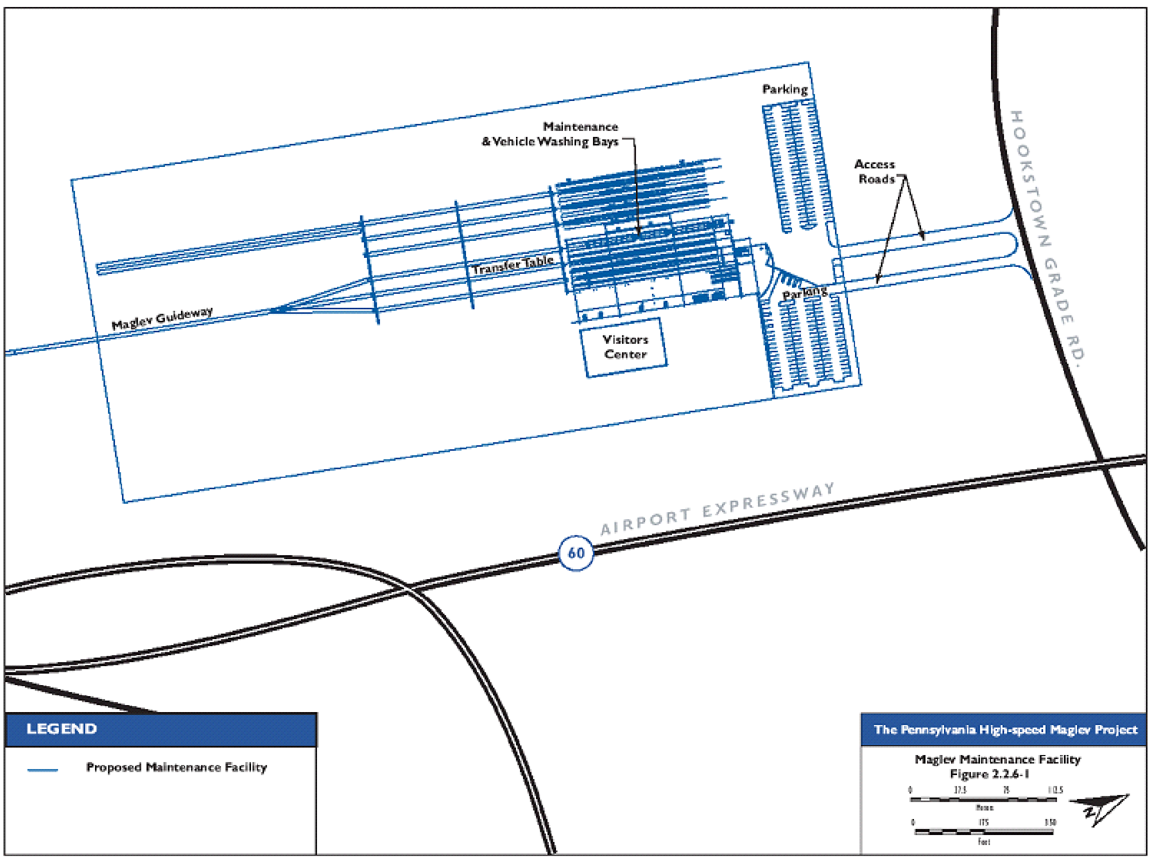
Source: SANDAG Maglev Study Phase 1, Final Report

[11] Sandag Maglev Study Phase 1, Final Report, March 17, 2006

3.9.6 Operations and Maintenance Facilities: Rail and Maglev

When planning for maintenance facilities, the size of the facility is an important consideration and will vary depending on the purpose and available locations along the route. Normal maintenance functions include daily cleaning, washing, inspection, repairs, scheduled and unscheduled maintenance, condition monitoring, replacement of vehicle or facility components, and storage. For a first approximation, normal maintenance functions (vehicle parking, washing, preventive maintenance, inspection, etc.) were sized according to the length of complete consists or train sets. Therefore, the size of the maintenance facility needed is based on the train sets required. For example, the Draft Environmental Impact Statement for the Pittsburgh maglev project includes a drawing of a combined operation control center /maintenance facility that requires approximately 35 acres, as shown in Exhibit 3-65.[12] Rail maintenance facilities are sized and configured very similarly.

Exhibit 3-65: Proposed Central Maintenance Facility (Pittsburgh, PA)



Source: Pittsburgh, PA Maglev Project website at www.maglevpa.com

[12] SANDAG Maglev Study Phase 1, Final Report, March 17, 2006

3.10 Summary

Representative routes were developed for the I-70 and I-25 corridors. These representative routes were based on the FRA route guidance manual. While the routes are not optimal and have not been subject to any formal environmental analysis, every effort has been made to avoid fatal flaws and develop routes that have a good prospect of being mitigated in any comprehensive environmental study. These routes were developed to support a Feasibility-level economic analysis to help Colorado understand the technology implications and development potential for a statewide intercity rail system. These routes are likely to be used as a possible input to a NEPA evaluation process. The options evaluated here were not intended to be an exhaustive list of all possible options, nor are any screening recommendations developed at this feasibility-level completely final. Rather there is still ample room for adjustment of route specifics during the NEPA process.

4 Route and Technology Options

This chapter will establish "base case" alternatives used for both the technology and routes to be evaluated as part of the RMRA High-Speed Rail Feasibility Study. For each alternative the aim is to produce a reasonable *representative* option for the type of technology. In the case of the slower speed alternatives (79-110 mph), the most effective option is to use existing railroad rights-of-way and where the volume of freight rail traffic is limited, to share tracks with freight traffic. As speeds and frequency of passenger rail service increase, first the ability to share tracks with freight becomes more limited, although the right-of-way may still be shared. For very high-speeds the ability to even use existing railroad rights-of-way is lost. Of course, sharing track or using freight rail right-of-way may still occur (at lower speeds) in urban areas to gain access to downtown stations, but away from the urban area true high-speed service is likely to require a greenfield route -- since high-speed rail operation need long stretches of straight track and very gentle curves to achieve high-speed. Exhibit 4-1 shows that higher speed routes usually have fewer stations since the distances needed to get up to speed and to stop are much longer. In general, faster systems have fewer stops. A compromise may be needed to ensure all key communities are served, but this results in a trade-off between end-to-end speed and connecting communities. Each station stop takes three to seven minutes (including deceleration, stop time and acceleration back to speed) so multiple stops soon dramatically increase end-to-end running times.

In terms of the route and technology framework, three sets of scenarios need to be identified:

1. Station locations
2. Representative technologies
3. Representative routes

4.1 Potential Stations

Station selection determines where the tracks have to go, and thus constrains the alignment choices. For this study, Exhibit 4-2 shows the potential stations that have been considered. The large green stations define the major production and attraction locations that must be served; the smaller red stations show what is thought to be desirable if possible. Red stations could be bypassed if necessary without undermining the financial viability of the system. Service to the green stations is considered vital to maintaining the ridership base of the system. (Exhibit 4-2 is a simplified schematic that focuses on the definition of station locations. It does not include junctions or route alternatives that were developed later in the study.)

Exhibit 4-1: Station Spacing Increasing with Speed

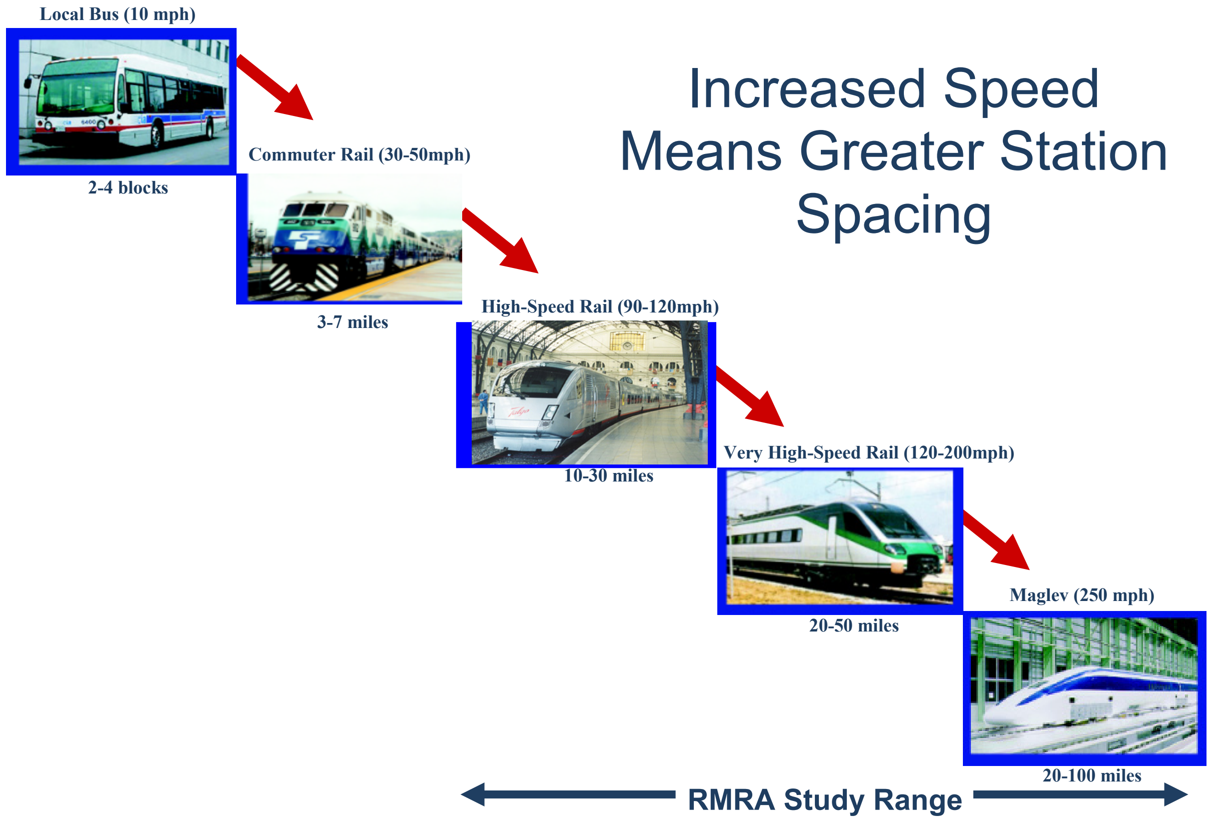
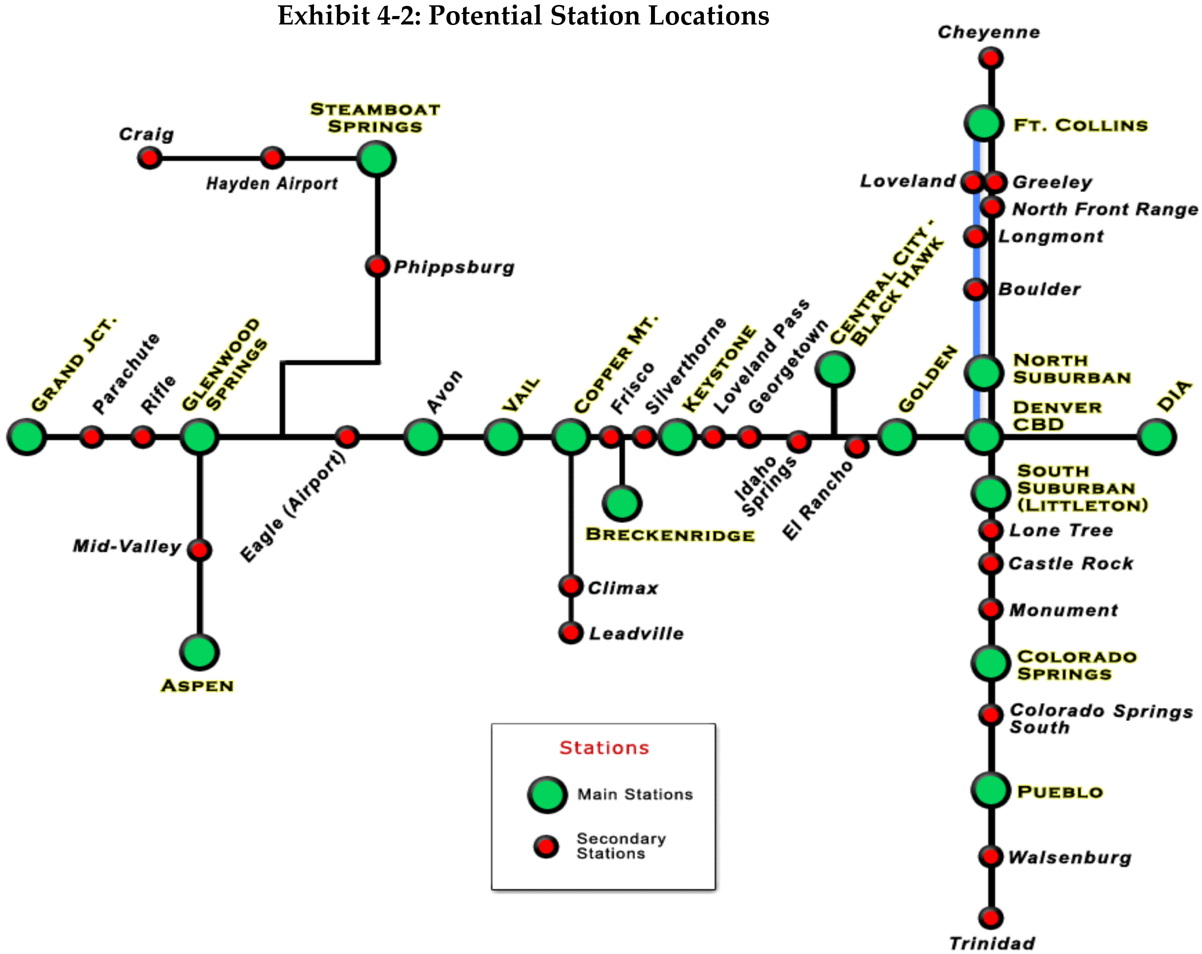


Exhibit 4-2: Potential Station Locations



Denver CBD and DIA are the largest producers and attractors of trips, while the three Denver suburban stations (North, South, and Golden) reflect the fact that individuals tend to drive towards their destinations, and do not like to drive backwards to take a train. For example, individuals traveling to Colorado Springs from Denver, who live in southern suburbs such as Littleton, Lone Tree or Parker are likely to want to drive to a southern suburban station located on E-470, rather than drive to the Denver CBD. These may well be large stations with significant car parking needs. Ft. Collins, Colorado Springs, and Pueblo are all major production and attraction centers along the I-25 corridor, while Loveland, Greeley, Longmont, Boulder, Castle Rock, Monument, and Trinidad are secondary stations.

Along the I-70 corridor it is the ski, casino and tourist resorts that are the major attractions. These resorts attract millions of visitors each year, which in any intercity context makes them attractors as large if not larger than the major towns and cities of the Front Range with the exception of Denver. Service to the small red stations is likely to be more limited than to the green stations and may only receive four to six trains per day in both directions compared with the twelve to twenty-four trains per day in both directions for the green stations.

The selection of station stops was largely market driven (i.e., the stop represents a major attraction or destination, as described in Chapter 2.) However, the study team received input on acceptability from the public outreach workshops, the I-70 Coalition and Colorado MPO's and other major transportation authorities such as Denver International Airport and RTD.

4.2 Representative Technologies

For the purpose of evaluation, vehicle technologies have been clustered into five generic technology categories, where each category corresponds to a specific vehicle technology and performance capability. The five categories that have been used as the basis of the evaluation are shown in Exhibit 4-3. It shows that four different rail technology groups and two maglev groups have been established, based on the *maximum speed capability* of the vehicle type on *straight-and-level track*.

Exhibit 4-3: Generic Technology Categories by Speed Range

	79 mph	110-130 mph	150 mph	220 mph	250-300 mph
Rail	X	X	X	X	
Maglev		X			X

By defining Generic Technology categories, route evaluations are valid for a range of equipment options rather than only for one specific manufacturer's train. To optimize the match of train equipment to the characteristics of the route, it is standard business practice in the transit industry to issue a Performance Specification as a part of a competitive equipment procurement process. Since the proposed Colorado I-70 corridor would be unique in the world, no existing or off-the-shelf train can reasonably be expected to meet all of Colorado's requirements. (Appendix J gives AGS performance criteria specified by the I-70 Coalition for EIS planning.) Even so, all of the features or components that need to be combined to create a Colorado train have been proven and are operational in revenue service in numerous applications throughout the world. Furthermore, for specifying train performance (e.g., rates of acceleration, performance on grades, and tilting capability through curves) the approach adopted is one of reasonable conservatism. Doing this in the equipment Performance Specification ensures that the operational analysis and financial projections are also conservative, increasing confidence that the system can be realized in practice.

Use of a Performance Specification will ensure the ability to maintain a competitive equipment procurement process, since in most cases several manufacturers could meet the performance criteria that are specified for each generic category. Therefore, each defined equipment category can be considered an appropriate basis for development of an RMRA equipment performance specification. The vehicle technology analysis is based on this performance specification, which represents a composite of proven equipment technologies, rather than on the characteristics of any single specific existing or "off-the-shelf "train.

As shown in Exhibit 4-3, there are four categories to reflect rail (steel wheel) vehicles, while two categories are for maglev technologies. The top two rail categories are very similar reflecting modern high-speed train designs, the main difference being that the 150-mph category is electric locomotive-hauled, whereas the 220-mph category has distributed power under the train (Electric Multiple Unit, or EMU.)

For both rail and maglev, an important criterion for this study is that the technology must be proven in revenue service. All four kinds of steel wheel vehicles are in revenue service today. With respect to high-speed maglev, the Transrapid system is in revenue service today. The Tobu Kyuryo Line in Nagoya, Japan demonstrates the feasibility of the low-speed maglev concept that was envisioned by the *2004 Colorado Maglev Study*, although this concept would require considerable additional development to achieve the 110-130 mph speed capabilities that were envisioned by the 2004 report.

A key requirement of this study is that all proposed technologies should be capable of receiving required regulatory approvals within the implementation time scales of the project. This section will assess relevant proven technology options and their potential speed, focusing on existing technologies that have been proven in actual revenue service, and clustering the technologies into generic categories.

Some have advocated new or "novel" technologies for potential application to the Colorado corridors. However, the funding grant from the Colorado Department of Transportation specifically excluded detailed consideration of novel technologies from this study, restricting application of funds only to proven technologies. Per direction from the RMRA and CDOT, novel technologies can not be evaluated at the same level as proven technologies because:

- The CDOT Transportation Commission Resolution Restricting Front Range Commuter Rail Study passed 6 to 1 in November 2006.
- DMU, EMU, Diesel Locomotive Hauled or Magnetic Levitation are the only technologies allowed by the Transportation Commission because of work done previously in I-70 Draft PEIS.

As part of this study, however, a technology survey was conducted that includes novel technologies so their development potential for possible long-run implementation in Colorado can be understood. It is important to note that the main focus of this study was to conduct a market and economic assessment for existing technology. To the degree that any novel technology can fully satisfy the vehicle performance requirements assumed by a generic category, then the market and economic assessment developed by this study should be applicable to that technology. The key results of the Novel technology survey are summarized in Appendix K.

4.3 Generic Technology Categories

This section addresses the speed ranges that characterize rail and maglev technology capabilities. Within these ranges any number of specific technologies could be chosen depending on how practical and cost effective they are for achieving any given speed.

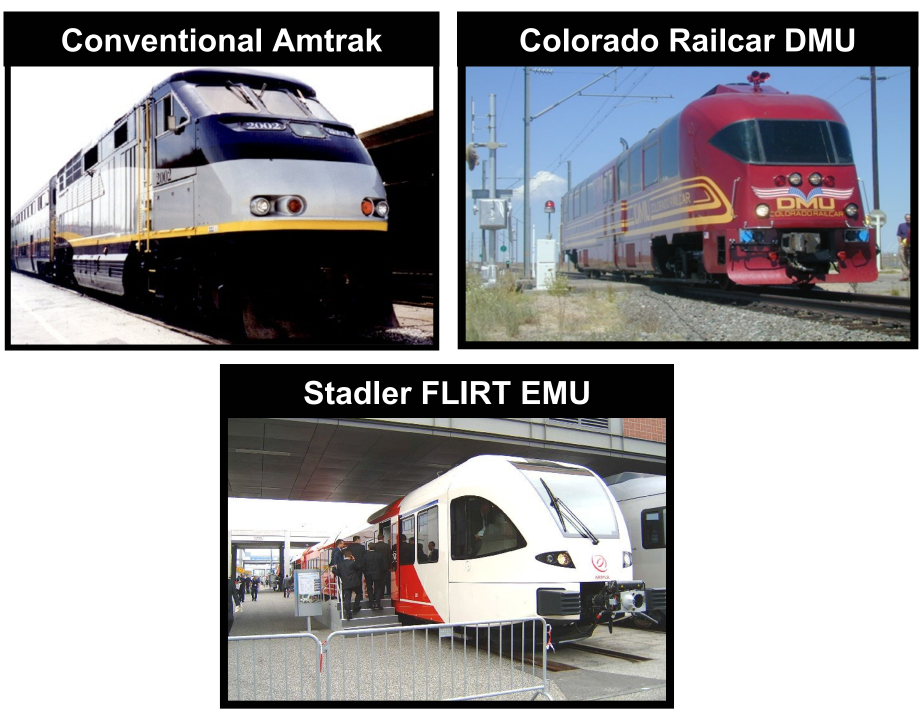
Conventional Rail - 79 mph or less: Conventional trains, as shown in Exhibit 4-4, can operate at up to 79 mph on existing freight tracks. 79 mph represents the highest speed at which trains can legally operate in the United States without having a supplementary cab signaling system on board the locomotive. The key characteristics of these trains are that they:

- Are designed for economical operation at conventional speeds
- Can be diesel or electric powered
- Are non-tilting for simplified maintenance

Because of the focus on economy these trains sacrifice performance; for example, the decision to employ non-powered "Cabbage Cars" rather than powered locomotives on Talgo trains currently operated by Amtrak in the Pacific Northwest. Double deck trains such as operated in California also seek to minimize cost rather than maximize speed but in the process, they sacrifice the time-competitiveness of the rail service as compared to driving, except in the most extremely congested highway corridors.

Both FRA compliant and non-compliant equipment fall into this conventional rail category. Representative trains include the conventional Amtrak train, compliant Colorado Railcar DMU and non-compliant Stadler FLIRT EMU, all pictured in Exhibit 4-4 on next page. (Colorado Railcar has gone out of business but the production rights to the DMU vehicle have been purchased by a firm called US Railcar, who is establishing a new production facility in the Midwestern US.)

Exhibit 4-4: Conventional Rail – Representative Trains



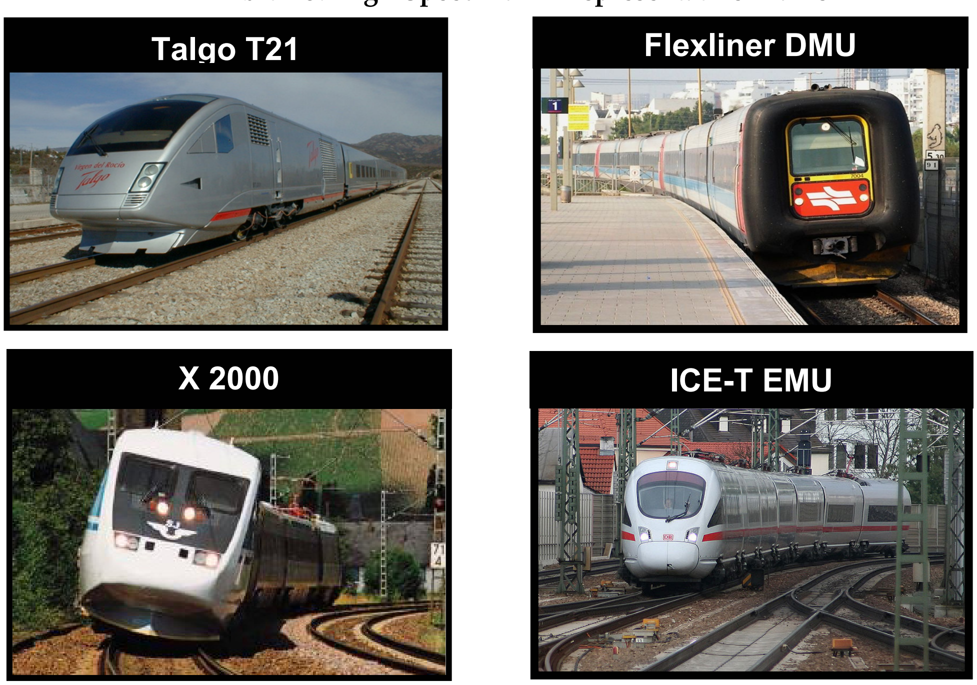
High-Speed Rail - 110-130 mph: A 110 to 130-mph service can often be incrementally developed from an existing conventional rail system by improving track conditions, adding a supplementary Positive Train Control safety system, and improving grade crossing protection. Tilt capability, built into the equipment by allowing trains to go around curves faster, has proven to be very effective for improving service on existing track, often enabling a 20-30 percent reduction in running times. Trains operating at 110 mph, such as those assumed for the Midwest and Ohio Hub systems, have generally been found to produce auto-competitive travel times, and are therefore able to generate sufficient revenues to cover their operating costs. High-speed trains:

- Are designed for operation above 100 mph on existing rail lines
- Can be diesel or electric powered
- Are usually tilting unless the track is very straight

In the United States, 110-mph service provides a low cost infrastructure option by using existing railroad rights-of-way, and quad-gating crossings, which are relatively low cost options. The costs of grade separation for 125 mph can easily double the capital cost of a project, as the number of public and private crossings can be as many as two per mile. Once full grade separation has been accomplished however, speeds can be pushed up to 150 mph or even higher to improve the economic return on that investment.

Representative trains include the Talgo T-21 diesel locomotive hauled trains, the Flexliner DMU, the X-2000 Electric locomotive hauled train and the ICE-T EMU, all pictured in Exhibit 4-5 below. It should be noted that the ICE-T is a derivative of the higher-powered ICE-3 train that operates at 186 mph on dedicated new tracks. The ICE-T extends the reach of Germany's high-speed train network into the Swiss Alps. It is included in this category because of its tilting capability.

Exhibit 4-5: High-Speed Rail – Representative Trains

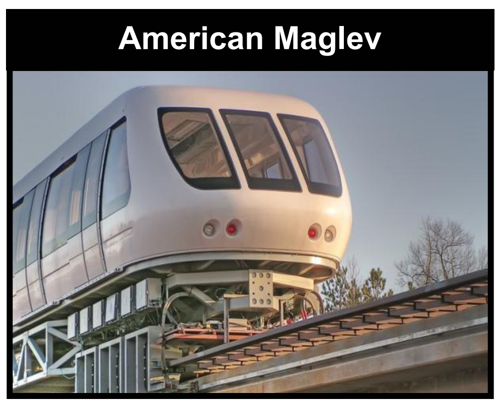


High-Speed Maglev - 110-130 mph: For this evaluation, the *2004 Colorado Maglev* proposal represents the High-Speed category. At present, this type of system has been implemented only in a low-speed urban transit application. Whereas high-speed maglev systems place the linear motor on the guideway (Linear Synchronous Motor, or LSM), low-speed systems place the motor on board the vehicle (Linear Induction Motor, or LIM) to reduce cost. Because of this, a LIM vehicle must be heavier than a LSM vehicle of equivalent capacity. The Japanese HSST is the best example of this type of urban maglev with a 5.5-mile operating line in Nagoya, Japan (see Exhibit 4-6). American Maglev and General Atomics both have similar urban maglev concepts on test tracks. The current HSST was designed as an urban transit mode, not as a high-speed system. It has a top speed of 65 mph[1]. The HSST technology would have to be adapted significantly to meet the speed requirements needed for high-speed service in Colorado. The key characteristics of these trains are:

- They are high-speed derivatives of urban maglev designs, as opposed to systems that were designed from the beginning to go as fast as possible.
- The HSST urban maglev system is operational and others are on test tracks, but the modifications needed to prove high-speed capability are still in the R&D phase.

For evaluation purposes in this study, however, both systems are treated as if they were operational today, on the basis of the system specifications as outlined in the *2004 Colorado Maglev Study*.

Exhibit 4-6: High-Speed Maglev – Representative Trains



[1] http://faculty.washington.edu/jbs/itrans/hsstpage.htm and http://maglev.com.www65.your-server.de/uploads/2002/pp01102.pdf

Very High-Speed Rail - 150-220 mph: This category covers two types of electric trains. The early French TGV and German ICE were locomotive-hauled trains. These operated initially at 150 mph and were improved to 186 mph. To go even faster, up to 220 mph, as well as improve the hill-climbing capabilities of the trains, both the French and Germans have shifted towards Electric Multiple Unit (EMU) designs with their latest generations of Alstom's AGV and Siemens' ICE-3 trains.

Rather than using locomotives, the EMU design places traction motors underneath each individual railcar. This has the advantage of eliminating the dead weight of the locomotive, increasing the number of traction motors leading to an increase in power, improving adhesion since half or more of the train's axles are powered, and making more effective use of station platform length. However, when high-speed services are extended beyond the reach of the high-speed tracks using conventional lines, tilting capability can still prove very advantageous. The key characteristics of these trains are:

- High-Powered for operation at 150 mph or higher on new lines.
- Electric only
- For trains that operate on conventional tracks beyond the new lines, tilting versions of Very High-Speed trains have been developed to allow them to go around curves faster.

Some representative trains are shown in Exhibit 4-7.

Exhibit 4-7: Very High-Speed Rail – Representative Trains

Ultra High-Speed Maglev - 250-300 mph: For speeds above 250 mph the only current technology is Maglev. (Rail has demonstrated speeds above 250 mph but only on experimental trial runs.) Such speeds are routinely attained by the Shanghai airport maglev in revenue service, as shown in Exhibit 4-8. This system is fundamentally different from a rail technology in that it does not use a steel wheel/steel rail contact, but rather uses magnetic levitation to float above a concrete guideway, as well as to propel the train. For ultra high-speed maglev, only Siemens' Transrapid shown in Exhibit 4-8 is in commercial operation. These maglev trains are capable of rapid acceleration up to their design limits and typically operate in consists of two to five cars. Seating capacity is generated by operating the trains at higher frequency than normal steel wheel/steel rail trains, or by linking car sets together if platform lengths permit. The key characteristics of these trains are:

- They were designed from the beginning for ultra high-speed.

There is only one existing operational system (Transrapid) in this class today, although there are additional high-speed concepts in R&D throughout the world. For example, the Japanese MLX01 superconducting Maglev is operating on a test track in the Yamanashi province, and it has recently been announced that the technology will be made available in the North American market.[2] However, detailed cost and performance specifications for this technology were not available within the time frame needed for the RMRA study. For evaluation purposes the Transrapid system has been assumed.

Exhibit 4-8: Ultra High-Speed Maglev – Representative Train

[2] See: http://www.usjmaglev.com/USJMAGLEV/News_Release.html

4.4 Technical Characteristics of Steel Wheel Technology

North American passenger train operators have benefited from the extensive global technology development as railways around the world have upgraded their passenger systems to high-speed rail operations. Over the past few years, true high-speed rail has become a reality in North America with the introduction of Bombardier's Acela technology, shown in Exhibit 4-9, in the U.S. Northeast.

Exhibit 4-9: Acela Train Set

The next section of the report will discuss the technical characteristics of steel wheel (rail) technology that affect its ability to operate in Colorado corridors. Issues of FRA regulatory compliance, required power and traction will be addressed. Section 4.5 will address similar issues for maglev technologies.

4.4.1 FRA Regulatory Requirements

Under current regulation, compliance with U.S. Federal Railroad Administration (FRA) equipment standards is required to operate rail equipment on tracks that are connected to the US mainline freight rail network. If the tracks are not connected then the U.S. Federal Transit Administration (FTA) regulations may apply instead.

The FRA regulations may apply if there is a need to co-mingle operations with freight trains and/or RTD commuter rail equipment over some portion of the Colorado intercity rail network. It has been conducted so the regulatory issues associated with a possible Colorado equipment procurement can be understood, along with the current risks and uncertainties that are associated with that process. A review of the FRA regulations reveals two basic kinds of safety rules:

- **Basic safety rules** address requirements such as window glazing, configuration of car exits, interior lighting, and securement of baggage. These apply uniformly to all equipment, regardless of speed. These rules have been adapted from aviation as well as historical rail practice, and would likely apply to all types of vehicles, including Maglev.

- **The Tier I and Tier II rules** relate to specific "buff" strength requirements for rail vehicles that are intended to operate on the national freight and passenger rail network. Tier I standards apply to vehicles designed to operate at speeds up to 125 mph. More stringent Tier II standards apply above 125 mph to 150 mph. The FRA has not yet issued specific standards for trains operating above 150 mph.

Basic safety rules apply to all passenger equipment, since the FTA as well as the FRA enforces these regulations. These rules would still apply to non-compliant rail vehicles as well as to Maglev and novel technologies.

FRA's Tier I and II rules have been controversial among some equipment manufacturers, who call into question the necessity of the regulation. However, another consideration is the economics of relatively small lot production of a customized product. Because fixed engineering and tooling costs have to be spread over the number of units produced, a sizeable (e.g., 50+ trains) equipment order is needed to obtain a reasonable unit cost for a customized train.

In terms of understanding Colorado's implementation options, it should be noted that California is planning a new high-speed rail system that would operate on dedicated track at speeds up to 220 mph, and they are planning to request a waiver from the FRA to operate non-compliant trains. However, the issues involved are complex. It is not clear at this time whether California will actually prevail in their effort to obtain the waiver. Because the outcome of the California waiver application has not yet been decided, there is still some risk associated with assuming that it will be granted.

For the record, California's current position on the issue of FRA compliance is:

> "Although compatible, there are significant differences in the approach to safety and technical requirements between modern high-speed train systems and the state and federal regulations that govern existing railroad equipment and operations in California. The responsible regulatory agencies include the FRA who seeks assurance that the same or greater level of railroad safety is provided as required in the U.S. Code of Federal Regulations (CFR), and the California Public Utilities Commission (CPUC) who is responsible for the safety and reliability of the state's electrical system, and for public railroad safety. The requirements within the Code of Federal Regulations are planned to be addressed by an FRA Rule of Particular Applicability (RPA) specific to the California High-Speed Train System. The RPA will address both dedicated high-speed routes and shared-track conditions. CPUC requirements regarding electrical system safety is anticipated to be addressed via their waiver process. It is important to note that the fully grade-separated feature of the California High-Speed Train alignment addresses many of the public safety concerns of both agencies.
>
> "One of the key technical differences between successful high-speed train technology and current U.S. regulatory requirements governing passenger trains is the trainset specification. Current U.S. trainset regulations are based more on a "crash worthiness" approach to safety, while a "collision avoidance" philosophy is used to design high-speed train systems in Asia and Europe. Due to this differing approach to system safety, the Code of Federal Regulations

currently requires all existing U.S. passenger trains to be at least twice as strong than the lightweight vehicles used in European and Asian high-speed trains. In order to meet this strength requirement, high-speed train manufacturers would have to structurally redesign their trains, adding significant development time and cost, resulting in higher costs to the Authority, but with uncertain effect on the ultimate safety of the operation. Such a redesign would make high-speed rolling stock heavier, require more energy for the same speed, and jeopardize the low axle loadings that effectively enable the high-speeds, low operating and maintenance costs, and positive cash flows enjoyed by high-speed train operations in Europe and Asia. In addition to being more costly to purchase and operate, heavier equipment will likely cause changes in other system components such as track or bridges and result in higher maintenance costs and shorter replacement cycles. In summary, it is unlikely that high-speed trainsets meeting current U.S. standards can be economically built and successfully operated at the 220 miles per hour speed targeted for the California High-Speed Train system.

"Trainset concerns are higher where the relatively light-weight high-speed trains might share track with much heavier conventional U.S. passenger trains. Shared track is being considered where existing tracks are available and a dedicated high-speed line is prohibitive due to environmental impacts, right-of-way impacts, and costs. Similar to railway systems in Asia and Europe, the California High-Speed Train System includes two short segments (Los Angeles to Anaheim in Southern California and Caltrain in the Bay Area) which are currently expected to share track with conventional rail providing a cost-effective way of bringing high-speed train service directly into major metropolitan business centers. In both segments, the high-speed trains will operate at reduced speeds no greater than 125 miles per hour. Passenger safety on high-speed systems, both dedicated track and shared-track, is achieved by a train signaling system that provides positive train control and separation, and automatic train-stop capabilities to monitor train traffic and avoid collisions. Crash-energy management components are also incorporated into the high-speed train design in the unlikely event of low speed collisions. It should be noted that high-speed train travel is the safest form of transportation in the world and that proven systems in Asia and Europe have been operating safely in shared-track conditions for over 40 years." [3]

The California system, as elsewhere, sees the need for sharing track and right-of-way with conventional trains on the final approach to urban centers. By assuming that they will be able to obtain an FRA waiver, California is basically assuming that the FRA will set aside the existing Tier I and II regulations and permit co-mingling of compliant and non-compliant trains on the same tracks. This creates a substantial implementation risk to their system, since there is no known historical precedent for this assumption.

Further, California's stance on the use of non-compliant equipment has exacerbated its freight railroad relations. The freight railroads are understandably concerned about the potential liability implications for allowing the operation of non-compliant trains on or near their rights-of-way.

[3] See: http://www.cahighspeedrail.ca.gov/images/chsr/20081118150606_Source Document 6 Engineering Elements.pdf, pages 5 and 6 of 28.

Union Pacific[4] has summarily concluded that "it was not in Union Pacific's best interests to permit any proposed high-speed rail alignment on our rights-of-way" and in item 12 that "HSR must comply with all applicable FRA regulations."

For Colorado, to mitigate the project risk associated with the use of non-compliant equipment, TEMS has suggested that FRA compliant equipment be used. Such equipment could operate without restriction. In the *Existing Conditions Report*, TEMS conducted benchmarking analysis that suggested a probable weight penalty for FRA compliance would be only in the 5-10 percent range. The FRA reviewed this analysis and concurred with it[5]. An additional 5-10 percent in vehicle weight has been built into the operating cost basis for the Colorado system but positive financial operating results are still projected for the system.

Specifically, under current regulation, the FRA rules require:

- **Buff Strength:** The amount of compressive force that a railcar or locomotive must withstand without permanent deformation. For passenger coaches, Tier I and Tier II require the same buff strength, 800,000 lbs. For locomotives, 800,000 lbs. are needed under Tier I, but under Tier II locomotives need 2,100,000 lbs. buff strength.
- **Crash Energy Management:** This performance specification kicks in only for Tier II equipment, but does not per se require a heavier vehicle. The rule addresses such things as crush zones and failure modes that are designed for the safety of the occupants. Crash Energy Management principles are already built into the design of most modern rail vehicles.
- **No Occupied Lead Cars:** The Crash Energy Management regulation prohibits passenger-occupied lead cars in Tier II equipment as can be expected with Push Pull train designs. However, if an EMU technology were chosen, the lead car could still be used, for example, for baggage compartment space.

The main difference between European and US regulations lies not with the Tier II requirement, but rather the 800,000 lbs. Tier I buff strength. This requirement is already substantially greater than that needed for railcars overseas, which typically require only 440,000 lbs compressive strength[6]. Under current regulations, European or Japanese designs would have to be adapted to American conditions for operations at *any* speed, not just for *high-speed* service.

Some potential high-speed train manufacturers are aware of this issue and have put significant effort into developing U.S. compliant equipment. For example, the Talgo T-21 train was proposed as a fully Tier I compliant train suitable for operation in the United States, with no more than a 10 percent weight penalty over its European counterpart[7]. In addition, Bombardier has already

[4] See letter from Union Pacific to the California High Speed Rail Authority dated February 23, 2009 http://home.pacbell.net/mbrown5//UPRR/UPRR-2-23-09.doc

[5] Personal correspondence, Federal Railroad Administration, November 6, 2008

[6] Some European railways (British and German) are however specifying vehicle strengths above (in some cases significantly above) those required in the UIC codes. Source: Federal Railroad Administration, personal correspondence, November 6, 2008.

[7] This 10 percent weight penalty has been validated by a direct benchmarking study, See Appendix E of the *Existing Conditions Report*, and by recent correspondence with Talgo. It has been further validated by Federal Railroad Administration studies that

produced a Tier II compliant passenger locomotive and coaches (the Acela). These coaches, which are very heavy (70 tons) weigh more than their European counterparts not because of the FRA regulations, but because of the use of carbon steel (rather than stainless steel or aluminum) in their construction. Because of this, the U.S. Acela is about 45 percent heavier than a comparable TGV.

In addition, the Acela's internal seating configuration is low-density leading to unfavorable benchmark comparisons with the capacity of an equivalent TGV. As built, Acela weighs 567 metric tons with six passenger cars, for a capacity of only 328 seats[8]. In contrast, TGV Atlantique weighs 484 metric tons for ten cars with a capacity of 485 seats.[9] It is worth noting, however, that the latest European designs could likely reduce this weight penalty to 10-15 percent and that the internal seating arrangement could be tightened up for higher capacity

The economic issue with the FRA Tier I and II regulations would appear not to be the technical feasibility of customizing equipment to comply with the rules, but rather the size of any order. A European or Japanese manufacturer simply needs a large enough order to make it worthwhile building a U.S. compliant train. The FRA agrees with this assertion[10].

4.4.2 Rail Acceleration Curves

This section will assess the ability of steel-wheel technologies to meet these unusual requirements for service in the I-70 corridor in Colorado. Any of the alignments that are selected for the I-70 corridor will have very large gradients that are way beyond any typical high-speed corridor. While maglev trains have the ability to deal with the 7 percent gradients that are common along the I-70 corridor, steel wheel trains are more restricted by gradients. Fortunately the latest generation of high-speed trains has both enough power to accelerate quickly, and enough traction to climb steep gradients without spinning wheels.

In terms of assessing rail technology, there are two main criteria that need to be considered: type of propulsion and source of power:

- **Type of Propulsion: Trains can be either locomotive-hauled or self-propelled.** Self-propelled equipment has each individual railcar powered whereas conventional coaches rely on a separate locomotive to provide the power. This is especially relevant in Colorado with its steep grades, because the issue of adhesion of a steel wheel on a steel rail limits the maximum amount of force that can be transmitted without spinning wheels.
- **Source of Power: Trains can be either diesel or electrically-powered.** Diesel or electric power can be used with either the locomotive hauled or self-propelled equipment options. (Turbine power has also been considered for high-speed trains, but does not offer any clear advantage over diesel at this time.)

estimated the weight penalty for Tier II compliance to be in the 6-7 percent range relative to comparable European practice. Source: Federal Railroad Administration, personal correspondence, November 6, 2008.

[8] See: http://www.railfaneurope.net/tgv/acela.html

[9] See: http://www.railfaneurope.net/tgv/formations.html

[10] Source: Federal Railroad Administration, personal correspondence, June 11, 2009.

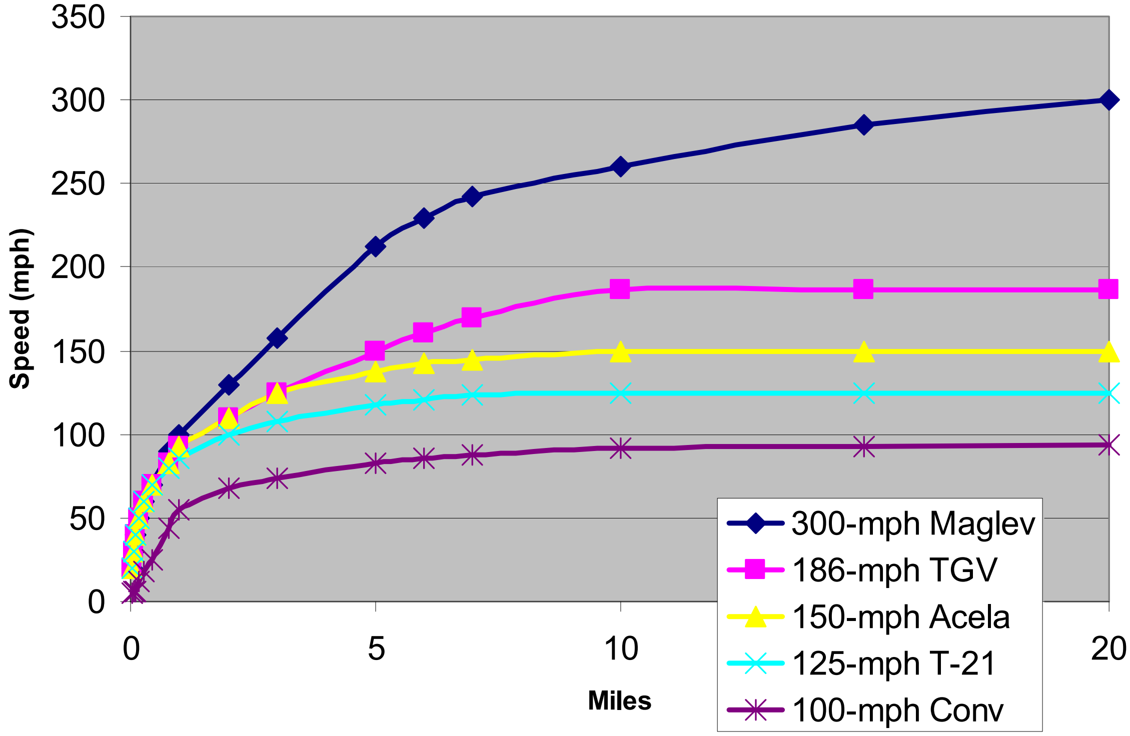
As a rule, diesel locomotives are heavier than electric locomotives, because of the weight of the engine and also of the fuel. Electric equipment also can be more powerful since it is not limited by the on-board generating capacity of the engine. Train performance curves for representative equipment types are shown in Exhibit 4-10. The curves reflect the acceleration capabilities of various rail technologies starting with conventional locomotive-hauled trainsets (the P42 option) up through Maglev.

Purpose-built diesel high-speed trains, such as the Talgo T-21, can offer considerably improved performance over conventional diesel trains that are based on freight-derived designs. Conventional locomotive-hauled diesel trains have a practical top speed of about 100 mph, whereas purpose-built high-speed diesel trains can achieve 125 mph to 135 mph and can accelerate much faster. As can be seen in Exhibit 4-10, conventional diesel-powered trains are barely capable of reaching 100 mph and operate most practically at speeds of 79 mph or less. For speeds above 135 mph, electrified trains are needed. Some European diesel-powered 125-mph trains offer up to 500 seats, but if U.S. safety regulations were applied, the added vehicle weight (10-15 percent) would likely reduce the practical capacity of such trains down to 400-450 seats.

Up to its top speed of 150 mph, Exhibit 4-10 shows that the Acela accelerates as fast as a TGV due to its very high power to weight ratio. This implies that the Acela could go even faster if it were given a straight enough track to run on. Acela's weight penalty however, expresses itself in terms of a higher operating cost and lower revenue generating capacity than a comparable TGV. However, this is not a serious problem in the special environment in which the Acela operates. Catering primarily to business clientele, the Acela is able to attract revenue yields exceeding 60¢ per mile. The train would need to be modified to be cost effective at the more typical levels of revenue yield obtainable in other corridors such as in Colorado, 30-40¢ per mile. The electric Eurostar train and Korean TGV offer 794 seats and 935 seats[11], respectively, which represent practically the upper limit of today's rail technology.

[11] See: http://www.railfaneurope.net/tgv/formations.html

Exhibit 4-10: Train Type/Technology Acceleration Curves: Straight and Level Track

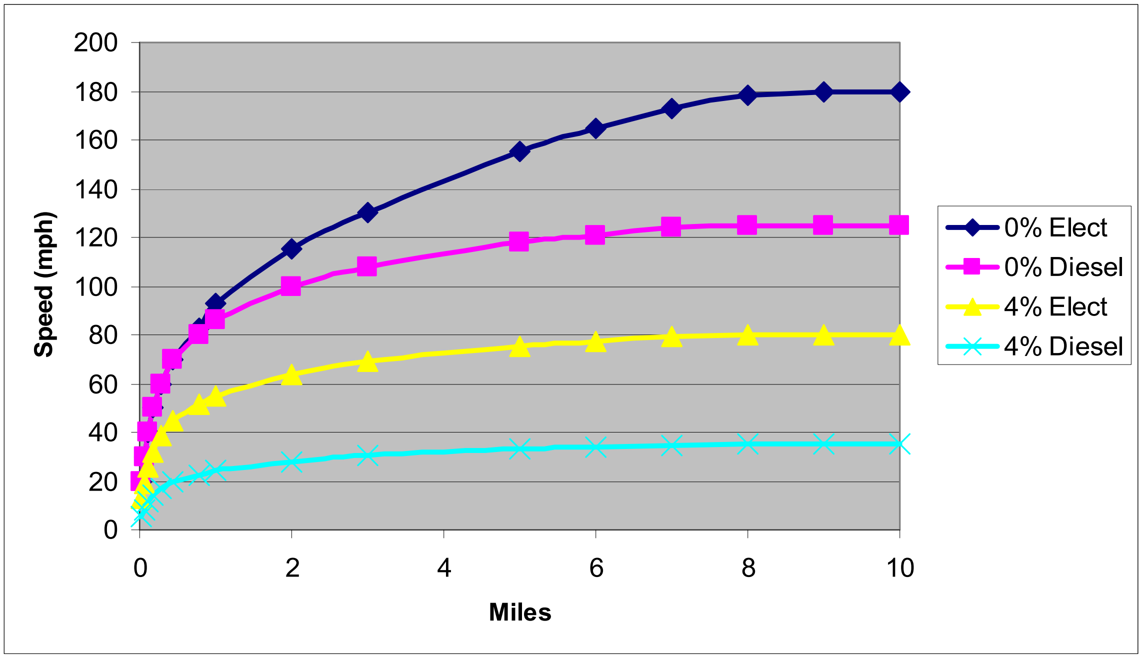


Source: TEMS *LOCOMOTION*™ Equipment Database showing typical technology performance parameters, as developed and validated over the course of previous rail studies.

Exhibit 4-11 compares the performance of the electric ICE train versus the diesel Talgo T-21 on a 4 percent grade versus on level track. Diesel equipment avoids the cost of the overhead electric wires, but because of their higher power, Exhibit 4-11 shows that electric trains give better performance at high-speeds and up steep grades. (The Talgo T-21 is also available in an electric version. The purpose of this comparison is to illustrate the difference between generic diesel and electric locomotive-driven technology on mountain grades, not to compare the performance of specific manufacturer's equipment.)

- The electric locomotive-hauled ICE train can achieve over 180 mph on level track but is reduced to 80 mph on a 4 percent grade.
- The diesel T-21 can achieve 125 mph on level track but is reduced to 35 mph on a 4 percent grade.

Exhibit 4-11: Power System Performance, Speed versus Grade



Source: Calculations detailed in Appendix C of the *Existing Conditions Report* comparing the performance of a diesel hauled T-21 to an electric ICE train.

From this, it can be seen that electric trains are really the only viable option for high-gradient rail lines. A diesel T-21 can perform adequately up to a maximum gradient of 2-3 percent but beyond this, electric power is needed. This is the reason why diesel options were screened for the I-70 corridor very early in the evaluation process, and only electric power options have been carried forward.

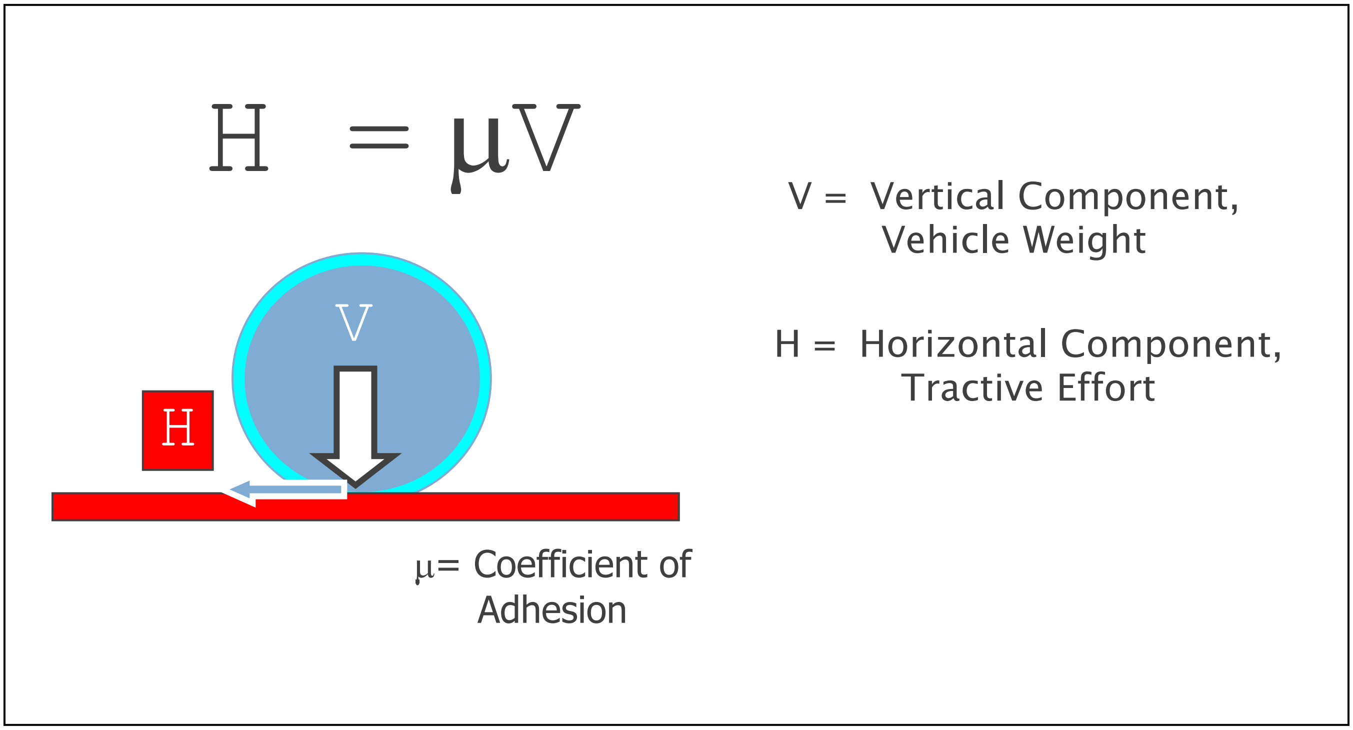
4.4.3 Rail Tractive Effort or Adhesion

A second issue is that of adhesion. Adhesion refers to the maximum amount of tractive effort, or pulling force that can be generated without spinning the wheels. Exhibit 4-12 states an equation that says the maximum pulling force that can be exerted by a wheel, or Tractive Effort (H), is equal to the amount of weight on the wheel (V), multiplied by the coefficient of adhesion(μ.) To increase the pulling force of a wheel (H) you can either add more weight (V) or else improve the friction (adhesion) coefficient (μ) between the wheel and rail. Conservatively, a coefficient of adhesion μ = 15 percent can be assumed for rail applications. For example, if the weight on the wheel (V) is 1,000 lbs. with a Coefficient of Adhesion of 15 percent, then the maximum pulling force (H) that could be generated is 150 lbs.

- Obviously, adhesion is not an issue for Maglev trains and has been cited as a major advantage of that technology.
- For rail equipment, the adhesion question determines whether a train set should be locomotive-hauled or self-propelled. Sometimes it is less expensive to have separate

locomotives and cars. Self-propelled units, however, have much better adhesion. Since traction motors are distributed along many more driving axles, and the weight of the train itself contributes to adhesion, self-propelled trains can have more power and climb steeper grades than locomotive-hauled trains.

Exhibit 4-12: Definition of Coefficient of Adhesion



Source: http://en.wikipedia.org/wiki/Traction_(engineering)

Using two real-world train sets as examples, Exhibits 4-13 and 4-14 show the maximum tractive effort for two versions of the German ICE train. Both are powerful electric trains, the 1st generation ICE train is locomotive-hauled, whereas the 3rd generation ICE train is a self-propelled Electric Multiple Unit (EMU) train that has traction motors under every car. Applying the tractive effort equation to these two trains, it can be seen that their hill-climbing capability is vastly different:

- The 1st generation ICE-1 train in Exhibit 4-11 has two lightweight locomotives, which sharply limit this train's hill climbing capability, because only the locomotive's weight is available to provide tractive effort. The ICE-1 cannot manage even a 4 percent grade without spinning wheels. A possible solution may be to make the locomotive heavier; this is done for freight locomotives but is not appropriate for a high-speed passenger locomotive, because the combination of high-speed and weight can be too damaging to the tracks. By reducing the number of coach cars, the ICE-1 could barely go up a 4 percent grade, which is considered the practical upper limit for a locomotive-hauled train.

- In contrast the 3rd generation ICE-3 train in Exhibit 4-12 can manage a 7.5 percent grade with only half the axles powered and it could manage a 15 percent grade with all axles powered. This difference is because the total weight of the train including passenger coaches, rather than just the weight of the locomotive, is available to contribute to tractive effort.

Exhibit 4-13: 1st Generation Locomotive-Hauled ICE-1 Train – Maximum Gradient Capability

- Weight of two locomotives: 187 tons
- Total train weight: 1,656,480 lbs. for 460 seats
- Assume μ = 15% *(A safe assumption for wet rails)*
- Tractive Effort Capability =
  187 x 2000 x 15% = 56,100 lbs.
- **Maximum Grade = 56,100 / 1,656,480 = 3.4%**

Exhibit 4-14: 3rd Generation EMU ICE-3 Train – Maximum Gradient Capability

- Train Weight: 1,000,000 lbs. (500 tons) for 404 seats
- 50% of axles powered
- Assume μ = 15%
- Tractive Effort Capability =
  500 x 2000 x 50% x 15% = 75,000 lbs.
  (could be 150,000 lbs. if all axles were powered)
- **Maximum Grade = 75,000 / 1,000,000 = 7.5%**
  (**<u>could make 15%</u>** if all axles were powered)

The ICE-1 shows the limitations of locomotive hauled trains. Electric locomotives tend to be very lightweight for the amount of power they produce. This can lead to difficulties with adhesion and spinning wheels, especially on wet rail. A good solution is to distribute the traction motors underneath the train, as in a DMU or EMU, so the weight of the train itself can contribute to traction.

Where gradients can be held to 4 percent or less, a locomotive-hauled electric train can work. The train's grade-climbing capability could be improved by adding a set of powered axles under the first or last coach car as the Eurostar train does, or by reducing the number of passenger coaches.

A T-21 diesel train could go up a 2 percent grade at about 65 mph. A diesel-powered train would not have problems with adhesion because of the added weight of the diesel engine, but because of its limited power, speed would be reduced to 35 mph on a 4 percent grade and only 21 mph on a 7 percent grade. These speeds are not auto-competitive and would probably not be acceptable in the marketplace. This rules out the diesel for grades much above 2 percent.

In summary, it can be seen that the following rail equipment options are available for Colorado corridors, depending upon the gradients. All of these options would be capable of maintaining a 60-mph speed climbing the grade:

- If gradients can be held to 2 percent or less, then any equipment option, including diesel, electric, locomotive hauled or self-propelled (DMU or EMU) train could be considered for the corridor.
- Any electric train option, either locomotive-hauled or EMU, could have enough power to maintain 60 mph on a 2-4 percent gradient.
- Only the EMU and Maglev option will work for gradients in the 4-7 percent range. An EMU train with 50 percent axles powered (like the ICE-3) could maintain 60 mph up a 4 percent grade whereas in theory an EMU with all axles powered or with a separate Power Car (electric locomotive) added to each end of the train could maintain 60 mph up a 7 percent grade, curvature permitting. (This would be a very powerful train. For perspective, this same EMU with all axles powered could do more than 220 mph on level track.)

4.5 Maglev Capabilities

Exhibit 4-15 details the technical capabilities of the Transrapid Maglev. In contrast with mechanical solutions used by traditional rail systems, Maglev technology uses innovative non-contact, electromechanical solutions to achieve traction, guidance and propulsion functions.[12] As shown in Exhibit 4-16, high grades are likely to reduce performance.[13]

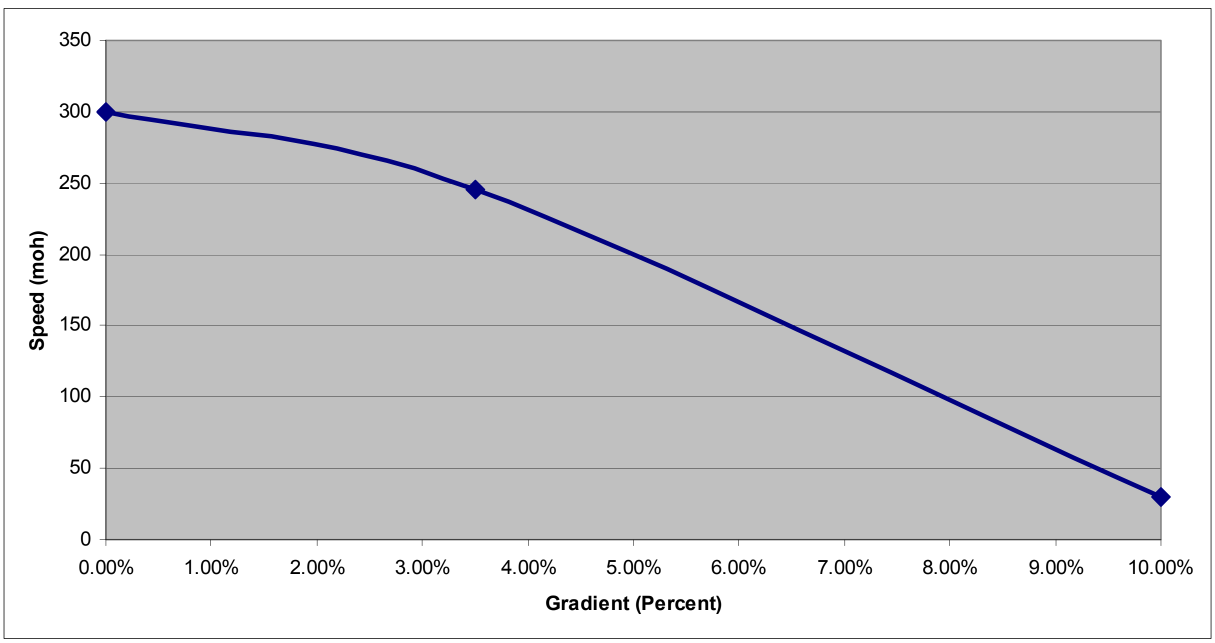
[12] Baltimore-Washington MAGLEV, Project Description Report, MTA, 2000
[13] See: http://www.crrel.usace.army.mil/techpub/CRREL_Reports/reports/maglev/Chap1+2(p1_16).pdf . Exhibit 4-16 shows that the Transrapid system does offer a 10 percent grade climbing capability, but it can maintain only 30 mph up this grade; in contrast, the Transrapid could maintain 245 mph up a 3.5 percent grade. The RMRA Peer Review has noted that this result was derived from a 1992 government study based on the Transrapid TR07 prototype vehicle, which was retired in 1999. Although the study is the only one found that directly addresses Transrapid's ability to climb grades, it is considered out of date. The curve was based on an assumed guideway configuration, but if the power provided by the guideway could be increased, there would be no strict relationship between speed and grade owing to the off-board power supply characteristics of the non-contact maglev technology.

Exhibit 4-15: Technical Specifications for Transrapid Maglev

Operating Parameters	Speed	Distance	Time
Design Speed	340 mph		
Operating Speeds:			
Rural areas	300 mph		
Urban areas	150 mph		
Acceleration	0- 60 mph	0.27 miles	31 s
	0- 120 mph	1.07 miles	62 s
	0- 180 mph	2.70 miles	104 s
	0- 240 mph	5.48 miles	159 s
	0- 300 mph	11.99 miles	278 s
Braking Performance	0- 60 mph	0.28 miles	58 s
	0- 120 mph	0.98 miles	85 s
	0- 180 mph	2.29 miles	115 s
	0- 240 mph	4.18 miles	146 s
	0- 300 mph	6.51 miles	176 s

Source: Baltimore-Washington Maglev Study, June 2000, see Appendix B.

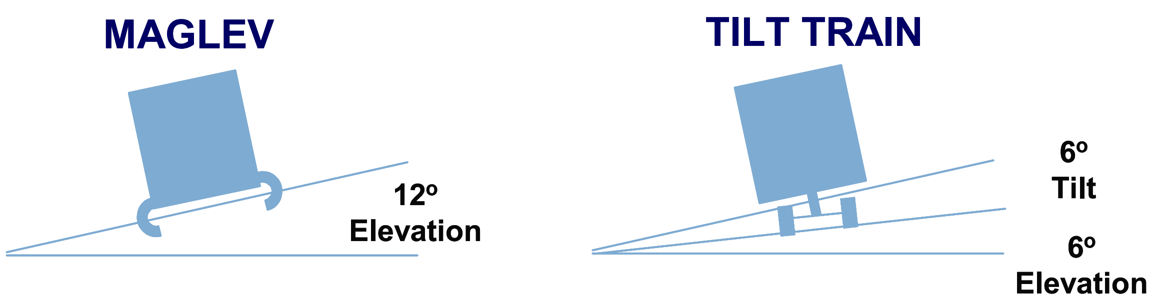
Exhibit 4-16: Transrapid Maglev – Equilibrium Speed as a Function of Gradient



Source: http://www.crrel.usace.army.mil/techpub/CRREL_Reports/reports/maglev/Chap1+2(p1_16).pdf

As shown in Exhibit 4-17, Transrapid's tilting capability of 12° is approximately equivalent to that of a tilting train which can operate with 6" of tilt plus 6" of superelevation. (Superelevation is the physical tilt of the track in the curve whereas tilt is the equivalent additional banking that is provided by the vehicle.) As a result, Transrapid would be expected to have about the same speed limit in curves as a tilting train. This would reduce the advantage of Maglev over rail unless a very straight alignment could be built.

Exhibit 4-17: Comparison of Tilt Capabilities – Maglev vs. Tilt Train



Because of its LIM propulsion, the proposed 125-mph Colorado Maglev has to carry its power transformers and linear motors on board, as compared to the LSM motor of Transrapid, which is built into the guideway. Accordingly the LIM system is limited by the capabilities of the power equipment that is on board the vehicle, which also necessarily adds to the vehicle weight. Even so within the lower speed range up to 125 mph it has been assumed that the acceleration and braking performance of these two maglev vehicle types would be comparable. The LIM vehicle was assumed to consume more electrical power than the LSM vehicle; however, this is due both to the greater weight and lower electrical efficiency of the LIM vehicle.

4.6 Matching Equipment Capabilities to Representative Routes

A set of representative routes has been defined in Chapter 3. For the I-70 corridor, these options consist of "Constrained" or Highway Right-of-Way options as compared to an "Unconstrained" alignment that is allowed to deviate from the highway right-of-way. For I-25, the options consist either of existing rail or greenfield options.

Given this set of representative routes, the next step in network formulation was to pair the routes in some manner based on the basic capabilities of train technologies. As described previously:

- 110-mph diesel technology can only handle grades up to about 2 percent without severe degradation in performance.
- Locomotive-hauled electric trains can handle 2-4 percent gradients.
- Self-propelled Electric Multiple Unit (EMU) equipment is required for gradients in the 4-7 percent range. In order to climb a 7 percent grade at any reasonable speed, it is essential either to power all the axles of the EMU or else to provide supplementary power cars or

electric locomotives to the train consist. On these heavy grades, locomotives could not haul the train up the hill by themselves but could still provide a significant power boost to improve adhesion capability and enable the train to go faster.

- Maglev trains are also capable of operating over 4-7 percent gradients.

For evaluation purposes, three main network options have been constructed based on the capabilities and limitations of equipment types. These networks were constructed as logical combinations of alignment options based on equipment capabilities. They are described as follows:

- **110-mph Rail on I-25 only**. This option uses diesel locomotive-hauled trains to offer passenger rail service on upgraded conventional rail tracks paralleling I-25. This network cannot be extended up I-70 since the diesels are not able to climb even 4 percent grades at any reasonable speed.
- **I-70 Unconstrained**. This consists of the unconstrained I-70 alignment that uses the Clear Creek canyon to bypass the heavy gradients on Floyd Hill. This I-70 network option limits grades to 4 percent. The unconstrained I-70 alignment is coupled with conventional rail on the I-25 corridor thus can be worked using electric locomotive-hauled trains with coach cars. It also uses several segments of existing rail alignment for extensions west of Eagle County Airport that are compatible with these equipment capabilities.
- **I-70 Right-of-Way**. This consists of the I-70 Right-of-Way alignment with grades up to 7 percent. It needs very powerful EMU equipment to climb the hill. This powerful equipment is also the best for maintaining high-speed on a new I-25 greenfield. The I-70 Right-of-Way alignment has therefore been coupled with greenfield alignments on I-25 and west of Eagle Airport, to make the best possible use of this powerful equipment. This network was assumed for both the Electric Rail EMU and Maglev equipment options.

These pairings of equipment to routes are only for evaluation purposes in the initial analysis in this feasibility study. For example, self-propelled EMU equipment could be used on any alignment in the network. The same is not true for other kinds of equipment; however, since an electric locomotive-hauled train with conventional coaches is unable to operate on the I-70 Right-of-Way alignment because of the steep grades. Similarly, diesel technology can go up the mountain only at a very low speed that would be unacceptable in the marketplace.

The unconstrained versus I-70 right-of-way networks are shown in Exhibits 4-18 and 4-19. The route and technology pairings assumed for evaluation purposes are shown in Exhibit 4-20. Exhibits 4-21 and 4-22 provide technical definitions of terms that have been used in this chapter and throughout the report, defining equipment-related terms, and route and alignment-based vocabulary. The “I-70 Highway ROW Alignment” described in Exhibit 4-22 for the Constrained network evaluation shown in Exhibit 4-19, and is based on the I-70 EIS alignment developed by J.F. Sato. This alignment was used for both the El Rancho and Vail Pass segments of the route. From Floyd Hill to Loveland Pass, an “I-70 Highway Corridor Alignment” was developed as part of the Unconstrained network (Exhibit 4-18) evaluation. This does not preclude the possibility that an “I-70 Highway Corridor Alignment” incorporating lower 4 percent grades may be developed in a future study of the El Rancho or Vail Pass segments.

Exhibit 4-18: Unconstrained I-70 Network with Existing Rail in I-25 and West of Eagle

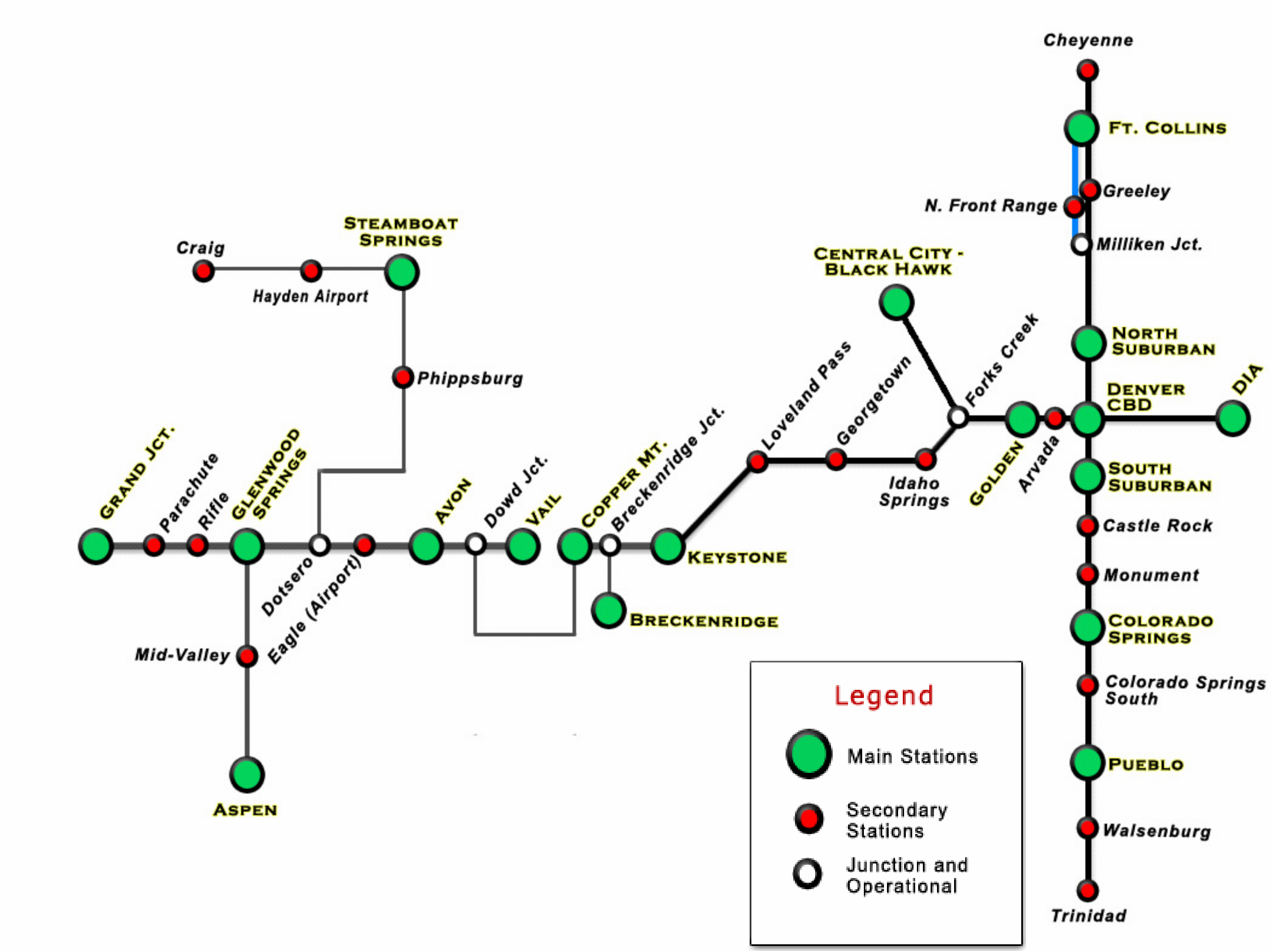


Exhibit 4-19: I-70 Right-of-Way Network with Greenfield's in I-25 and West of Eagle

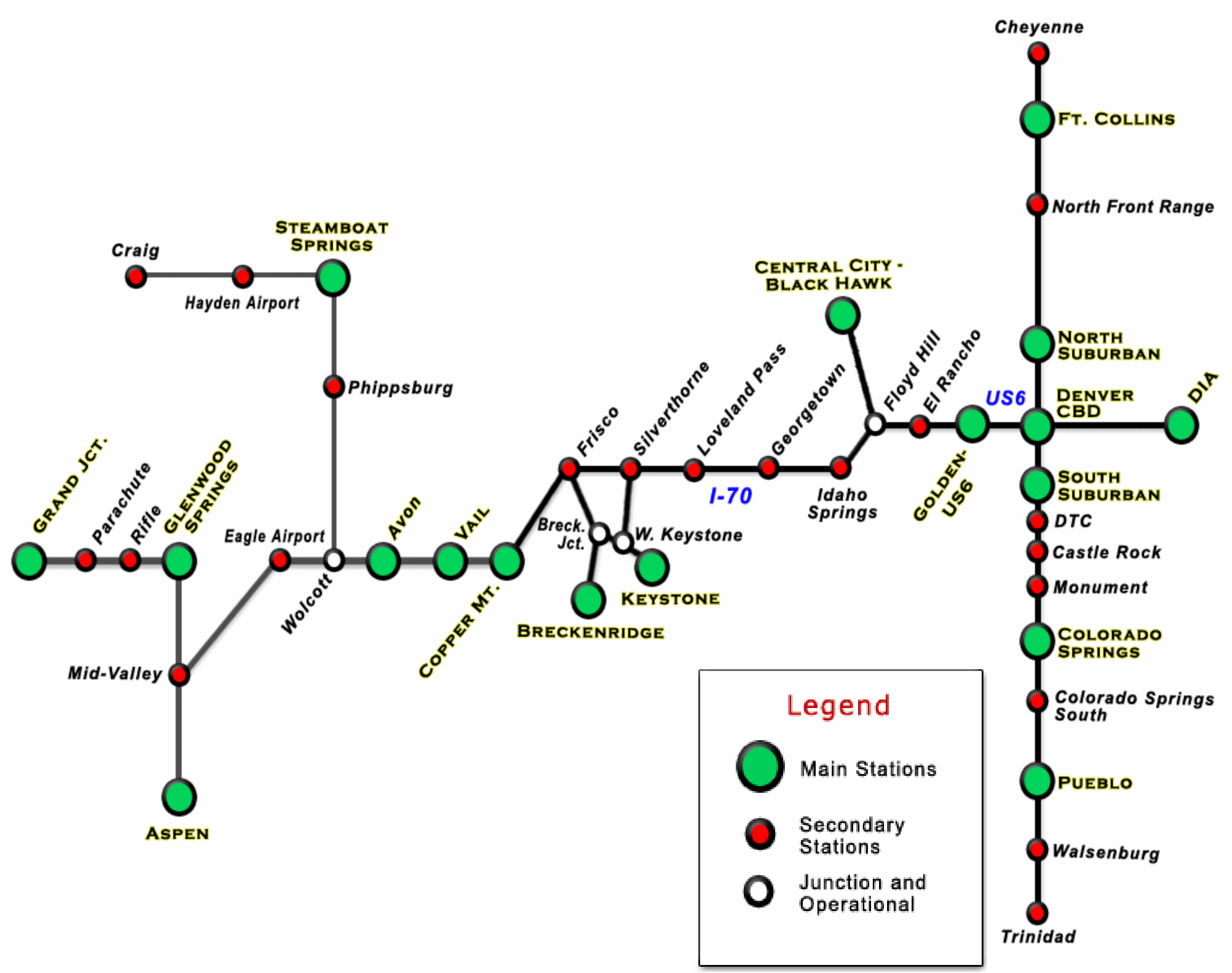


Exhibit 4-20: Equipment and Route Pairings Matrix

Corridor	I-25 North Wyoming Border to North Suburban Station	I-25 South New Mexico Border to South Suburban Station		I-70 East Golden to Avon	I-70 West Avon to Grand Junction
Alternative					
1					
1 (a)	Diesel, 79-mph Track Speed Existing Rail with R2C2*	Diesel, 79-mph Track Speed Existing Rail with R2C2		Not Applicable due to lack of power for gradients	Not Applicable due to lack of power for gradients
1 (b)	Diesel, 79-mph Track Speed Existing Rail, without R2C2	Diesel, 79-mph Track Speed Existing Rail, without R2C2		Not Applicable due to lack of power for gradients	Not Applicable due to lack of power for gradients
2					
2 (a)	Diesel, 110-mph Track Speed Existing Rail with R2C2	Diesel, 110-mph Track Speed Existing Rail with R2C2		Not Applicable due to lack of power for gradients	Not Applicable due to lack of power for gradients
2 (b)	Diesel, 110-mph Track Speed Existing Rail, without R2C2	Diesel, 110-mph Track Speed Existing Rail, without R2C2		Not Applicable due to lack of power for gradients	Not Applicable due to lack of power for gradients

*R2C2 refers to Colorado DOT's Freight Rail Relocation Study

Corridor	I-25 North Wyoming Border to North Suburban Station	I-25 South New Mexico Border to South Suburban Station		I-70 East Golden to Avon	I-70 West Avon to Grand Junction
Alternative					
3					
3(a)	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-25 Highway Corridor Alignment	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-25 Unconstrained Alignment		I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-70 R.O.W. Alignment	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-70 R.O.W. Alignment
3(b)	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-25 Highway Corridor Alignment	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-25 Unconstrained Alignment		I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-70 Highway Corridor Alignment	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-70 Highway Corridor Alignment
3 (c)	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-25 Highway Corridor Alignment	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-25 Unconstrained Alignment		I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-70 Unconstrained Alignment	I-70 PEIS Advanced Guideway System Maglev, 125-mph Track Speed I-70 Unconstrained Alignment
4					
4	Electric, Locomotive Pulled 150-mph Track Speed Existing Rail, with R2C2	Electric, Locomotive Pulled 150-mph Track Speed Existing Rail, with R2C2		Electric, Locomotive Pulled 150-mph Track Speed I-70 Unconstrained Alignment	Electric, Locomotive Pulled 150-mph Track Speed I-70 Unconstrained Alignment

Corridor	I-25 North Wyoming Border to North Suburban Station	I-25 South New Mexico Border to South Suburban Station		I-70 East Golden to Avon	I-70 West Avon to Grand Junction
Alternative					
5					
5(a)	I-70 PEIS Rail Alternative Electric, EMU Non Tilting 220-mph Track Speed I-25 Highway Corridor Alignment	I-70 PEIS Rail Alternative Electric, EMU Non Tilting Electric, 220-mph Track Speed I-25 Unconstrained Alignment		I-70 PEIS Rail Alternative Electric, EMU Non Tilting 220-mph Track Speed I-70 R.O.W. Alignment	I-70 PEIS Rail Alternative Electric, EMU Non Tilting 220-mph Track Speed I-70 R.O.W. Alignment
5 (b)	Electric, EMU Tilting 220-mph Track Speed I-25 Highway Corridor Alignment	Electric, EMU Tilting 220-mph Track Speed I-25 Unconstrained Alignment		Electric, EMU Tilting 220-mph Track Speed I-70 R.O.W. Alignment	Electric, EMU Tilting 220-mph Track Speed I-70 R.O.W. Alignment
5 (c)	Electric, EMU Tilting 220-mph Track Speed I-25 Highway Corridor Alignment	Electric, EMU Tilting 220-mph Track Speed I-25 Unconstrained Alignment		Electric, EMU Tilting 220-mph Track Speed I-70 Unconstrained Alignment	Electric, EMU Tilting 220-mph Track Speed I-70 Unconstrained Alignment
6					
6 (a)	Maglev, 300-mph Track Speed I-25 Highway Corridor Alignment	Maglev, 300-mph Track Speed I-25 Unconstrained Alignment		Maglev, 300-mph Track Speed I-70 Highway Corridor Alignment	Maglev, 300-mph Track Speed I-70 Highway Corridor Alignment
6 (b)	Maglev, 300-mph Track Speed I-25 Highway Corridor Alignment	Maglev, 300-mph Track Speed I-25 Unconstrained Alignment		Maglev, 300-mph Track Speed I-70 Unconstrained Alignment	Maglev, 300-mph Track Speed I-70 Unconstrained Alignment

Exhibit 4-21: Technology Definitions

RMRA Technology - Definitions					
Diesel, 79-mph Track Speed	**Diesel, 110-mph Track Speed**	**Maglev, 125-mph Track Speed**	**Electric, 120 to 150 mph Track Speed**	**Electric, 150 to 220 mph Track Speed**	**Maglev, 250 to 300 mph Track Speed**
Conventional Rail, FRA Compliant, Diesel Powered, Locomotive Pulled or Diesel Multiple Unit	High-Speed Rail, FRA Compliant Diesel Powered, Locomotive Pulled or Diesel Multiple Unit	Medium Speed, Non FRA Tier 1 Compliant Maglev Vehicle Vehicle and performance capability as defined by the 2004 FTA Colorado Maglev Project Study using an advanced vehicle derived from the Japanese HSST technology. It is assumed that the American Maglev and General Atomics Maglev passenger vehicles would satisfy this technology and performance category.	High-Speed Rail, FRA Compliant, Electric Powered, Locomotive Pulled or Electric Multiple Unit with Tilt	Very High-Speed Rail, FRA Compliant, Electric Powered, Locomotive Pulled or Electric Multiple Unit, with and without Tilt	Ultra High-Speed Rail, Vehicle technology and performance capability based on the Siemens Transrapid maglev vehicle technology.

Exhibit 4-22: Route Definitions

RMRA Route - Definitions					
I-25 North-South Alignments	**Existing Rail without R2C2**	**Existing Rail with R2C2**	**I-25 Highway ROW**	**I-25 Highway Corridor Alignment**	**Unconstrained Alignment**
	Rail alignment largely within the existing BNSF and UP railroad right-of-ways, but allowing freight traffic within those rights-of-way.	Rail alignment largely within the existing BNSF and UP railroad rights-of-way, with the assumption that through freight traffic is moved to a new alignment further east as evaluated in the R2C2 Study.	Not Applicable, Highway ROW unsuitable for high-speed rail.	Rail alignment completely within the I-25 highway right-of-way including, but not limited to the shoulder to shoulder actual width of the existing highway. The alignment can be on-grade, elevated or tunneled to make the best use of the highway right-of-way in order to minimize grade changes and maximize curve radii.	Rail alignment capable of being within the highway corridor alignment as defined above, but can also be on-grade, elevated or tunneled in truly "Greenfield" areas completely outside the highway corridor, including areas to the east outside the I-25 highway right-of-way and outside the freight railroad rights-of-way. This is the most unconstrained rail alignment designed to minimize grade changes and maximize curve radii and still reach the critical Front Range passenger markets.

RMRA Route - Definitions					
	Existing Rail without R2C2	**Existing Rail with R2C2**	**I-70 Highway ROW Alignment**	**I-70 Highway Corridor Alignment**	**Unconstrained Alignment**
I-70 East-West Alignments	Not Applicable, No rail infrastructure	Not Applicable, No rail infrastructure	Mostly elevated rail alignment within the current highway right-of-way. The elevated sections of the rail alignment can vary between above the right-of-way adjacent to the roadway, above the highway shoulders, above the highway lanes or above the highway median in order to minimize grade changes and maximize curve radii. The ROW alignment may include on-grade sections in areas where there is enough space in the median or adjacent to the actual highway (allowing room for snow storage) and on-grade in tunnels parallel to the current highway tunnels.	Rail alignment capable of being in the highway right-of-way as described above can also be on-grade, elevated, or tunneled in areas outside the actual highway right-of-way in order to make use of the corridor valley and hillsides to minimize grade changes and maximize curve radius. A highway corridor rail alignment will remain within the primary I-70 highway corridor and does not include adjacent highway corridor rights-of-way such as US-6, US-40, US-24 or SH-91 or any freight railroad rights-of-way.	Rail alignment capable of being within the highway corridor and highway ROW alignments as defined above, but can also be on-grade, elevated or tunneled in areas completely outside the highway corridor including adjacent highway rights-of-way and adjacent railroad rights-of-way. This is the most unconstrained rail alignment designed to minimize grade changes and maximize curve radii and still reach the critical mountain corridor passenger markets.

4.7 Summary

By a careful review of potential station locations, technologies, and potential routes, a set of preliminary alternatives were defined.

The alternatives were integrated to provide two types of route options:

- Constrained alignment, with up to 7 percent grade in I-70, and using greenfield routes in I-25. This option can only be used by the most powerful trains (220-mph steel wheel and maglev).
- Unconstrained alignment with up to 4 percent grades in I-70, and use of existing rail corridors in I-25. Electric trains can use this alignment, but diesel trains are confined to the I-25 corridor.

Six types of high-speed train technology with maximum performance speeds were considered:

- 79-mph Diesel
- 110-mph Diesel
- 125-mph Maglev
- 150-mph Electric
- 220-mph Electric
- 300-mph Maglev

These alternatives would serve up to 18 major stations and 20 secondary stations, depending on the particular route combination and technology, as shown in Exhibit 4-18 and 4-19. All the stations shown in these Exhibits have been included in the demand forecasts for each scenario. Stations were selected based on the locations of cities, towns, resorts and attractions along the route and were situated not only for the convenience of tourists, but also for the use of local residents. However, it was assumed that only half of the trains stop at the Secondary stations. The demand forecast did not assume any specific site for any station, but only assumed a certain level of modal connectivity and access time from surrounding zones. As such the station selection is generally consistent with that developed by the I-70 Coalition but perhaps allows more flexibility than the Coalition's work. Specific station sites could not be assumed for the current study because the assumed route alignments are still very preliminary, so some flexibility must still be retained to adjust the alignments due to local constraints and along with them, the proposed station sites.

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5 Operating Plans

This chapter describes the potential for rail service in the I-25 and I-70 corridors, and development of the range of alternative technology and route options. A key requirement for operating plan development is matching the capabilities of vehicles to the characteristics of each route. For example, diesel-powered trains could work on I-25, but do not have enough power to tackle steep mountain grades on I-70. This led to the early exclusion of diesel scenarios and a focus on electric rail and maglev technologies for I-70. Diesel options were evaluated for the I-25 corridor only.

A second important consideration has been interoperability, particularly the ability to provide a single-seat ride between the I-25 and I-70 corridors, since the entire Front Range corridor, not just the Denver metropolitan area, generates I-70 traffic. For compatibility with I-70, interoperable electric rail and maglev options were developed for I-25 as well. As described in the previous chapter, two alternative networks were designed for evaluation:

- An Unconstrained alignment on I-70 with maximum 4 percent gradients was paired with existing rail lines on I-25. A locomotive-hauled electric train could operate on these I-70 gradients as well as on existing I-25 rail alignments.
- A Constrained or I-70 Right-of-Way alignment (the terms are used interchangeably) was paired with a proposed greenfield alignment on I-25. The only kind of train that could give satisfactory performance on the 7 percent gradients on this alignment would be a state-of-the-art Electric Multiple Unit (EMU) train or a maglev vehicle. Such vehicles could operate at up to 220 mph or 300 mph respectively on straight and level track, but they cannot achieve that speed in the I-70 mountain corridor due to its steep grades and curves.

These combinations optimize the match of equipment to each route, but do not preclude other combinations. For example, EMU or Maglev trains could operate on any of the alignments, but they were focused on the greenfield options because those maximize the speed benefit associated with these extremely powerful trains. Also, there is some overlap between features of locomotive hauled versus EMU rail technologies. This overlap promotes the flexibility to mix and match segments from the two competing network options to combine the most practical features of each network into a single FRA Developed Option, the derivation of which will be described in Chapter 9.

The train operation analysis for each technology/ route option has focused on the following:

- Development of train running times
- Train timetable development
- Assessment of freight rail operations and their interactions with proposed timetables
- Computation of rolling stock requirements

Train timetables are determined from running times and are used to calculate rolling stock requirements. Train frequencies and the number of cars required per train are determined via an interactive process using the demand forecast *COMPASS*™ model discussed in Chapter 6.

A key tool used for development of pro-forma train schedules was the *LOCOMOTION*™ Train Performance Calculator. *LOCOMOTION*™ works in conjunction with a *TRACKMAN*™ infrastructure database to estimate train speed given various types of track geometry, curves, gradients and station-stopping patterns. The *TRACKMAN*™ database captures all the details of grades, curves, superelevation, speed limits and station locations along the line. *LOCOMOTION*™ then calculates the train running time for each route segment and sums the running times to produce a timetable. *LOCOMOTION*™ assumes a train will accelerate to a maximum possible speed and will only slow down for stations or speed restrictions due to curves, crossings, tunnels or civil speed restrictions such as grade crossings and sensitive urban areas.

The inputs for *LOCOMOTION*™ consist of milepost-by-milepost data (as fine as 1/10th of a mile) defining gradient and curve conditions along the track. For this study, these data were derived from a condensed profile for existing rail alignments and the use of field inspection data along with satellite photography and GIS mapping to develop the geometry for new routes.

In addition, as described in Chapter 4, *LOCOMOTION*™ includes a train technology database that defines the acceleration, top speed, and braking characteristics of each train technology type. The database includes many train types with varying performance characteristics, ranging from heavy freight trains all the way up through Maglev options.

The *LOCOMOTION*™ model has been calibrated on many different routes using data reflecting track geometry, station-stopping patterns, and train technology used at current speeds in today's operating environment. The results taken from *LOCOMOTION*™ are faster than the actual times, since they are based on optimized performance of trains under ideal conditions. While it is assumed that passenger trains will have dispatching priority over freight, practical schedules still need to allow 5-10 percent slack time in case of any kind of operating problem, including the possibility of freight or commuter train interference, depending on the degree of track sharing with freight.

For timetable development in this study, an additional slack time of 5 percent was added to the schedule, appropriate for a passenger operation on dedicated track. Because of the high level of investment assumed to develop dedicated passenger infrastructure, freight train interference will not pose a significant schedule reliability issue.

Timetables have been developed for each technology using *LOCOMOTION*™ with limited-stop and full stopping patterns. Train running times have incorporated a dwell time of 2 minutes at each station. (With additional time lost for slowing down before and accelerating after a station stop, usually this results in a 5-7 minute schedule impact for each added station stop. However *LOCOMOTION*™ calculates the exact impact based on the local conditions associated with each stop.)

For a direct comparison of the performance of various route options, these running time comparisons will be presented in this chapter on a corridor basis.

5.1 I-25 Corridor

Both existing rail segments and proposed new greenfield alignments were evaluated in the I-25 corridor.

- As described in Chapter 3, the northern I-25 corridor from Cheyenne to Denver, BNSF and UP railroads operate on widely separated lines. BNSF's line hugs the mountains, while UP's line lies east on the plains. Several branch lines connect the UP and BNSF main lines north of Denver, two of which were included in this evaluation. A greenfield option using I-25 right-of-way north of E-470 and a connection to Denver International Airport (DIA) is also part of this northern corridor system.
- South of Denver through Colorado Springs to Pueblo, UP and BNSF railroads share the Joint Line, which is an historical composite of the tracks of each former railroad. A new greenfield corridor option was also defined that lies east of the existing rail corridor, where the terrain is easier and more favorable to high-speed rail construction.
- From Pueblo to Walsenburg, the BNSF and UP each have a track on a shared right-of-way. At Walsenburg the UP line heads west across La Veta pass, while the BNSF continues south to Trinidad. From Walsenburg to Trinidad, only a single track exists. This segment belongs to BNSF, although the UP has trackage rights over it. A greenfield alternative would connect several miles north of downtown Trinidad and follow the existing BNSF tracks into the station.

5.1.1 North I-25 Corridor

Several route options in the North I-25 corridor were screened early in the evaluation process. For documenting the reasons why these alternatives were screened, results of the operations analysis will still be described here.

Originally a comparison of the complete BNSF versus UP routes from Denver to Cheyenne was performed. In Exhibit 5-1 and 5-2, it can be seen that the UP line via Greeley is shorter and much faster than the BNSF line via Boulder. The BNSF line serves a much more densely populated area hugging the mountains, but the alignment has numerous sharp curves with 45-mph speed restrictions, as well as constrained running through Longmont, Loveland and Fort Collins. The UP line in contrast, has straight track with few speed restrictions.

It can be seen in Exhibit 5-1 that the north end of the BNSF line from Fort Collins to Cheyenne, because it is reasonably straight, has significant stretches that could support 90-110 mph speeds. However, south from Fort Collins, this route is severely constrained starting with street running in Mason Street in downtown Fort Collins, additional restrictions in cities farther south and sharp curves. In addition, south of Longmont, the route is being incorporated into RTD's FasTracks system as its North West corridor. As a result it will be very difficult to attain auto-competitive speeds using the BNSF corridor south of Fort Collins. Therefore, the Denver-Fort Collins segment of the BNSF corridor was screened from further consideration in this study.

While the UP route is fast, it lies so far east that it misses the important travel market of Fort Collins as well as the communities along the Front Range farther south. As a result the Greeley-Cheyenne segment of the UP corridor was screened from further consideration in this study.

To develop a reasonably straight alignment with reasonable market access, a composite route was assembled using the UP line from Denver to Greeley, the Great Western Railway of Colorado (GWRCO) from Greeley to Fort Collins, and the BNSF from Fort Collins to Cheyenne. This route serves both Greeley and Fort Collins, but is longer than other route options, and it still misses Loveland, Longmont and Boulder.

In the Alternatives Alignments workshop held in November 2008, an alternative route, a Milliken option, was suggested that would use the UP line from Greeley to Fort Collins instead of the GWRCO. Developing a direct connection from the UP mainline to the Milliken branch would require construction of a short greenfield connection, roughly paralleling State Route 60, from north of Platteville to Milliken. From there, the alignment would pass west of Greeley to the I-25 / US-34 interchange just east of Loveland. At this point a proposed North Front Range station with I-25 highway connectivity would serve both Loveland and Greeley. The train would then continue following the Milliken line north into Fort Collins and then using the BNSF alignment possibly on to Cheyenne.

A key benefit of the Milliken alignment is that it adds the important Loveland population base to the system while still remaining accessible to Greeley. The proposed North Front Range station would link to shuttle bus service that was recently launched between those two cities along US-34. It would not serve Longmont and Boulder.

A greenfield option was also developed that would parallel E-470 west to the E-470 / I-25 interchange, then follow I-25 north to Fort Collins. This alternative would still serve the North Front Range station but would add a Suburban North station as well near the junction of the two interstates[1]. This proposed Suburban North location would be located far enough west to provide convenient access to Longmont and Boulder patrons.

[1] By sharing a short segment of the RTD North Metro rail corridor connecting the two highways, there is an option to co-locate this station with the RTD North Metro corridor's 162nd Street station. This would provide excellent transit connectivity and an alternative access to downtown Denver. Given the advanced status of engineering and environmental planning on the RTD North Metro corridor, it was not clear that the RTD plans could be changed to accommodate the needs of intercity rail. The capital cost was therefore developed on the basis that the intercity rail alignment stays on E-470 and I-25. If RTD were willing and able to share a portion of its rail corridor, this assumption could be changed in the future to permit co-location of the stations.

Exhibit 5-1: Speed Profile – BNSF Denver to Cheyenne via Boulder
115 miles – 1:48 Running Time – showing Severe Constraints south of Fort Collins

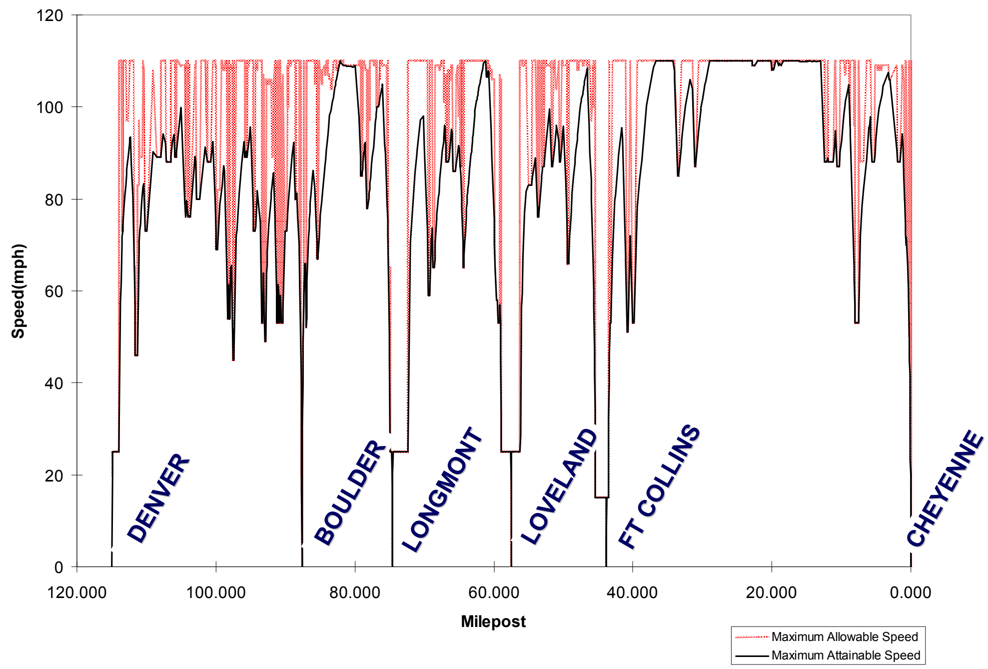
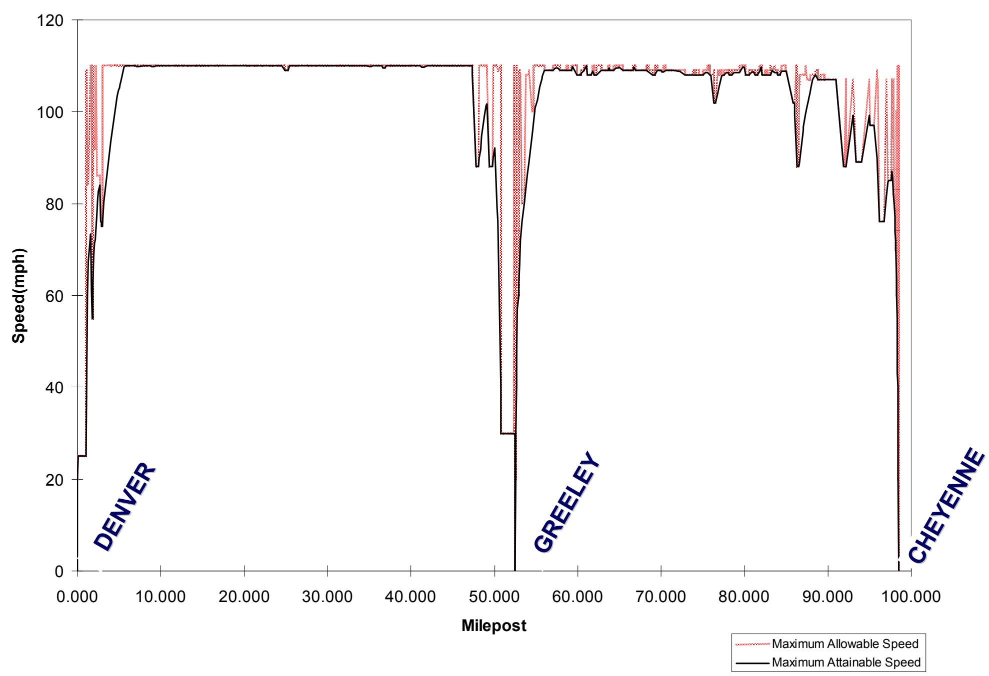


Exhibit 5-2: Speed Profile – UP Denver to Cheyenne via Greeley
98 miles – 1:05 Running Time



Exhibits 5-3 through 5-5 show the speed profiles simulating 110-mph service for the Greeley GWRCO, Milliken and 220-mph service on the I-25 greenfield. From Cheyenne to Fort Collins the GWRCO and Milliken options use the BNSF line, while the I-25 option uses the highway alignment as far as the Colorado/Wyoming state line.

The GWRCO option in Exhibit 5-3 makes stops in downtown Greeley and in Fort Collins. The Milliken option in Exhibit 5-4 stops at the North Front Range station and in Fort Collins.

The 220-mph greenfield option in Exhibit 5-5 bypasses Fort Collins at high-speed on the I-25 alignment but makes a stop just south of Fort Collins at the North Front Range station. Although a suburban Fort Collins stop could be added, the station spacing to the North Front Range station is too short for a high-speed service, so it would be recommended to combine the stops into a single station. However, the 220-mph option on I-25 adds a stop at Suburban North for the convenience of Longmont and Boulder patrons, which is not available on the UP Greeley or UP Milliken alignments.

Exhibit 5-3: Speed Profile – Cheyenne to Denver via Fort Collins and Greeley GWRCO
110-mph Diesel - 122 Miles -1:28 Running Time

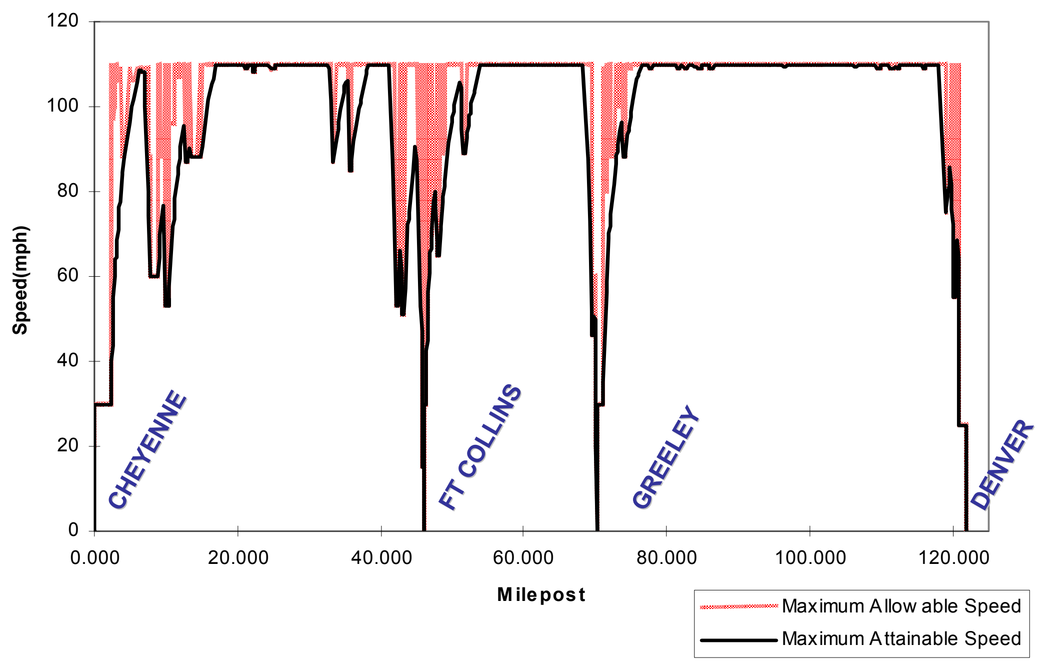


Exhibit 5-4: Speed Profile –Cheyenne to Denver via Fort Collins and Milliken
110-mph Diesel - 114 miles – 1:23 Running Time

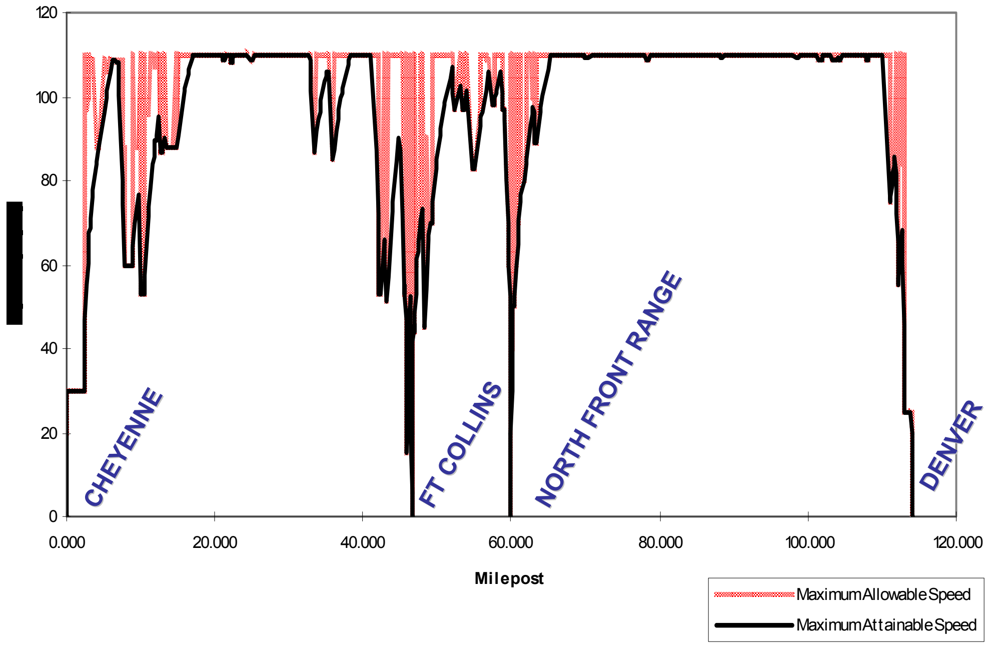
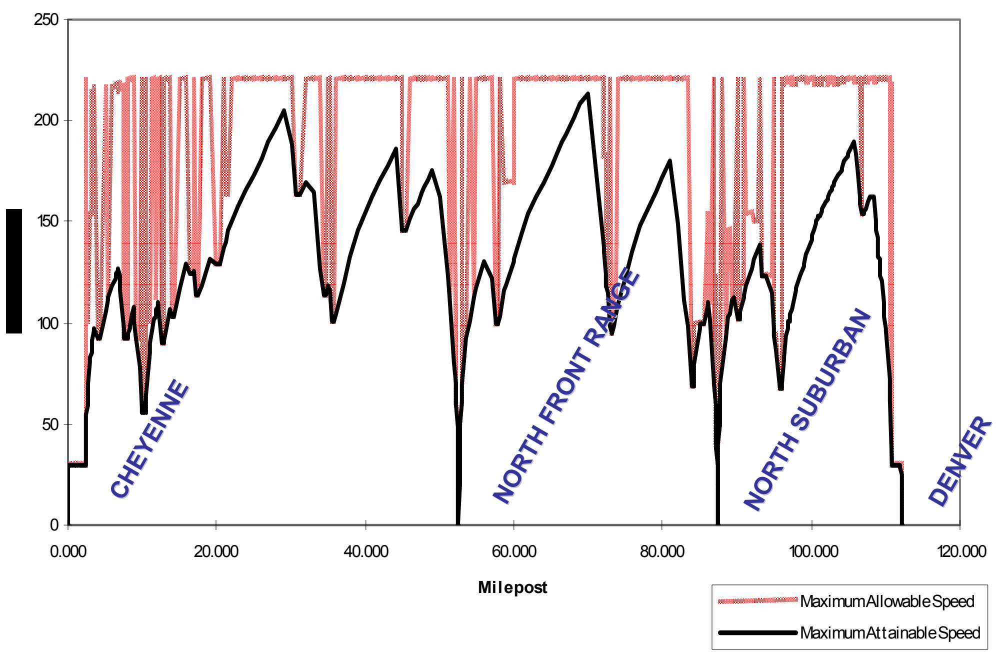


Exhibit 5-5: Speed Profile – Cheyenne to Denver via Fort Collins and I-25
220-mph Electric - 112 miles – 1:05 Running Time



The I-25 greenfield is also the route that was used for the Maglev evaluations in this study. Exhibit 5-6 shows the speed profile for a 300-mph Maglev using this I-25 Highway alignment. It can be seen that the speed profile for the 300-mph Maglev is very similar to that of the tilting 220-mph electric train, but with a higher top speed. This top speed can be sustained only for short distances because of curves and station stops along the line.

With regard to geometry, it can be said that the I-25 highway alignment is often better than available rail routes, but still impose significant operational restrictions on the true high-speed technologies. Minor curves on the highway alignment are responsible for the speed restrictions that must be applied to both the 220-mph rail and 300-mph maglev technologies.

In the train performance simulation, in many places the speeds of the maglev and electric train are identical because of curves. Even so, because of its superior acceleration as well as higher top speed, the Maglev could save up to five minutes over the electric train on this route.

The results of the train performance simulations for the I-25 corridor north of Denver are summarized in Exhibit 5-7. These show that the running times for the Milliken existing rail option versus the I-25 greenfield are within minutes of one another. The two routes are of very similar length and although neither route is completely straight, both offer acceptable geometry for supporting a high-speed rail service. The 220-mph service via I-25 actually takes 2 minutes longer than 150-mph service on the Milliken alignment, because of the added North Suburban station stop.

Demand modeling (see Chapter 6) suggests that the North Suburban station serving Longmont and Boulder would be a valuable addition to the system. However, if the Milliken alignment were selected, some of those riders would be recaptured by either driving or taking RTD to a downtown Denver station. The question to be resolved by a future environmental study is whether the benefit of adding a North Suburban stop justifies the greater cost of constructing a greenfield alignment along I-25, as opposed to the lower cost associated with the opportunity for upgrading the existing Milliken rail line.

Exhibit 5-6: Speed Profile – Cheyenne to Denver via Fort Collins and I-25
300-mph Maglev – 112 Miles – 1:00 Running Time

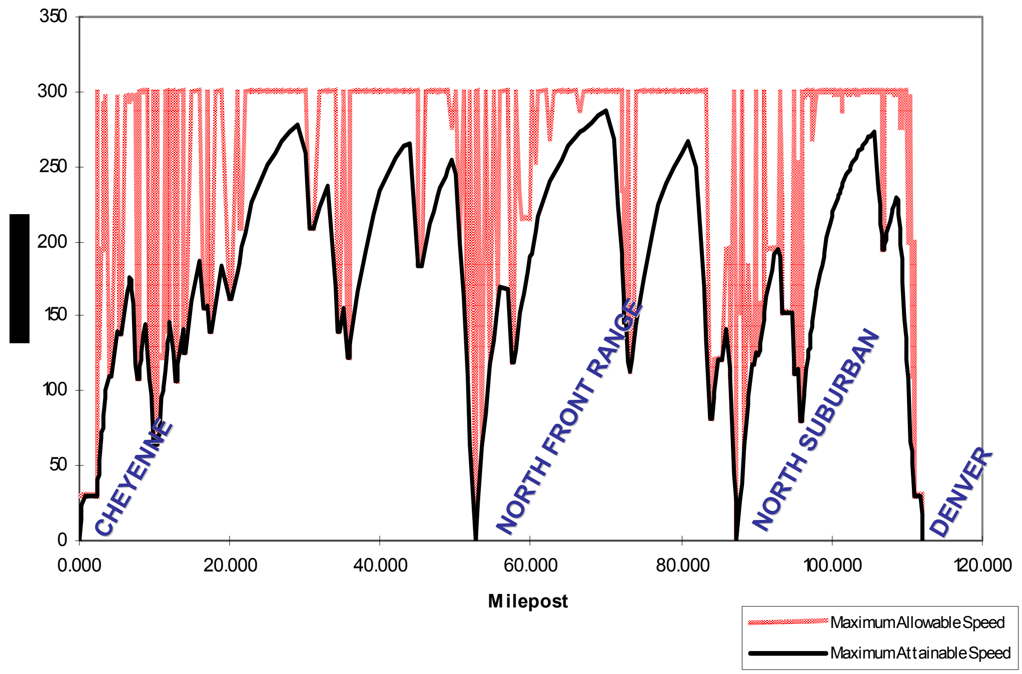
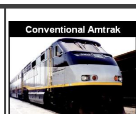
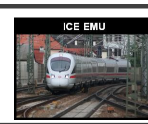


Exhibit 5-7: Schedule Time Summary (including slack) for the I-25 North Corridor

Technology								
Description		79-mph Existing Rail Non tilting	110-mph Existing Rail Tilting	125-mph GF	150-mph ER Tilting	220-mph GF Non tilting	220-mph GF Tilting	300-mph GF
SUMMARY Cheyenne - to - Denver	***Best Combo*** 114 mi	***2:05*** *55 mph*	***1:27*** *79 mph*	***1:15*** *91 mph*	***1:15*** *91 mph*	***1:13*** *94 mph*	***1:07*** *102 mph*	***1:03*** *107 mph*
Cheyenne - to - Fort Collins	**BNSF** 46 mi	0:53	0:38	-	0:35	-	-	-
	Via I-25 46 mi	-	-	0:30	-	0:28	0:25	0:23
Fort Collins - to - Denver	**Greeley** 76 mi	1:21	0:55	-	0:45	-	-	-
	Milliken 68 mi	1:12	0:49	-	0:40	-	-	-
	I-25 68 mi	1:12	0:49	0:45	-	0:45	0:42	0:40
	Boulder 72 mi	1:56	1:22	-	1:19	-	-	-

Access to DIA is provided as part of the I-25 north network. While the original thought was to follow the RTD East Line to the airport, the available RTD right-of-way will only be wide enough to accommodate the proposed RTD tracks. This suggested a different approach to the airport for intercity trains. Assuming intercity trains do not need to make any local stops between downtown Denver and the airport, RTD suggested this study consider an alternative alignment following the BNSF Brush line north from Denver Union Station, then connecting to the airport an a greenfield alignment along the northern boundary of the Rocky Mountain Arsenal National Wildlife Refuge. This approach to the airport was also compatible with input received at the Alternative Alignments workshop. This input suggested a desire on the part of northern Front Range communities to facilitate direct rail access to DIA without needing to go all the way into downtown Denver, switch trains and then come back out to the airport.

The proposed routing from I-25 north passes DIA, so it would be physically possible to offer direct rail access to DIA from the north if enough passenger volume were available to support a service. Because DIA is on a stub-end branch line, adding an intermediate stop at the airport terminal with the necessary turn-around and reverse move would add 15-20 minutes to the Fort Collins-downtown Denver schedule. It is not clear that enough demand exists to support scheduling direct trains from Fort Collins to DIA. A compromise solution would add a shuttle bus connection from Suburban North station to DIA to provide DIA connectivity from the northern communities.

The analysis of the DIA to Denver schedule will be presented as part of the I-70 corridor results.

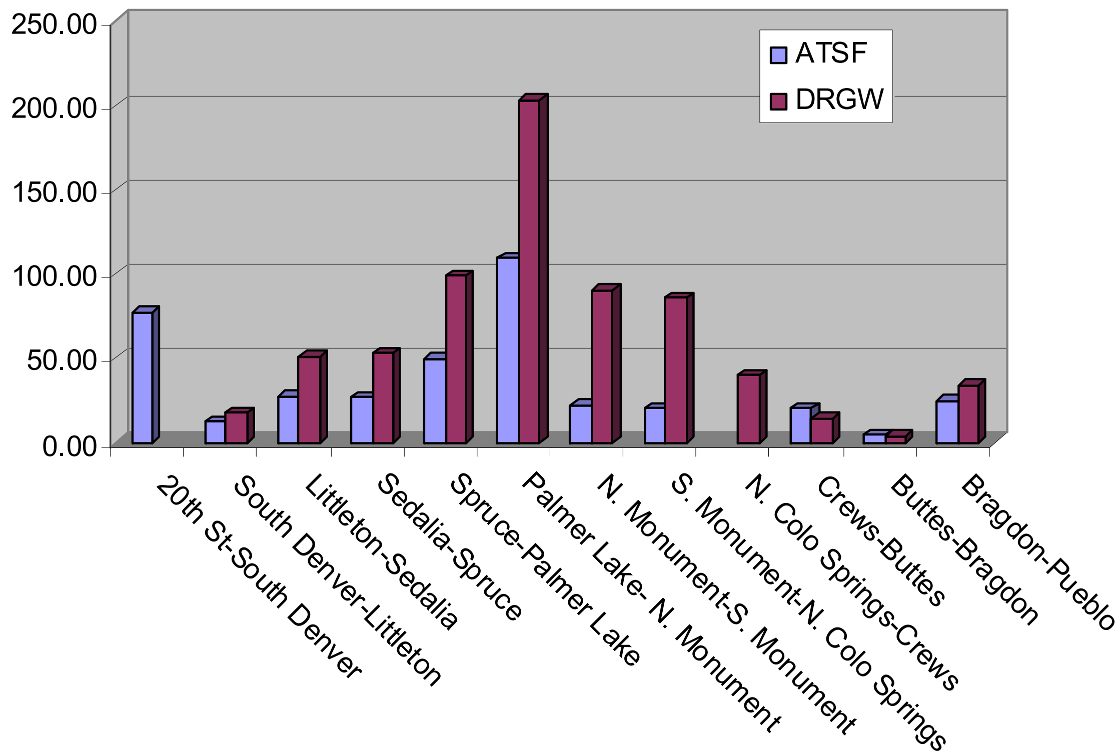
5.1.2 South I-25 Corridor

From downtown Denver to Littleton, this study assumes that the alignment will follow the existing Joint Line tracks. South of Littleton, the possibility exists for developing a new greenfield rail alignment. Even so, there will still be a need for passenger trains to share right-of-way with freight from Denver to Littleton, through downtown Colorado Springs and Pueblo, and for the last few miles into Trinidad.

The history of the Joint Line is significant for understanding its geometric characteristics. The DRGW line is older and was built to narrow gauge standards; the former ATSF line is newer and was built to better geometric standards than the former DRGW. Prior to 1918, the ATSF crossed over the DRGW at several points, including Crews, Spruce, and Sedalia, on overhead truss bridges. By order of the USRA, these bridges were removed and the tracks “straight lined” into one other at the crossing points. As a result, the current #1 and #2 tracks each consist of a combination of former DRGW and ATSF track. Crossovers were installed at several points so the two former single-track lines could be operated as an integrated double-tracked railroad from Pueblo to Denver.

As can be seen in Exhibit 5-8, horizontal curvature starts out gradually on both ends of the line and worsens toward the middle, which reflects the very difficult topography of Monument Hill from Palmer Lake to Colorado Springs. However, even on Monument Hill the comparable ATSF segments have less than half the curvature of DRGW segments, reflecting their higher construction standard.

Exhibit 5-8: I-25 South Existing Rail Corridor, Curvature Degrees per Mile by Line Segment



In 1974, ATSF abandoned its track on Monument Hill, from Palmer Lake through Colorado Springs to Kelker; the DRGW track was abandoned from Kelker to Crews, and so all traffic was consolidated onto a single track from Palmer Lake to Crews. As can be seen, this single-tracked segment of the Joint Line features the worst curves and grades of the entire line. It is clearly the bottleneck on the entire line, so any capacity mitigation plans for this area must be developed cautiously.

Because of the severely limiting effect of curves on passenger train performance, it would seem reasonable to undo the USRA-era mix and match that has been in place since 1918 and restore the overpass bridges necessary to re-integrate the original ATSF alignment for passenger use. The former DRGW alignment would then become an exclusive freight track. Even so, in spite of what would appear to be a natural advantage, the ATSF segments still do include a few sharp curves, at intervals often enough to constrain passenger train speeds. Given the current configuration of the lines, selection of either the DRGW or ATSF alignment, or any combination thereof, would only reduce by a few minutes the passenger train running times.

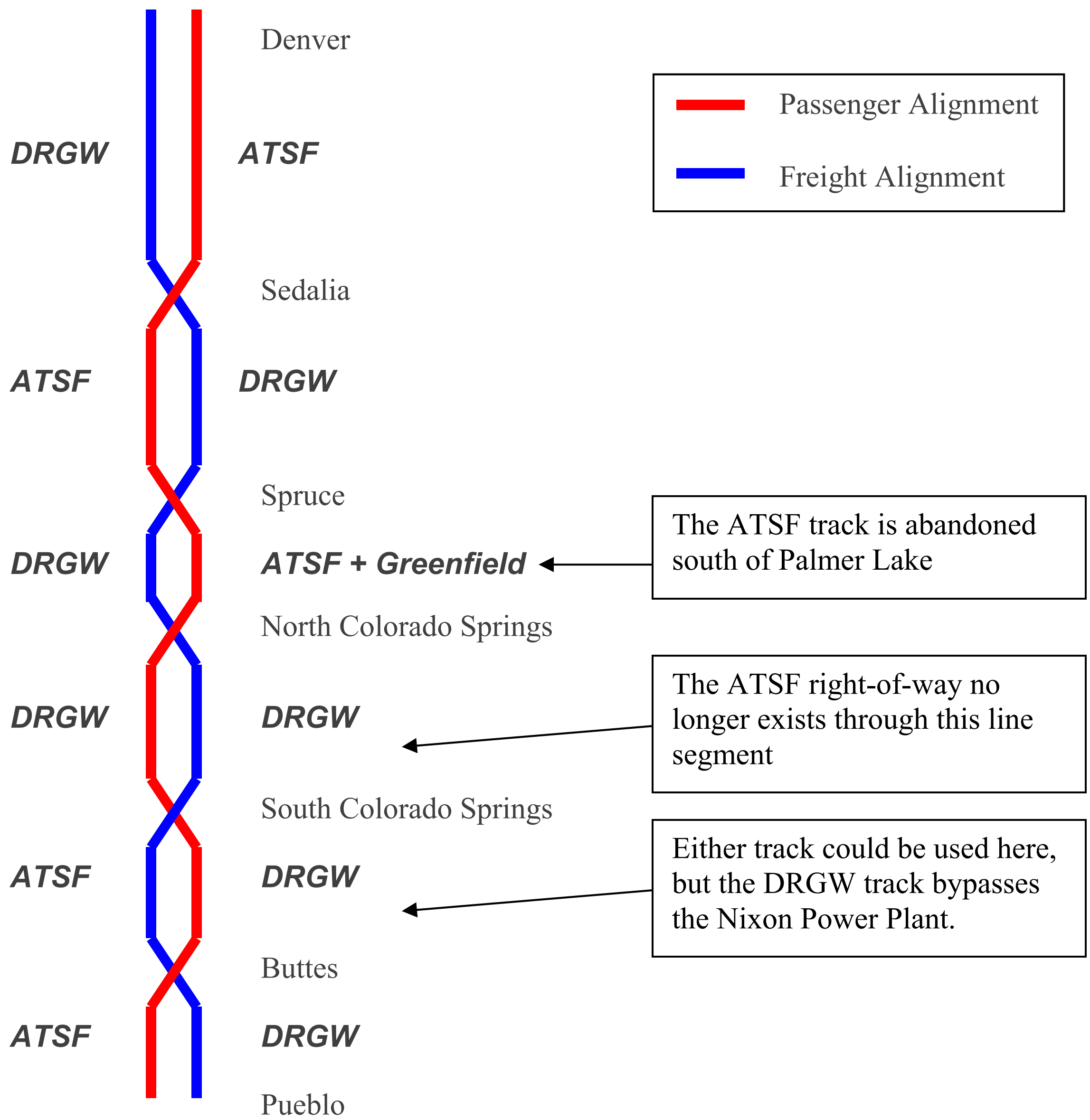
Nonetheless, for longer-term development of the corridor, a curve easement plan should be implemented to improve running times. Under this scenario, *ATSF segments will need far fewer curves modified than would the DRGW alignment for achieving an equivalent running time improvement*. This provides the primary cost justification for wanting to re-integrate the former ATSF segments. If the intention is to ease curves in the future for improving running times, it would be more cost-effective to select the former ATSF segments to begin with.

The only exception to this is on the Crews to Buttes segment, where either the DRGW or ATSF alignment options turn out practically equivalent from a geometry perspective. As a tiebreaker, the former DRGW segment from Crews to Buttes bypasses the Nixon Power plant, leading to a suggestion that it be preferred for passenger use. However, either alignment could be used for this segment of the route.

This leaves only the Palmer Lake to Colorado Springs segment, where the former ATSF track has been abandoned and where existing DRGW track on Monument Hill exhibits extremely poor geometry. It is recommended that serious consideration be given to development of a greenfield alternative bypassing this segment of track. It is possible that some of the abandoned ATSF right-of-way could be incorporated along with I-25 highway corridor segments to develop a new greenfield alignment. Doing this would avoid both the geometric concerns and also compatibility issues with respect to freight trains on Monument Hill.

This approach for using the ATSF line for passenger and the DRGW track for freight, as shown in Exhibit 5-9, would completely separate freight from passenger trains except for a few short segments of shared right-of-way in urban areas. The two existing rail lines are for the most part widely separated (sometimes by as much as a mile) since they were originally constructed as separate lines.

Exhibit 5-9: Proposal for Separating Freight from Passenger Operations on the Joint Line



As an alternative to the existing rail corridor, a greenfield option has been proposed several miles east of the current I-25 corridor, where the terrain is flatter, rail construction would be easier, and the needed right-of-way would be easier to assemble. At several points there is a possibility for connecting to the existing rail line, allowing the possibility of a phased implementation plan.

For I-25 south, the four segments of greenfield alignment are:

- **Littleton to Castle Rock via Lone Tree:** As an alternative to the existing rail line via Sedalia, from Littleton this option would follow C-470 to the I-25 / C-470 interchange; provide a connection to RTD's Southeast Light Rail at Lone Tree, then parallel I-25 south to Castle Rock. This Light Rail connection would provide access to the Denver Technical Center as well as the proposed future light rail extension up I-225. Castle Rock, the county seat of Douglas County, is an important intermediate station stop. It would be possible to reconnect to existing Joint Line track at Castle Rock.
- **Castle Rock to Colorado Springs:** The proposed greenfield alignment moves east of I-25 where the terrain is flatter and construction would be easier. It bypasses Monument about 10 miles to the east and could continue south around the east side of Colorado Springs where a suburban station could be built. However, the option evaluated for this study uses the former Rock Island right-of-way to come back into downtown Colorado Springs about two miles north of the historic station. From there the alignment would parallel the existing Joint Line track through Colorado Springs, until it diverges again in the vicinity of Fountain.
- **Colorado Springs to Pueblo:** At Fountain the greenfield alignment diverges to the east and heads south to the outskirts of Pueblo. One alternative would be to develop a suburban station in the vicinity of the Pueblo Memorial Airport, but the option evaluated for this study parallels the Union Pacific (former DRGW) alignment into downtown. This uses a different station than the existing rail option, which would use the ATSF alignment to access the former Union Station site.
- **Pueblo to North Trinidad:** From Pueblo the greenfield alignment again diverges to the east and stays on the east until the outskirts of Trinidad. It bypasses Walsenburg, but a suburban station could be provided.

It is desirable to construct new high-speed lines to be as direct as possible, so train running times are reduced both by a shorter distance as well as a higher speed. As shown in Exhibit 5-10, a possible disadvantage of the current I-25 greenfield alignment options is that, except for one segment south of Pueblo, the new greenfield segments are all longer than their existing rail counterparts. Because of their higher speed capability, time savings are still possible using these greenfield routes. Nonetheless, in laying out the final alignments, an attempt should be made to shorten them if possible, so they are no longer than the existing rail alignments.

Exhibit 5-10: Mileage Comparison Greenfield vs. Existing Rail on I-25 South

Segment	Existing Rail	Greenfield	Ratio
Littleton to Castle Rock	18.8 miles	21.8 miles	116%
Castle Rock to N. Colo. Springs	40.0 miles	46.3 miles	116%
S. Colorado Springs to Pueblo	36.4 miles	48.1 miles	132%
Pueblo to N. Trinidad	84.0 miles	80.0 miles	95%

Exhibits 5-11 through 5-16 show speed profiles from Pueblo to Denver for 110-mph service for the existing Joint Line geometry; an improved Joint Line geometry; 220-mph rail and 300-mph maglev on greenfield with rail alignment through Colorado Springs, and the same equipment on a pure greenfield alignment with improved right-of-way through Colorado Springs.

Exhibit 5-11: Speed Profile – Pueblo to Denver – Joint Line Current Geometry
110-mph Diesel – 121 Miles – 1:41 Running Time

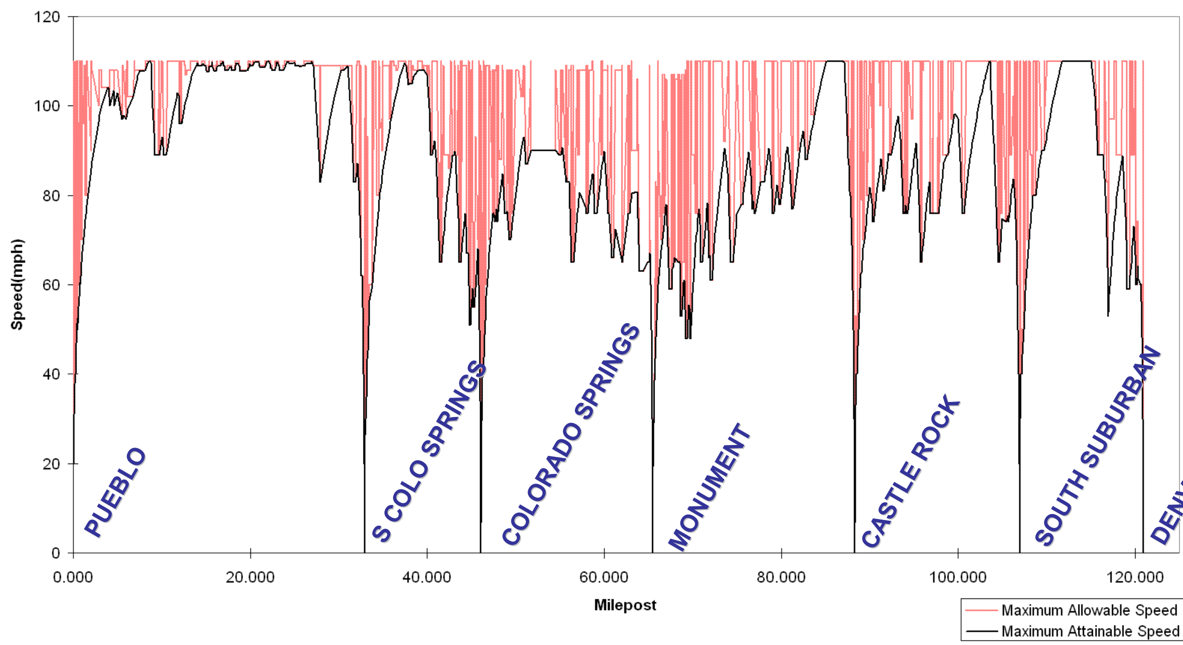


**Exhibit 5-12: Speed Profile – Pueblo to Denver – Joint Line Improved Geometry
110-mph Diesel – 121 Miles – 1:34 Running Time**

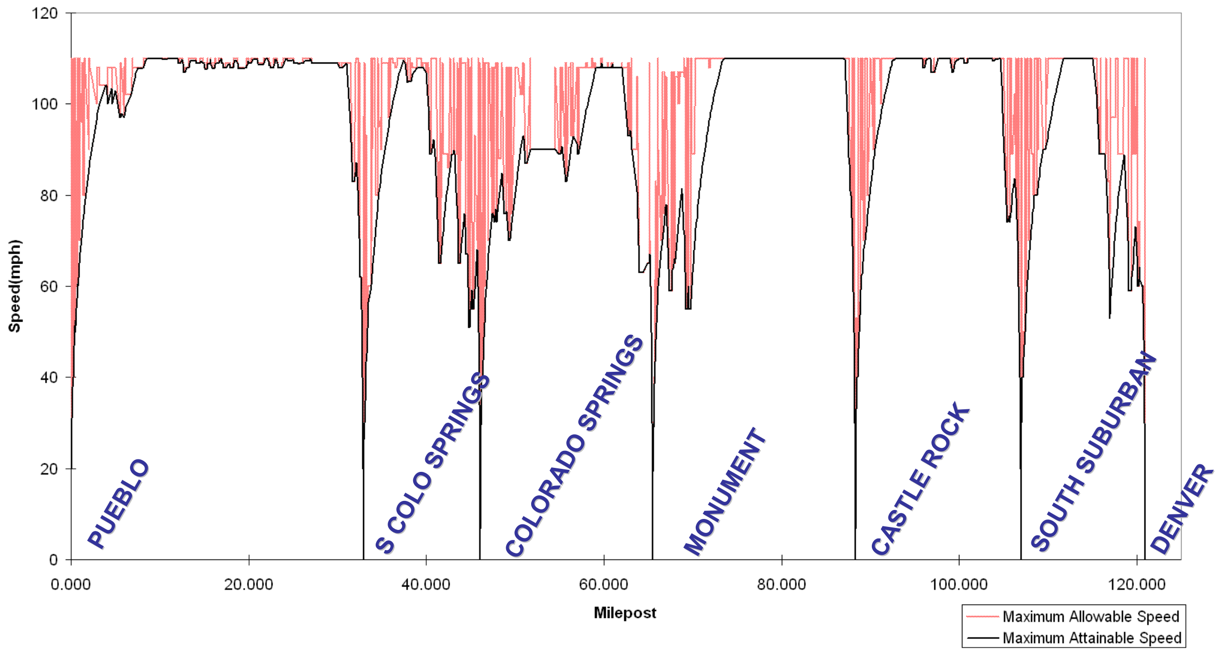


**Exhibit 5-13: Speed Profile – Pueblo to Denver – Greenfield w/Rail Option
220-mph Electric – 142 Miles – 1:19 Running Time**

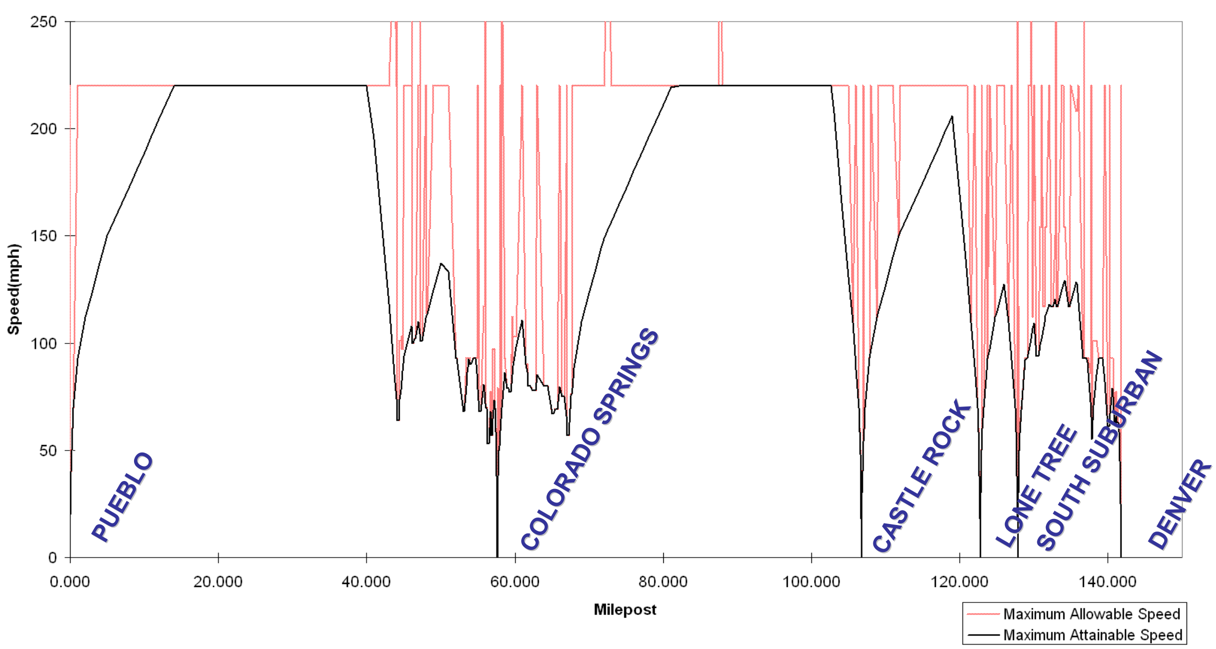


Exhibit 5-14: Speed Profile – Pueblo to Denver – Greenfield w/Rail Option
300-mph Maglev – 142 Miles – 1:16 Running Time

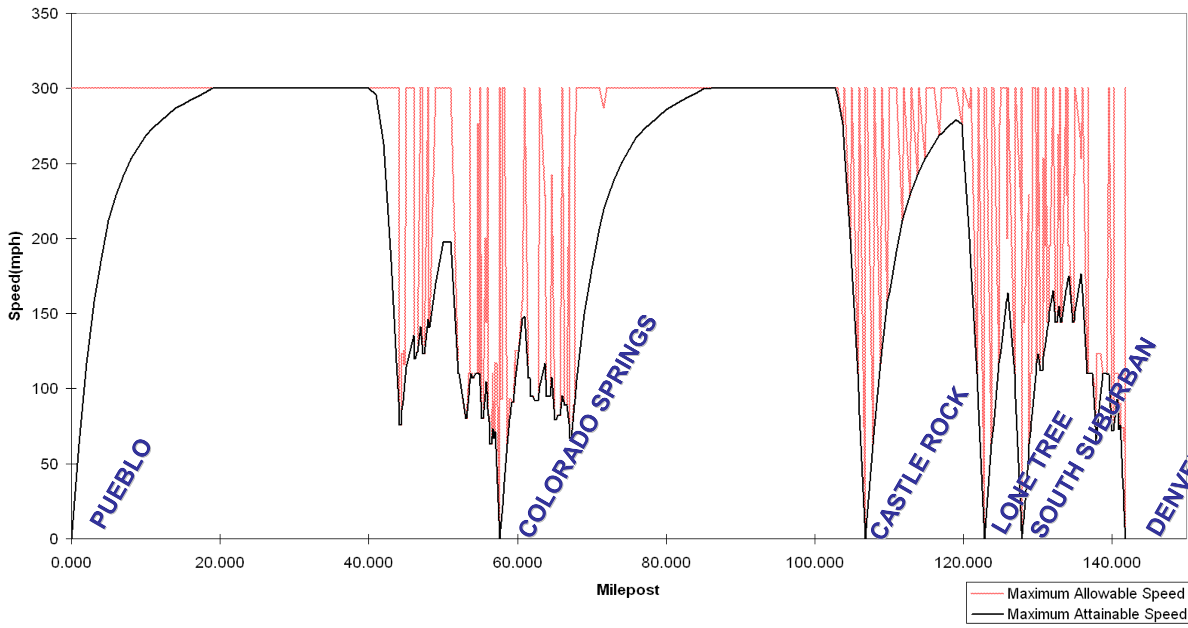


Exhibit 5-15: Speed Profile – Pueblo to Denver – Pure Greenfield Option
220-mph Electric – 142 Miles – 1:10 Running Time

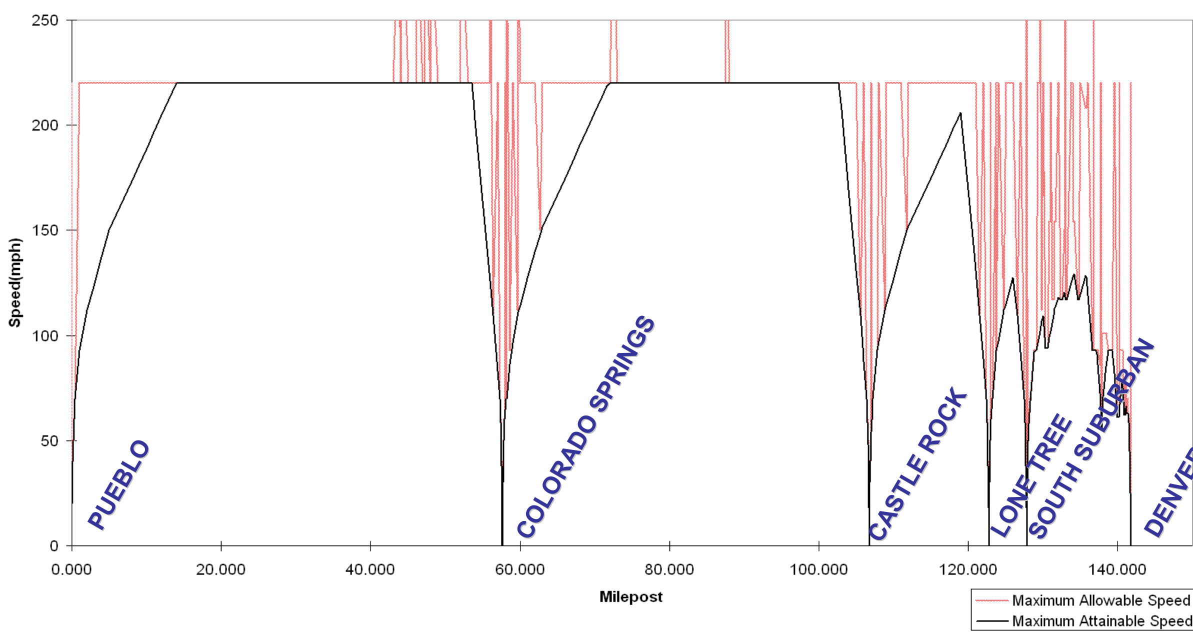


**Exhibit 5-16: Speed Profile – Pueblo to Denver – Pure Greenfield Option
300-mph Maglev – 142 Miles – 1:05 Running Time**

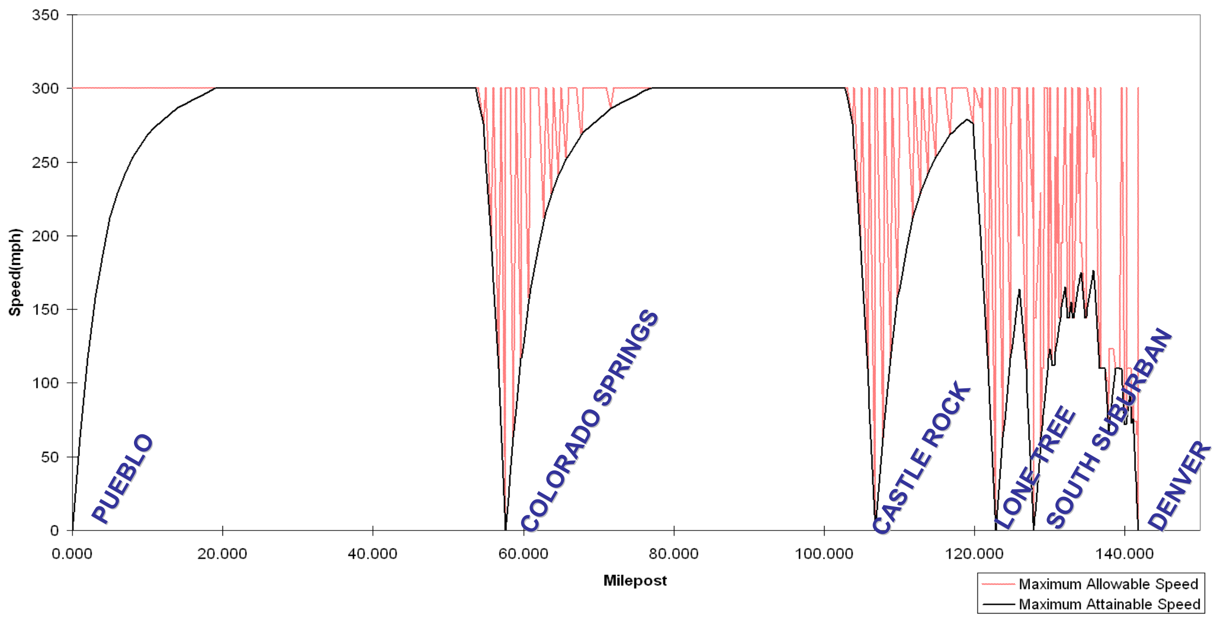


Exhibit 5-11 shows the result of running a 110-mph diesel over the existing Joint Line alignment from Pueblo to Denver. The simulation includes 2-minute station stops at South Colorado Springs (Fountain), Colorado Springs, Monument, Castle Rock, and Littleton. As described previously this simulation assumes the use of former ATSF segments, but without any curve easements. It yields a 1:41 unimpeded running time from Pueblo to Denver, which is barely competitive to driving times. Using the existing alignment, 110 mph is achievable south of Colorado Springs, but in few places north of there.

Exhibit 5-12 shows that unimpeded running times are reduced with curve easements by 7 minutes to 1:34. Most restrictive curves occur north of Colorado Springs, so this simulation reflects the ability to improve much of the line up to 110-mph standards through a systematic program of curve easements.

Exhibits 5-13 and 5-14 show the simulation of 220-mph electric rail and 300-mph maglev on the proposed greenfield alignments. The greenfield as described still includes two significant segments of existing rail right-of-way: from Denver to Littleton and through downtown Colorado Springs. Inclusion of these two segments of existing rail right-of-way, particularly through Colorado Springs, significantly inhibits the performance of the high-speed technologies. Exhibits 5-15 and 5-16 show that if the use of existing freight alignment through Colorado Springs could be avoided, then running times for the high-speed technologies would be about 10 minutes faster.

Exhibit 5-17 shows 110-mph train performance from Trinidad to Pueblo. The simulation includes one 2-minute station stop at Walsenburg. It can be seen that the southern portion of the Spanish Peaks line, from Trinidad to Walsenburg, with very severe curvature, can barely support 60-mph speeds in most places. North of Walsenburg on the section of line that BNSF shares with UP, the terrain is flatter so the line can support a consistent 90 mph with a few short stretches of 110 mph between curves. From Pueblo to Trinidad, a greenfield alignment would be both faster and shorter than the existing rail line.

Exhibit 5-17: Speed Profile – Trinidad to Pueblo
110-mph Diesel – 92 Miles – 1:12 Running Time

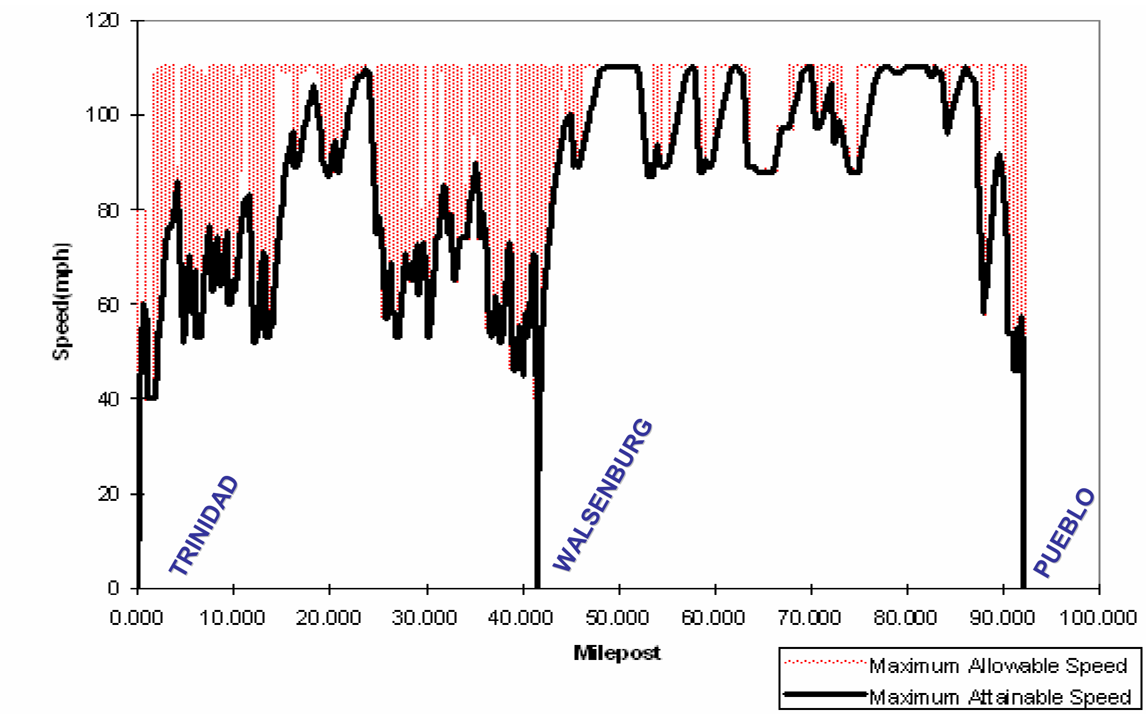
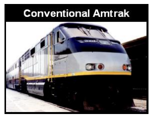


Exhibit 5-18 summarizes the results of the analysis for the I-25 corridor south of Denver.

Exhibit 5-18: Schedule Time Summary (including slack) for the I-25 South Corridor

Technology		Conventional Amtrak 	Talgo T21 	Proposed Colorado Maglev 	Eurostar 	ICE EMU 		Transrapid Maglev 
Description		79-mph Existing Rail Non tilting	110-mph Existing Rail Tilting	125-mph GF	150-mph ER Tilting	220-mph GF Non tilting	220-mph GF Tilting	300-mph GF
SUMMARY Denver - to - Trinidad	***Joint Line*** 210 mi ***Greenfield*** 231 mi	***4:30*** *47 mph*	***2:55*** *72 mph*	***2:17*** *101 mph*	***2:40*** *79 mph*	***2:05*** *111 mph*	***2:00*** *116 mph*	***1:45*** *132 mph*
Denver - to - Colo Springs	**Joint Line** 72 mi	1:45	1:05	-	0:58	-	-	-
	Greenfield 97 mi	-	-	0:47	-	0:45	0:44	0:40
Colo Springs - to - Pueblo	**Joint Line** 46 mi	1:00	0:35	-	0:32	-	-	-
	Greenfield 48 mi	-	-	0:30	-	0:29	0:27	0:25
Pueblo - to - Trinidad	**Joint Line** 92 mi	1:45	1:15	-	1:10	-	-	-
	Greenfield 86 mi	-	-	1:00	-	0:51	0:49	0:40

5.2 I-70 Corridor

For analysis purposes the I-70 corridor has been split into two portions, east of Avon versus west of Avon. This is a logical break point because of the corridor east of Avon is almost entirely greenfield construction, whereas existing rail can be used west of there. Since Wolcott and the proposed "Route 131 cutoff" to Steamboat Springs lie east of Eagle Airport, for explanatory purposes Avon became the more logical break point for subdividing the eastern vs. western networks in this study. Doing this allows all the cutoff options to be defined as part of the western rail system.

5.2.1 I-70 Corridor East of Avon

As described in Chapter 3, two distinctly different corridor development options have been defined for the I-70 corridor east of Avon: either an I-70 Right-of-Way or constrained alignment option with 7 percent grades; or an alternative unconstrained alignment with 4 percent grades that was developed for comparison purposes by this study.

The I-70 corridor consists of a number of distinct segments that provide the ability to mix and match I-70 right-of-way segments along with unconstrained segments for different portions of the route.

- From DIA to Denver CBD, only one alignment was developed for this study. The proposed route follows a greenfield alignment along 96th Street to BNSF's Brush Line that goes downtown.
- From Denver to Golden, two route options were developed by this study. The existing BNSF rail line via Arvada was evaluated but speeds are slow, the right-of-way is limited and high-speed rail use would conflict with RTD development of the Gold Line. Using US-6 to I-70 is both straight and direct; it provides the fastest access to downtown from the west, and offers the most options for development of a possible downtown station. An I-70 alignment from Denver to Golden was examined but because of accessibility, right-of-way width and geometric issues, the US-6 option appeared to provide a better alternative for a fixed guideway connection. In addition, a station at the junction of US-6/I-70 could also allow for a connection to the RTD West light rail line, now under construction. The US-6 option from Denver to Golden was assumed for this study.
- From the junction of US-6/I-70 to Floyd Hill, there is a choice between steep grades (7 percent) on I-70 via El Rancho or sharp curves and tunnels on a possible low-grade (4 percent) alignment via the Clear Creek Canyon. The main disadvantage of the route via El Rancho is the steep 7 percent grades that would be needed, both ascending to El Rancho and then descending down to Clear Creek at Floyd Hill. In contrast, Clear Creek Canyon was the historical route of the narrow-gauge Colorado Central Railroad; when the rail line was abandoned in 1941, the right-of-way was converted into the current US-6 highway.

  The old narrow gauge alignment with its sharp curves is unsuitable for high-speed passenger rail use; what is proposed would be a series of alternating bridges and tunnels for enabling a new, reasonably straight alignment through the canyon. Most of the alignment would either be elevated on structure or underground in tunnels, minimizing the long-term environmental impact of rail's presence in the canyon. While the needed bridge and tunnel would be costly on a per-mile basis, these improvements would comprise a relatively small share of the overall cost of building a new rail line up I-70 and over the Continental divide.

  By providing a low-grade alternative, the canyon alignment would keep open the option for operating the line using conventional locomotive hauled trains. In addition to providing more flexibility in passenger equipment procurement allowing the use of off the shelf train designs, development of a low-grade route through the Rockies could allow the operation of economical truck and automobile shuttle trains, especially in the wintertime. In Europe, such shuttles are currently operated underneath the English Channel and through many Swiss rail tunnels. The project scope did not allow for the full development of this option, but early screening of the Clear Creek Canyon option could possibly foreclose it. The options for development of this segment of the corridor are critical since the specification of maximum ruling grade is one of the most critical parameters in development of the overall rail system.

- From Floyd Hill to Loveland Pass, two parallel alignments were developed. The I-70 Right-of-Way alignment is constrained to the existing highway right-of-way as defined by the I-70 PEIS. In addition, an unconstrained right-of-way option was developed that allowed deviations from the highway right-of-way where it could either improve the geometry of the rail line or reduce construction cost. A key objective for development of the unconstrained option was to hold grades to 4 percent or less, so the unconstrained option uses a tunnel from Georgetown up to Silver Plume; in contrast the I-70 Right-of-Way option uses 7 percent grades to hug the mountainside on this short stretch of the existing highway alignment.
- From Loveland Pass to Copper Mountain, two distinctly different route alternatives were developed. The I-70 Right-of-Way option would use a tunnel paralleling the Eisenhower Johnson Memorial Tunnel to penetrate the Continental Divide, and then follow I-70 down to Silverthorne, through Frisco, and on to Copper Mountain. The evaluation of this I-70 Right-of-Way option includes the development of branch lines enabling direct rail service to important traffic generators at Keystone and Breckenridge. In contrast, the unconstrained option tunnels directly underneath Loveland Pass to Keystone. From there, the route would pass south of Lake Dillon to Breckenridge. From Breckenridge it would tunnel to Copper Mountain. The unconstrained route is shorter and would serve the main ski resorts directly as opposed to relying on branch lines, but constructing it needs extensive tunnels.
- From Copper Mountain to Dowd Junction, two distinctly different route alternatives were also developed. A key consideration is the requirement to utilize 7 percent grades for crossing Vail Pass, whereas an alternative looping south via Pando could make the western connection using only 4 percent grades. The Pando routing also has the potential to make greater use of the existing Tennessee Pass rail alignment; if shared use of the right-of-way can be negotiated with Union Pacific, this could offer a significant cost-savings opportunity.

  A key consideration for selection of an alignment option would be the suitability of a station at Dowd Junction for serving Vail, as opposed to the possibility for direct rail service to Vail, accompanied by construction impacts, should the Vail Pass route ultimately be selected.
- From Dowd Junction to Avon and on to Eagle Airport, consistent with the I-70 PEIS, the existing Union Pacific rail corridor was used, although the I-70 highway alignment could offer better geometry. Nonetheless, the distance from Dowd to Avon is short, minimizing the overall travel time impact for using this segment of existing rail right-of-way.

Exhibits 5-19 and 5-20 show speed profiles for the I-70 Right-of-Way option using powerful EMU rail equipment (220-mph class) to tackle the 7 percent mountain grades. Two profiles have been developed to show the impact of train performance on grades. Exhibit 5-21 shows the performance of the unconstrained alignment that limits grades to 4 percent. Although it can be seen that speeds above 150 mph are not achieved west of Golden, the same 220-mph train technology was used in all three runs, to produce a consistent evaluation of the alignment impact on running times. Maglev speeds and performance would be very similar to that shown for the 220-mph electric train in Exhibit 5-20, since curves on the 7 percent grades would still practically limit speed to 60 mph regardless of the amount of power available to the train.

**Exhibit 5-19: Speed Profile – DIA to Avon – 220-mph Electric Rail Technology
I-70 Right-of-Way (45 mph on Grades) – 130 Miles – 2:20 Running Time**

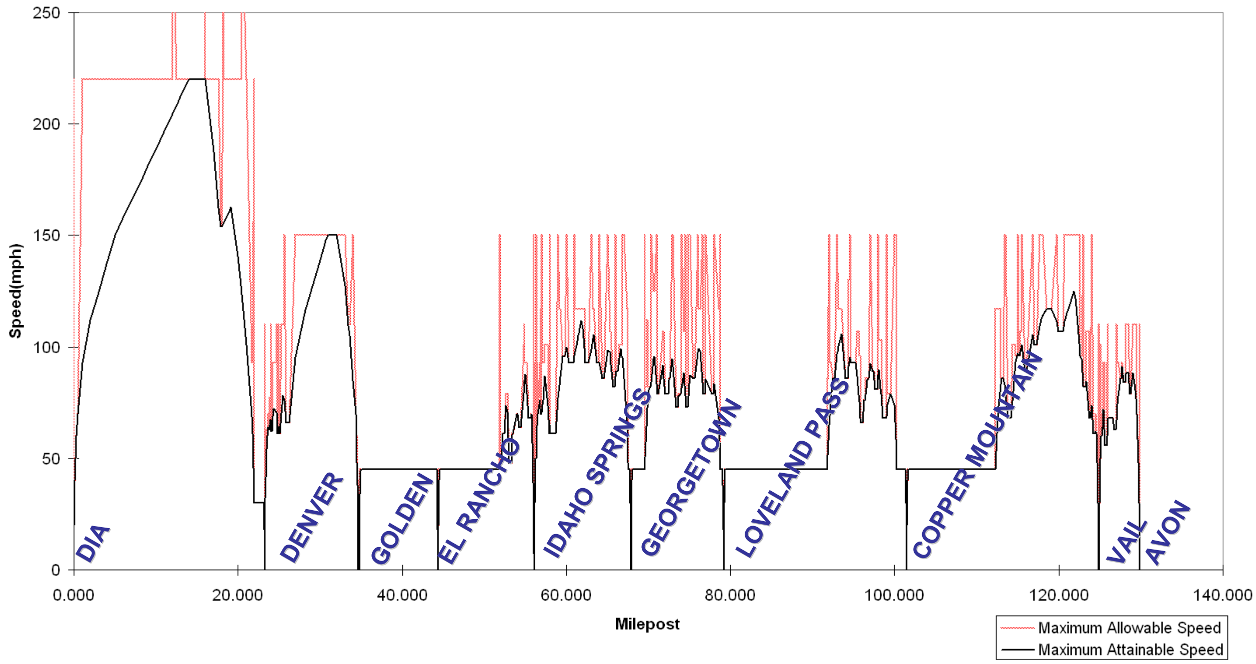


**Exhibit 5-20: Speed Profile – DIA to Avon– 220-mph Electric Rail Technology
I-70 Right-of-Way (60 mph on Grades) – 130 Miles – 2:05 Running Time**

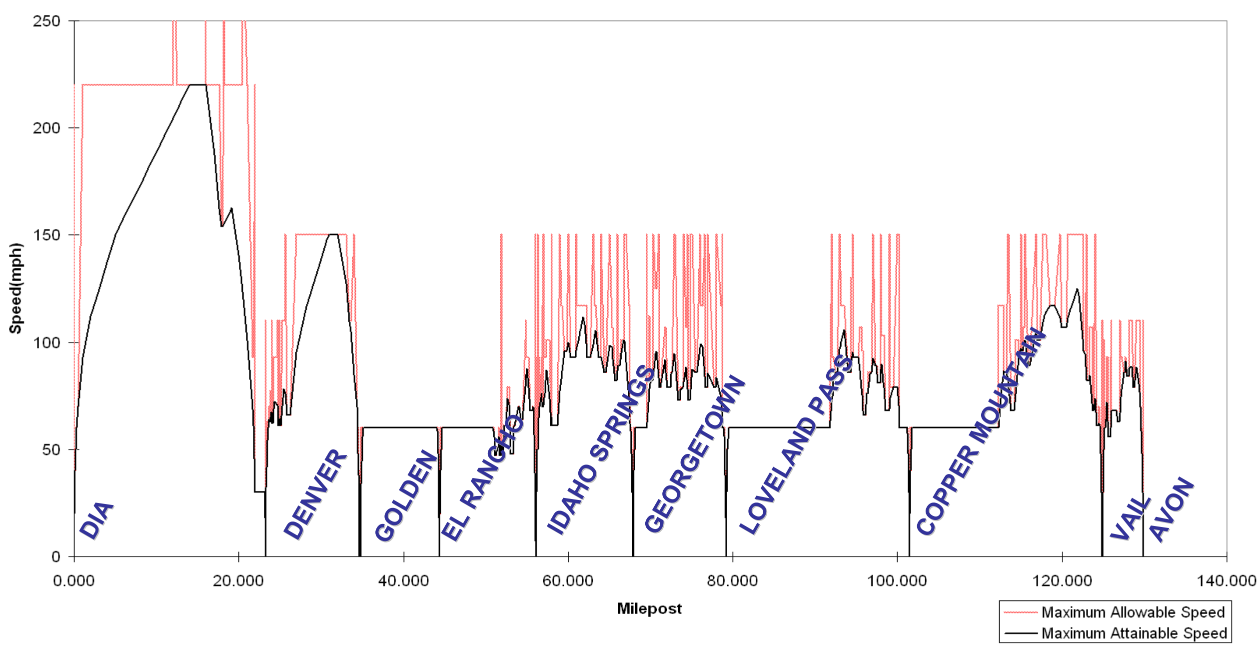
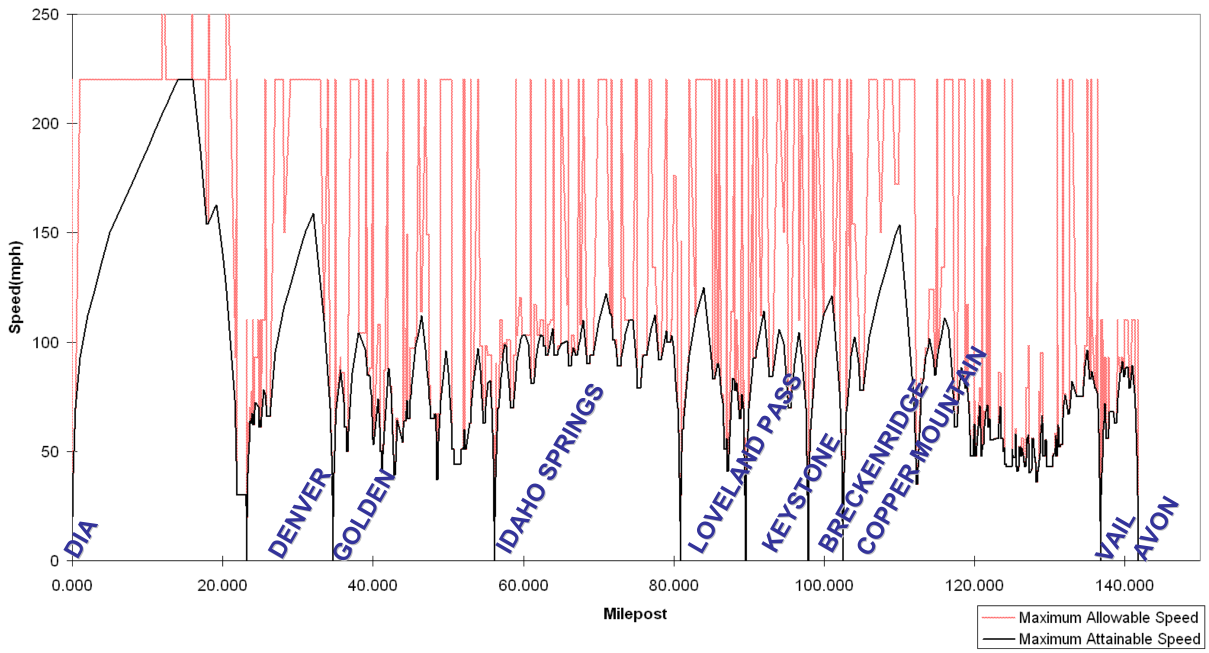


Exhibit 5-21: Speed Profile – DIA to Avon– 220-mph Electric Rail Technology
I-70 Unconstrained – 142 Miles – 2:05 Running Time



In the two simulations of the I-70 Right-of-Way option from DIA to Avon in Exhibits 5-19 and 5-20, trains stop at DIA, downtown Denver, Golden (I-70 and US-6), El Rancho, Idaho Springs, Loveland Pass, Silverthorne, Copper Mountain, Vail and Avon. The train could continue on to Eagle Airport if desired.

Existing High-Speed trains, even those capable of achieving 220-mph top speed, do not have enough power to go up or down 7 percent grades at 60 mph. This study has assumed the technical feasibility of adding power to a train that is specifically designed for Colorado conditions; however, current off-the-shelf trains could only achieve 45 mph on the 7 percent grade segments. The suggested 45-mph or 60-mph limits reflect the electrical capabilities of the traction motors for maintaining speed going up hill, as well for resisting acceleration of the train going downhill. The trains would have enough installed electrical capability to maintain design speed going uphill as well as to hold the same speed going downhill, in full regenerative braking mode.

Regenerative braking recaptures energy from train braking and returns it back into the power grid. By using the traction motors as electrical generators, a resistive force is produced, slowing the train. Tread or disk brakes, in contrast, simply dissipate braking energy as heat. This limits the maximum length of time during which they can be used. However, dynamic braking can continue indefinitely provided the ratings of the electrical equipment are not exceeded. Limiting downhill speed so it does not exceed the uphill speed ensures the maximum energy recovery from regenerative braking.

Accordingly, a 45-mph speed sensitivity on the 7 percent grades was tested. Imposing this speed limit to reflect the capabilities of off-the-shelf trains would add about 15 minutes to the overall running time, as compared to a more powerful train that could do 60 mph on the grades. Curves on I-70 will generally permit 60 mph, so it is recommended that the trains be upgraded with additional power in order to attain this higher speed, if possible. Maglev speed profiles look very similar to Exhibit 5-20, except the trains run just a few minutes faster than the rail option.

The simulation of the unconstrained alignment follows the same alignment as the I-70 Right-of-Way option from DIA, through downtown Denver to Golden (I-70 and US-6 station). This unconstrained simulation includes stops at DIA, downtown Denver, Golden (I-70 and US-6), Idaho Springs, Loveland Pass, Keystone, Breckenridge, Copper Mountain, Vail (at Dowd Junction) and Avon. Exhibits 5-22 through 5-24 compare the mileage, time and speed of the two I-70 options east of Avon. For consistency all comparisons are performed using the same 220-mph rail technology. 150-mph rail technology would be only a few minutes slower and either maglev technology would be just a few minutes faster.

From Golden to Floyd Hill, the route option via Clear Creek Canyon is about the same distance using I-70, but is more than 7 minutes faster. This is because the curves on the proposed Canyon alignment would allow an average speed of 60 mph, whereas the route via El Rancho has a top speed of 60 mph due to its heavy grades. In addition, there is a 2-minute station stop in El Rancho, but even if this station stop were omitted, the unconstrained route via the canyon would still be faster.

From Floyd Hill up to Loveland Pass, the unconstrained alignment is again faster as well as offering easier grades, since it has the use of the entire width of valley, which results in easier curves, better grades, lower construction costs and a two-minute time advantage.

From Loveland Pass to Copper Mountain, the unconstrained route is again shorter and faster with a two-minute time advantage, and has the benefit of serving the important resort destinations directly. However, the alignment would require construction of three major tunnels totaling 10.7 miles in length, compared to only a single tunnel of 1.2 miles on the I-70 Right-of-Way alignment. The FRA Developed Option will seek to reduce the tunneling cost on this segment while preserving direct rail service to all the resorts.

From Copper Mountain to Dowd Junction, the I-70 Right-of-Way route via Vail Pass is 11 miles shorter and 11 minutes faster than the unconstrained" alignment via Pando. There is a 60-mph speed restriction associated with the 7 percent I-70 grades on Vail Pass, but once reaching the valley floor on the west side of the pass, trains could speed up until they reach the Vail station stop.

Exhibit 5-22: Mileage Comparison I-70 ROW vs. Unconstrained on I-70 East of Avon

Segment Miles	I-70 ROW	Unconstrained	Ratio
DIA to Denver	23.2	23.2	100%
Denver to Golden I-70/US-6	11.5	11.5	100%
Golden to Floyd Hill	16.9	17.2	98%
Floyd Hill to Loveland Pass	27.6	29.0	95%
Loveland Pass to Copper Mtn	22.3	21.6	103%
Copper Mtn to Dowd Jct	23.4	34.3	68%
Dowd Jct to Avon	5.0	5.0	100%
OVERALL	129.9	141.8	92%

Exhibit 5-23: Time Comparison I-70 ROW vs. Unconstrained on I-70 East of Avon

Segment Time (HH:MM:SS)	I-70 ROW	Unconstrained	Ratio
DIA to Denver	0:12:08	0:12:08	100%
Denver to Golden I-70/US-6	0:09:53	0:09:53	100%
Golden to Floyd Hill	0:24:46	0:17:16	143%
Floyd Hill to Loveland Pass	0:24:44	0:22:34	110%
Loveland Pass to Copper Mtn	0:25:40	0:23:31	109%
Copper Mtn to Dowd Jct	0:21:41	0:32:22	67%
Dowd Jct to Avon	0:06:53	0:06:55	100%
OVERALL	2:05:45	2:04:39	101%

Exhibit 5-24: Speed Comparison I-70 ROW vs. Unconstrained on I-70 East of Avon

Segment Speed (mph)	I-70 ROW	Unconstrained	Ratio
DIA to Denver	115	115	100%
Denver to Golden I-70/US-6	69	69	100%
Golden to Floyd Hill	41	60	69%
Floyd Hill to Loveland Pass	67	77	87%
Loveland Pass to Copper Mtn	52	55	94%
Copper Mtn to Dowd Jct	65	64	102%
Dowd Jct to Avon	44	43	100%
OVERALL	62	68	91%

In contrast, Exhibit 5-21 shows that a new greenfield alignment paralleling State Route 91 from Copper Mountain towards Climax could be very straight in a wide valley, and could permit speeds up to 150 mph. But once the top of the grade is reached at the mine tailing ponds, the alignment down to Pando is more difficult, and from Pando to Dowd Junction the existing UP right-of-way would be used. The main advantage of the Pando route is its low 4 percent gradient as opposed to 7 percent gradient on Vail Pass. Selection of this route may facilitate a future service extension of diesel-powered services to Leadville, and into Summit County from Eagle County and the west.

While the eastern greenfield of the Pando route is very fast, the western segment would be slower than the alternative routing via Vail Pass. However, it needs to be faster in order to overcome the distance disadvantage associated with the Pando option. By developing a greenfield alignment alternative from Pando to Dowd Junction instead of relying on the existing UP right-of-way, this running time comparison could possibly be improved.

Exhibits 5-22 through 5-24 reflect the results of the detailed Locomotion simulation, whereas the times in Exhibit 5-25 have 20 minutes of slack time added, to develop a realistic schedule for each alignment. To simplify the summary, the mileages shown reflect a composite or average of the unconstrained and I-70 Right-of-Way alternatives. It should be noted that the 150-mph 4 percent option Vail station is at Dowd Junction so the Copper to Vail segment times are not directly comparable to the other columns. However, it can be seen that the overall running times from DIA to Avon are very comparable via either alignment.

Exhibit 5-25: Schedule Time Summary (including slack) for the I-70 Corridor East of Avon

Technology						
Max Speed		125-mph 7% RW	150-mph 4% UC (Tilting)	220-mph 7% RW (Non tilting)	220-mph 7% RW (Tilting)	300-mph 7% RW
SUMMARY DIA - to - Avon	***I-70*** 135 mi	***2:13***	***2:25***	***2:45***	***2:25***	***2:10***
DIA - to - Denver	BNSF 23 mi	0:16	0:13	0:13	0:13	0:13
Denver - to - Copper	I-70 80 mi	1:20	1:20	1:45	1:30	1:20
Copper - to - Vail	I-70 22 mi	0:25	0:37	0:30	0:27	0:25
Vail - to - Avon	UP RR 10 mi	0:12	0:15	0:17	0:15	0:12
Denver - to - Black Hawk	US-6 35 mi	0:53	0:54	0:58	0:54	0:53

5.2.2 I-70 Corridor West of Avon

The I-70 corridor west of Avon includes the critical Glenwood Canyon segment of UP rail line from Dotsero to Glenwood Springs, which forms a barrier to the westward expansion of the rail system. Two "cutoff" options, the "Route 131 Option" and "Aspen Tunnel" option via Cottonwood Pass, have been considered in conjunction with the I-70 Right-of-Way network. Since Eagle Airport is west of Wolcott, trains from Denver to Steamboat Springs using the Route 131 Option could not go to Eagle Airport, since they would have to turn north at Wolcott before they get to Eagle Airport.

The evaluation of the Western corridor options is largely based on the utilization of existing rail routes. From Avon, a train could operate directly to Grand Junction, Aspen or Steamboat Springs using any of the route alternatives. As a result Avon is a natural starting point for all the evaluations. Exhibits 5-26 through 5-28 show the speed profiles for each of the existing rail segments, for 220-mph electric trains. Assuming that highway grade separations are not undertaken, maximum train speeds would be limited to 110 mph. At that speed on the existing rail alignments, diesel trains would have a very similar speed profile but run just a few minutes slower than the electric train simulations presented here.

Exhibit 5-26: Speed Profile – Grand Junction to Avon
220-mph Electric – 141 Miles – 1:52 Running Time

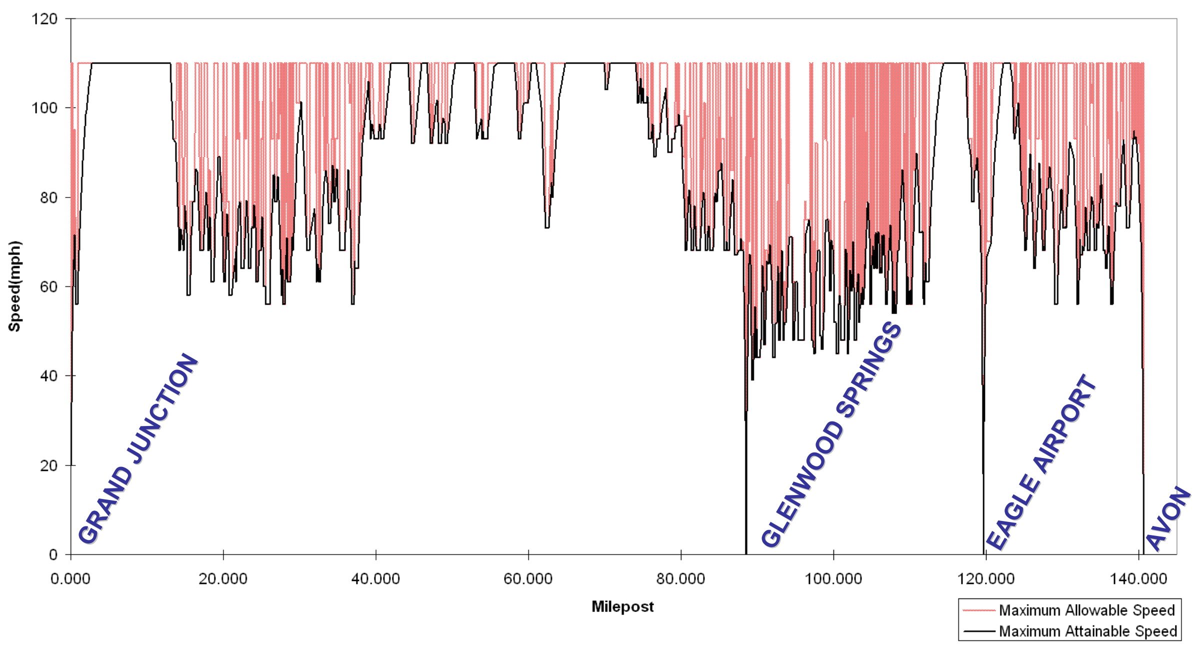


Exhibit 5-27: Speed Profile – Craig to Dotsero
220-mph Electric – 141 Miles – 2:04 Running Time

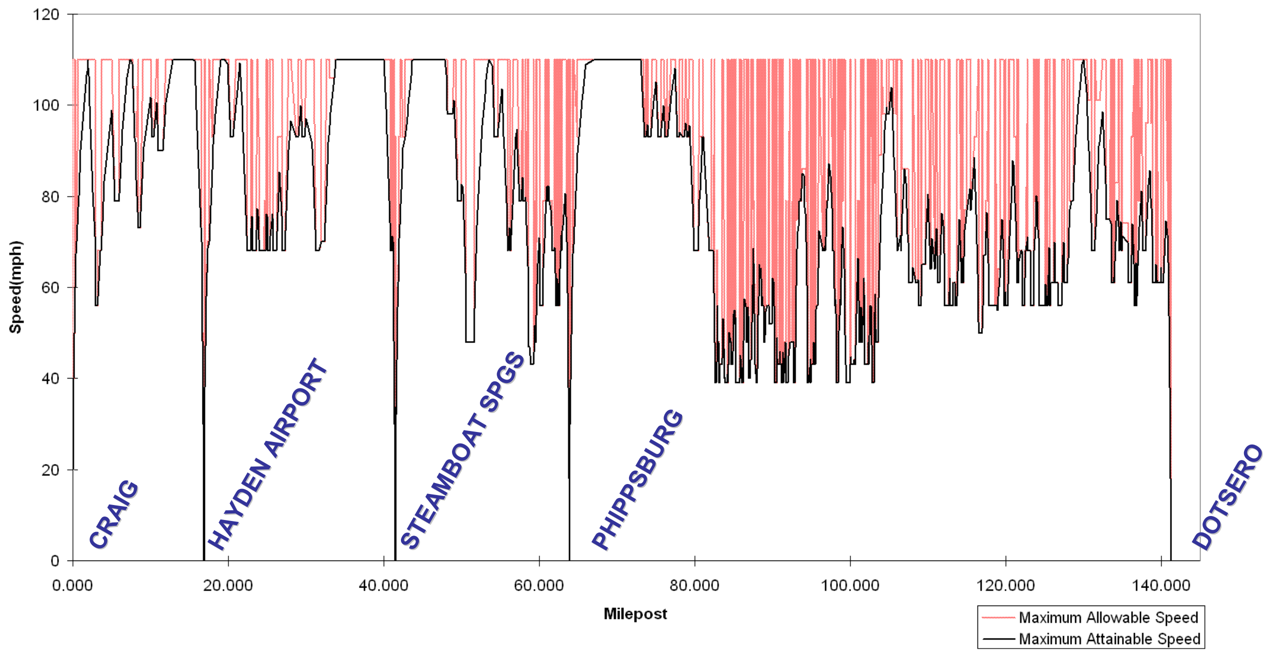
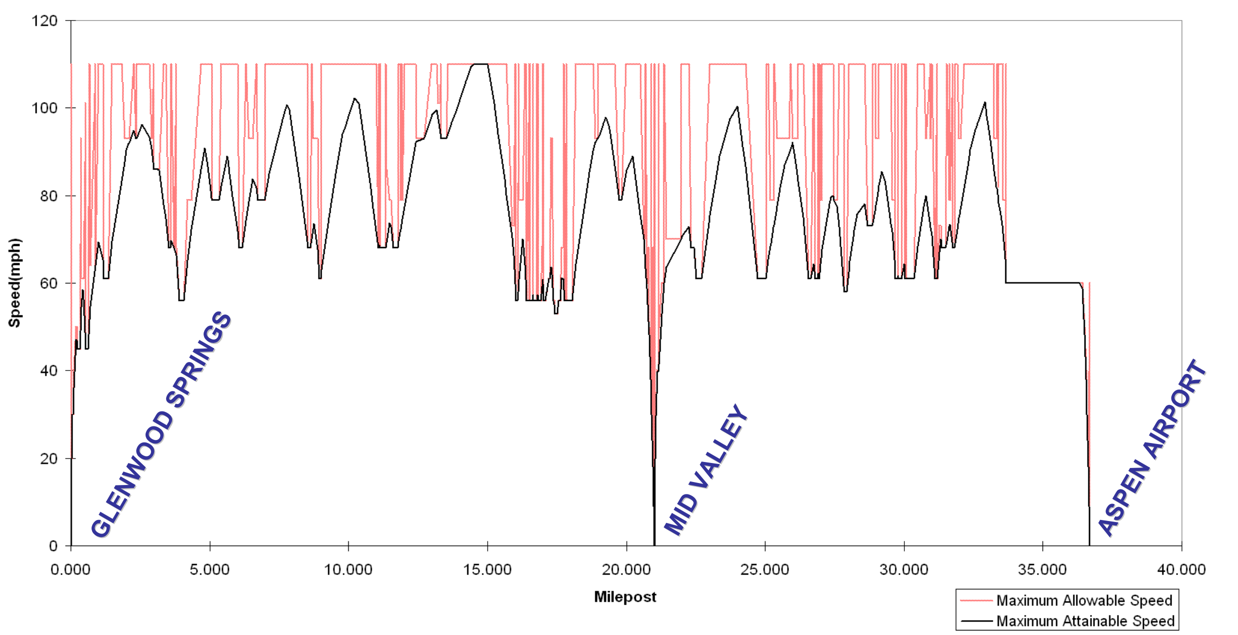


Exhibit 5-28: Speed Profile – Glenwood Springs to Aspen Airport
220-mph Electric – 37 Miles – 0:33 Running Time



From Grand Junction to Avon as shown in Exhibit 5-26, 110-mph speeds are possible until the UP alignment enters the De Beque Canyon, reducing train speeds down to 60 mph through the canyon. This simulation assumes intermediate station stops at Glenwood Springs and Eagle airport on the way to Avon. East of the De Beque canyon, speeds of 90-110 mph can again be attained through Parachute until reaching the western outskirts of Glenwood Springs. At this point curve speed restrictions begin again and remain in place through the Glenwood Canyon, which allows speeds only in the 40-50 mph range. After this there is a fairly short stretch of straight track on which 110-mph speeds could possibly be obtained, but the Eagle Airport stop is in the middle of it. For the last few miles of the route into Avon speeds generally would be restricted in the 60-mph range because of curves on the former Tennessee Pass rail line.

From Craig to Dotsero in Exhibit 5-27, the western end of the Craig branch exhibits good geometry overall, with a few tight curves which restrict the speed at some locations. However there is little passenger rail traffic potential west of Steamboat Springs to take advantage of this geometry. While some parts of the Craig Branch are fairly straight, the most significant speed restrictions lie farther south where the Craig branch hugs the mountainside above the Rock Creek Canyon, imposing speed limits of less than 40 mph for 20 miles. South of Bond, the route joins the UP main line along the Colorado River to Dotsero, where the geometry would allow maximum speeds in the 50-mph range.

Exhibit 5-28 shows the alignment from Glenwood Springs to Aspen. Restoring rail on the existing track bed would enable operations at speeds up to 60 mph due to curvature with some short stretches permitting higher speed.

Exhibit 5-29 summarizes the overall results for the I-70 corridor west of Avon.

Exhibit 5-29: Schedule Time Summary (including slack) for the I-70 Corridor West of Avon

Technology						
Description		125-mph 7% RW	150-mph 4% UC Tilting	220-mph 7% RW Non tilting	220-mph 7% RW Tilting	300-mph 7% RW
Avon - to - Grand Jct	UP RR 141 mi	***1:42*** *83 mph*	***1:45*** *81 mph*	***1:55*** *74 mph*	***1:45*** *81 mph*	***1:37*** *87 mph*
Avon - to - Glenwood	UP RR 52 mi	0:42	0:45	0:50	0:45	0:42
Glenwood - to - Grand Jct	UP RR 89 mi	1:00	1:00	1:05	1:00	0:55
Avon - to - Steamboat	Wolcott 90 mi	1:20	1:30	1:40	1:30	1:20
	Dotsero 133 mi	2:10	2:15	2:25	2:15	2:10
Avon - to - Aspen	UP RR 89 mi	1:15	1:22	1:38	1:22	1:15
	Tunnel 65 mi	0:50	0:53	1:00	0:53	0:50

5.3 Summary Travel Time Comparison

Exhibit 5-30 compares the range of rail travel times for selected origin destination pairs to typical auto travel times for the same city pairs. The range of rail travel times depends on the exact combination of rail technology, alignment, and route option (e.g., Aspen Tunnel vs. Glenwood Canyon) that will ultimately determine the rail travel time. It has been reflected as a range in the exhibit to reflect the differences in performance of the rail options now under consideration, but would be replaced with a fixed value based on the timetable for any specific rail option. The range of auto times reflects varying traffic conditions, for factors such as congestion and weather that are likely to be encountered.

Exhibit 5-30: Auto Travel Time Comparisons

From	To	Rail Range	Auto Off-Peak	Auto Peak
DIA	Avon	2:25 - 2:45	2:29	3:45
	Steamboat Springs	3:55 - 5:25	3:41	4:30
	Grand Junction	4:10 - 5:05	4:30	5:45
	Aspen	3:18 - 4:33	4:20	5:30
	Keystone	1:15 - 1:30	1:55	2:45
Denver	Ft. Collins	0:42 - 0:55	1:01	1:30
	Pueblo	1:11 - 1:40	1:53	2:20
	Black Hawk	0:55 - 1:00	0:46	1:15

All of the proposed rail services are able produce auto-competitive travel times, with the possible exception of rail service to Steamboat Springs via Dotsero, which due to the circuity of the routing is likely to take longer than auto driving time from Denver. All the other rail travel times are reasonably competitive even with off-peak auto driving time, indicating that these services are likely to be well received by potential riders.

5.4 Train Service and Frequencies

As train speeds improve, especially beyond auto-competitive travel times, rail services become attractive to more riders. This in turn allows a higher fare to be charged while ridership growth allows more trains to be operated, which boosts the attractiveness of the rail or maglev system even more.

Exhibit 5-31 shows the level of service frequencies that are typically offered as a function of train speed. These frequency levels are used as the starting point for the interactive analysis process, described in Chapter 1. As a result of the interactive analysis, the planned frequencies and train sizes are fine-tuned to balance ridership with capacity. As a rule, when speed goes up, so do fares, service frequency and average train size. Increasing frequency as speed and ridership builds is needed to properly balance capacity (seat-miles) with demand (passenger-miles.)

Exhibit 5-31: Service Frequency and Base Fare as a Function of Train Speed

Trains / day	Fare ¢ / mi	4	6	8	10	12	14	16	18	20	24	30
79 mph	20¢	X	X	X								
110 mph	28¢			X	X	X						
125 mph	30¢			X	X	X						
150 mph	32¢					X	X	X				
220 mph	38¢						X	X	X	X		
300 mph	45¢							X	X	X	X	X

This speed/frequency matrix was used to establish the initial base-line train frequency assumptions for the Colorado network evaluations. Green boxes indicate the base line train frequency levels that were assumed for the initial *COMPASS*™ demand model evaluations of each scenario. For example, it can be seen that the green boxes match the frequencies that were used for each technology between Fort Collins and Denver. However, some other parts of the system needed frequency adjustment to either cut or add capacity. Because of expected weaker demand, base frequencies were cut in half on the western branch lines to Steamboat, Grand Junction and Aspen. Making this reduction provided a better starting point for the iterative interactive analysis process that was described in Chapter 1.

Once initial results were obtained, train frequencies were further adjusted on a segment basis as necessary to match supply to demand. Some route segments, primarily from Denver to Vail, had very strong initial demand that required operation of additional trains for capacity reasons. This process of adjusting frequency to match demand was iterative until the demand forecast and operating plan came into balance. Exhibits 5-32 through 5-37 show where additional trains were needed for each equipment technology/train speed scenario. These exhibits show the frequency assumptions that were used for demand forecasting and operational costing purposes. Adjusting frequencies to balance demand with capacity was done to ensure that system revenues and operating costs were consistent with one another. Finally, consistent with these criteria, a set of pro-forma train schedules was designed for the FRA Developed Option as defined in Chapter 9. These schedules are listed in Appendix L.

Exhibit 5-32: Train Service Pattern for 79-mph Diesel Rail Option

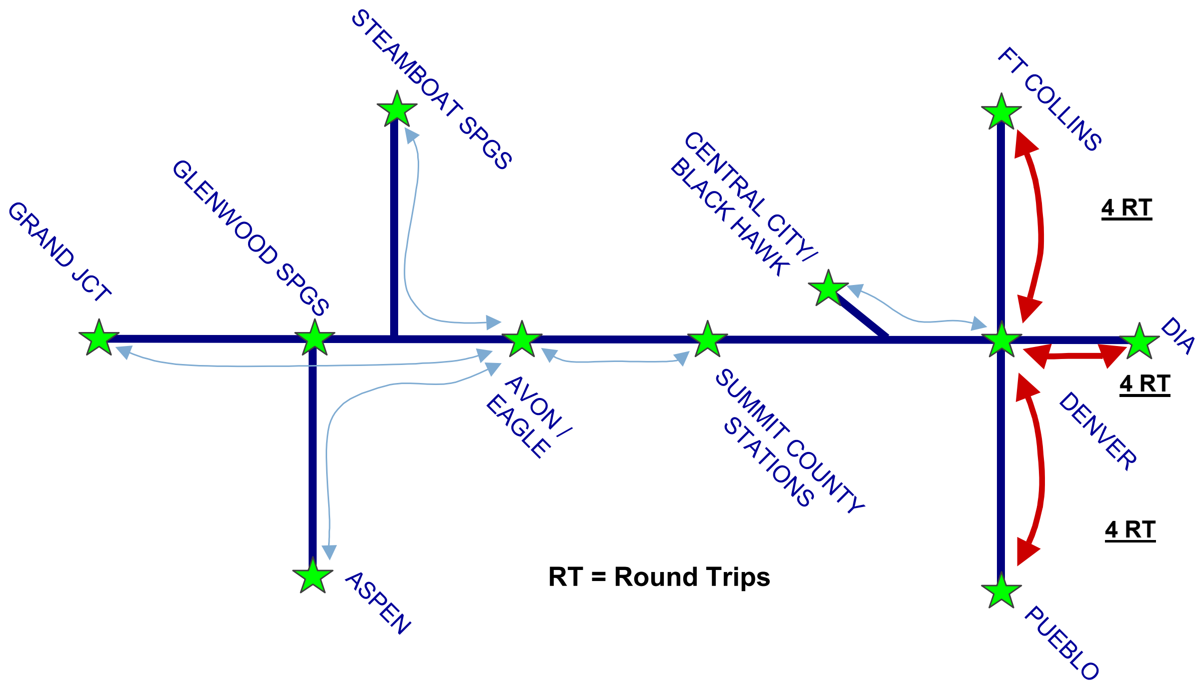


Exhibit 5-33: Train Service Pattern for 110-mph Diesel Rail Option

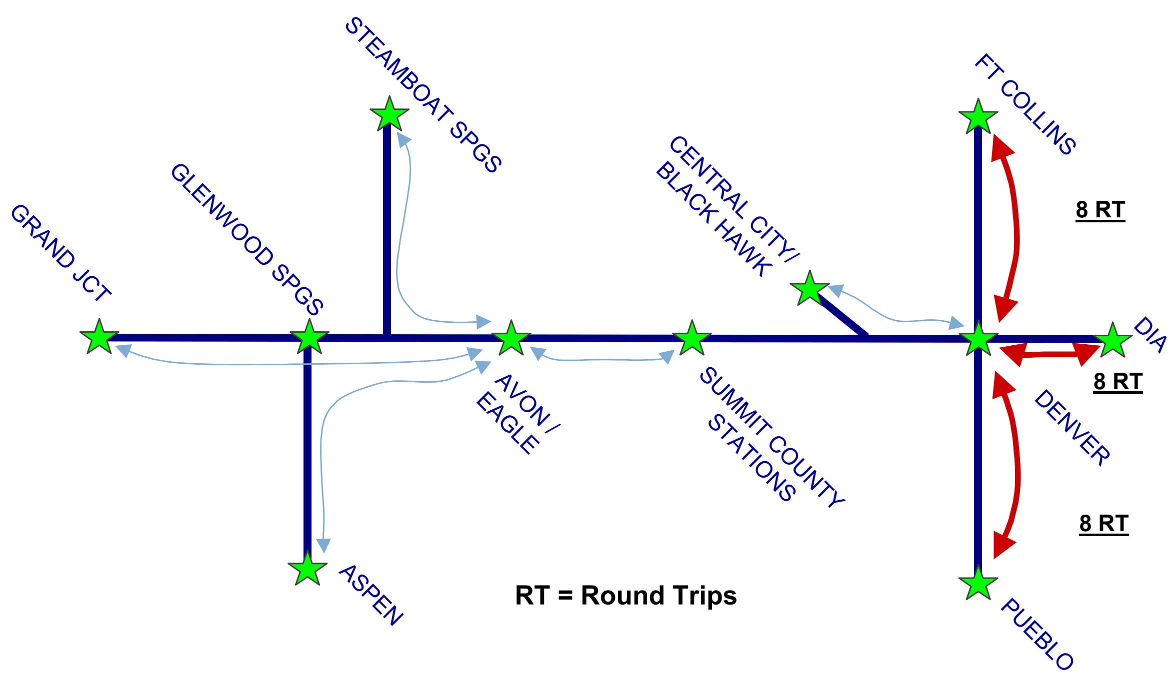


Exhibit 5-34: Train Service Pattern for 125-mph Maglev Option

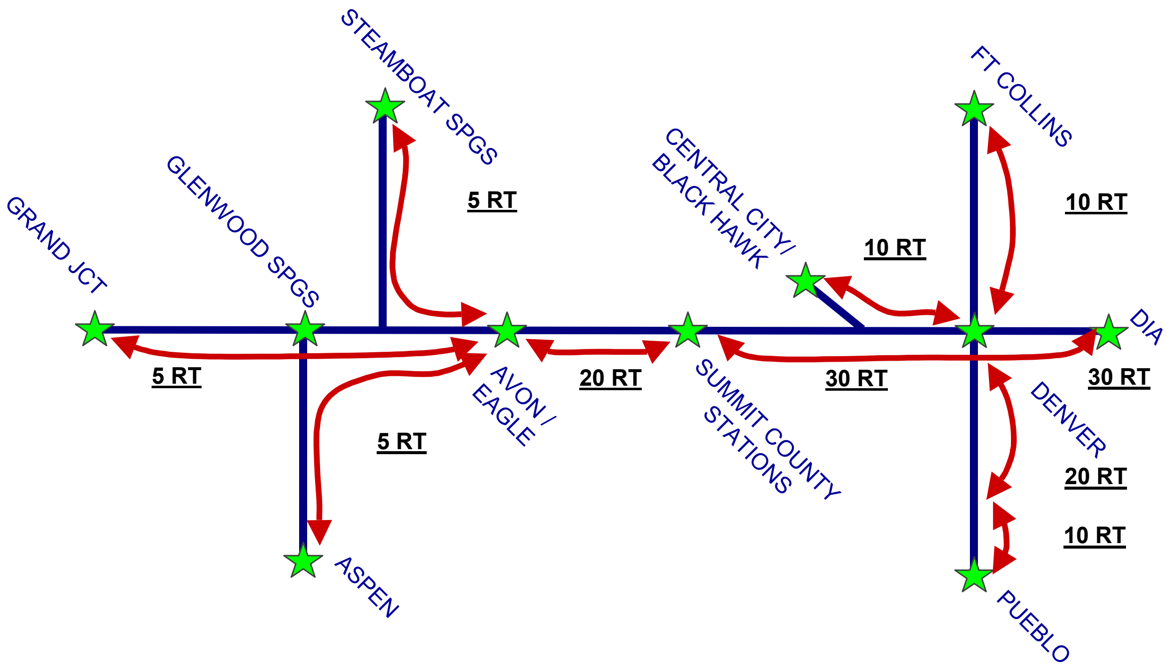


Exhibit 5-35: Train Service Pattern for 150-mph Electric Rail Option

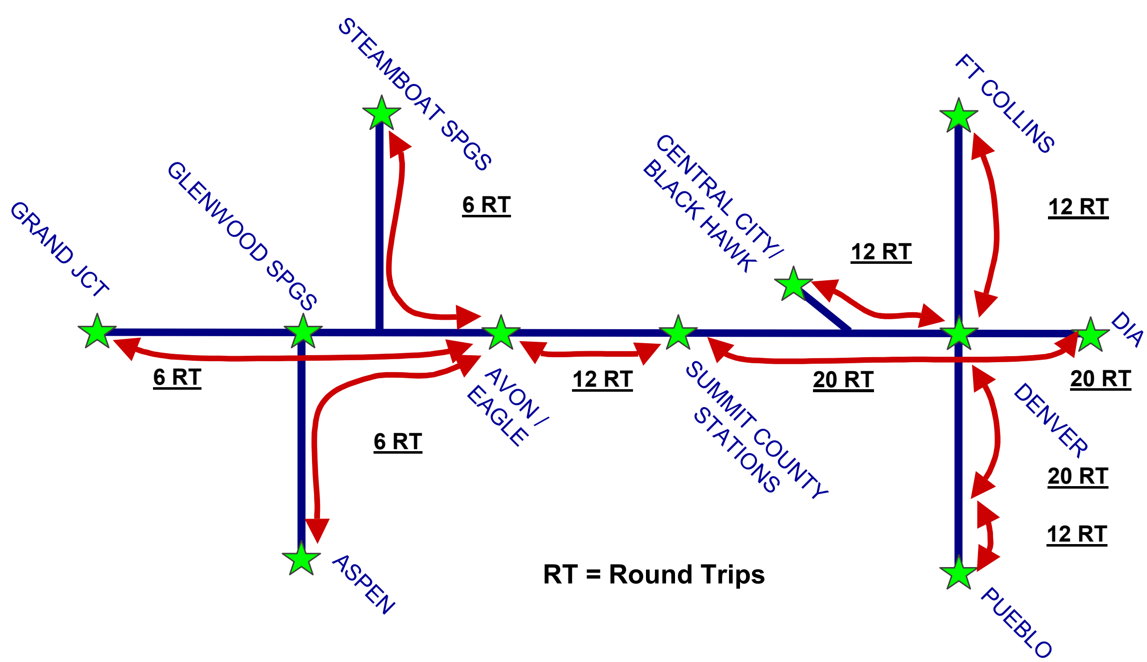


Exhibit 5-36: Train Service Pattern for 220-mph Electric Rail Option

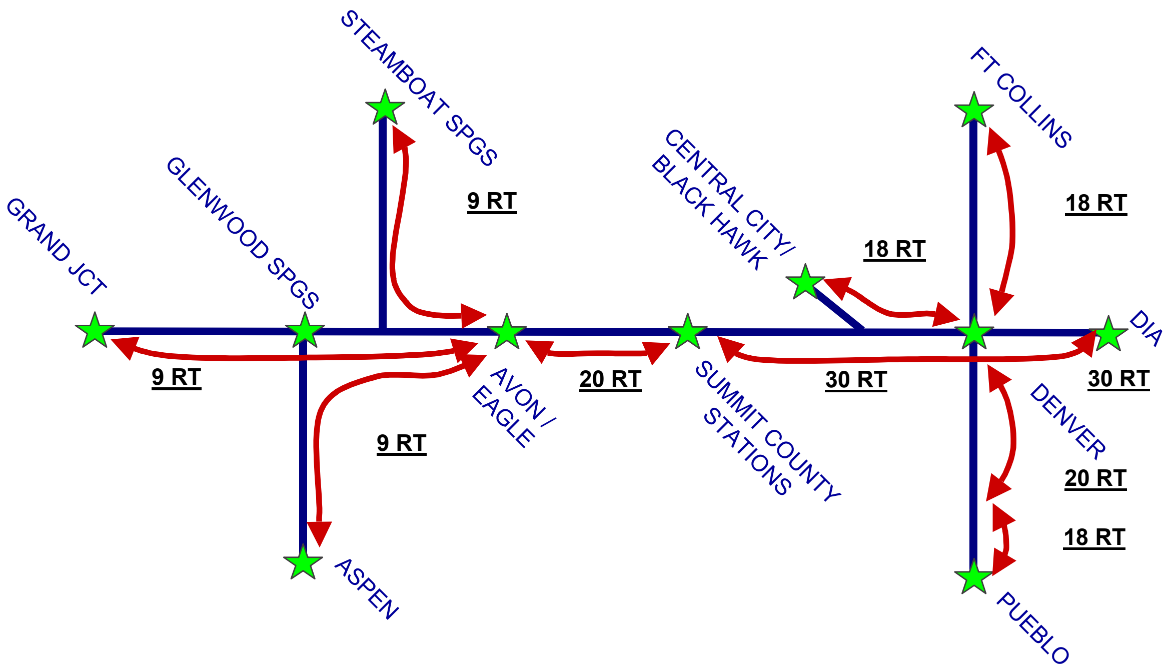
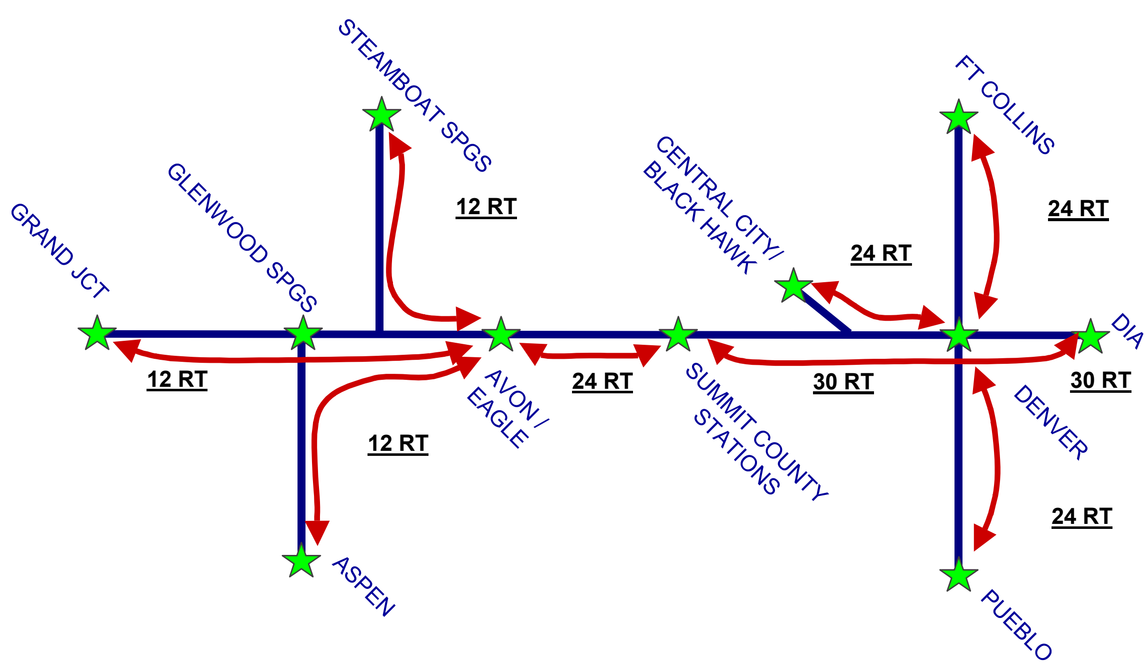


Exhibit 5-37: Train Service Pattern for 300-mph Maglev Option



5.5 Fleet Requirements

With a train timetable developed for each speed and equipment technology scenario, the fleet size can be determined (appropriate for demand) via an iterative process comprised of testing service frequencies, assessing demand, and refining frequency timetables and train consist sizes. For screening initial scenarios, a simple annual average utilization rate will suffice to estimate the required fleet size. Exhibit 5-38 summarizes the rolling stock requirements for each scenario.

In Exhibit 5-38 the number of train-miles were estimated based on the ridership forecast, an assumed pattern of operations for each technology as described in Exhibits 5-32 through 5-37, but where the train frequency assumption is adjusted each year to optimize train load factors. Accordingly additional equipment purchases are required to augment the fleet each year. The cost for these purchases has been included in the Capital plan and in the Cost Benefit ratio calculations for the system.

The maximum allowable annual mileage reflects an equipment utilization rate that is typical for passenger rail systems, and includes the reserve fleet requirement and equipment units in the maintenance shop. As a rule the utilization rate improves as speeds go up, which is reflected in the fleet size calculation shown in Exhibit 5-38.

Exhibit 5-38: 2020 Startup Fleet Requirements for Each Scenario

	Train Miles	Maximum Allowable Annual Mileage	Trainsets Required
79-mph Diesel	881,000	132,000	7
110-mph Diesel	1,762,000	167,000	11
125-mph Maglev	6,839,000	192,000	36
150-mph Electric Rail	7,030,000	192,000	37
220-mph Electric Rail	9,533,000	195,000	50
300-mph Maglev	11,766,000	195,000	61

5.6 Winterization Requirements

Either Rail or Maglev operations in the Colorado mountains imposes requirements for winterization of both the right-of-way and rail equipment. Snow, ice and cold temperatures can cause reliability problems with electrical equipment on board trains, as well as with slippery steps and platforms, frozen doors and other vehicle mechanical and electrical components.[2] For example, extremely fine snow if ingested into electrical equipment may cause short-circuits, component failure and jammed sliding doors. Amtrak has extensive experience with extreme weather conditions due to the "Lake effect" snows frequently encountered in Chicago and other parts of the Midwestern United States,

[2] See: *Rail Combats the Cold* at http://www.railway-technology.com/features/feature1526/

so Colorado is not unique in having to deal with adverse winter conditions. As a result, Amtrak has implemented specific equipment modifications for dealing with snow and ice, and has built these into its equipment specification for the proposed Midwest Regional Rail System (MWRRS) 110-mph trains.

A second requirement for reliable operations under winter conditions is to protect the infrastructure where it is needed. For example, rather than letting the line be blocked with the related infrastructure damage, trains delays and clearing expenses, it is important to provide snow sheds at all known avalanche chutes, and snow drift fences in areas known to have this problem. Switch point heaters, either electrically or oil-fired, are also commonly deployed to prevent the freezing of switch points.

The trains themselves are generally capable of clearing small amounts of accumulation from the lines, and so one key to prevent excessive accumulation is to run trains frequently. This may on occasion necessitate the operation of additional trains in the late night hours when frequencies are reduced. Such additional operations however, have only a minimal impact on operating cost since they need occur on only an occasional basis, and do not increase the required size of the train fleet that has to be maintained. For a passenger service, it is better to keep the line open by running a few additional trains at night, rather than to let snow drifts accumulate and have to use a plow to reopen the line in the morning.

While winter conditions in the mountains can be severe, the worst effects of these conditions can be largely mitigated through appropriate equipment design and infrastructure protection to ensure continued reliable operations. Because severe snowy conditions are not unique to Colorado, both the operating and capital cost of required basic winterization equipment is already included in the base unit cost of trains and infrastructure that have been assumed in this study.

5.7 Summary

This chapter focused on train operation analysis in order to develop operational plans for various technologies and route options. The *LOCOMOTION*™ model was used to estimate train running times. Since travel times and frequencies are major variables that influence passengers and revenue, timetables including travel time and train frequency, by route segment, were developed for each technology. Frequencies increased according to the level of improvement in travel time. Based on the timetables, train frequencies, and estimated number of train miles, the likely number of train sets can be estimated based on a reasonable average utilization rate.

6 Travel Demand and Forecasting

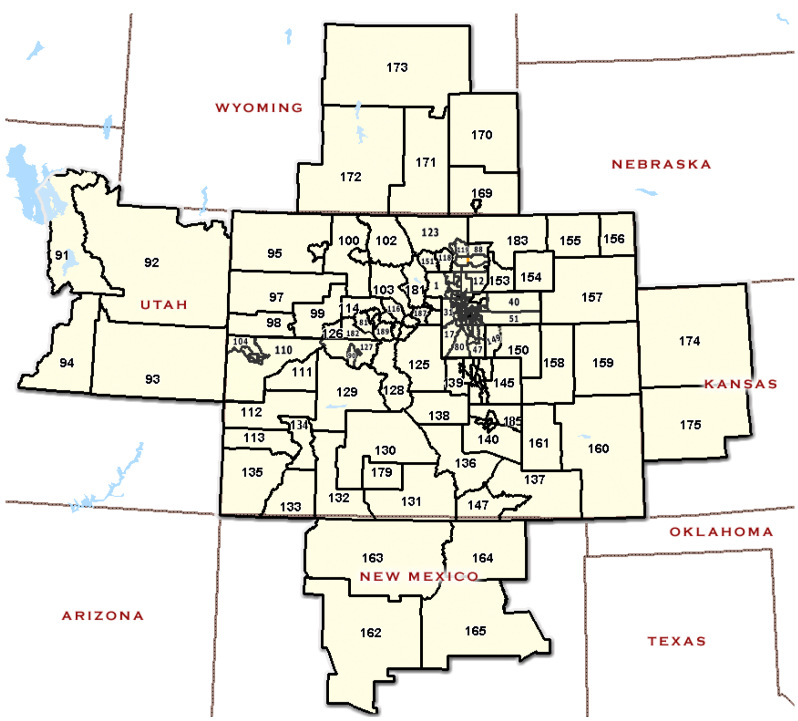
This chapter describes the major steps taken to develop the travel demand model for the RMRA high-speed rail system. The demand model predicts public responses in the RMRA study region to various rail service characteristics including train frequency, travel time, and fares.

The creation of the travel demand model for the RMRA high-speed rail study required the delineation of the study area and definition of a zone system; collection of data including stated preference survey data, socioeconomic data and origin-destination data; and development of transportation networks for the competing intercity modes of travel (auto, air, bus, and rail). (See Appendix C for more details of zones and demand forecast models)

6.1 The Zone System

An early step in developing the forecasting tool was developing the RMRA zone system to provide a precise definition of travel between the origins and destinations in the corridor. The zone system provides a reasonable representation of the market area in which travel would be served by the high-speed rail system. It covers the whole state of Colorado, as well as portions of the adjoining states of Wyoming, New Mexico, Utah and Kansas.

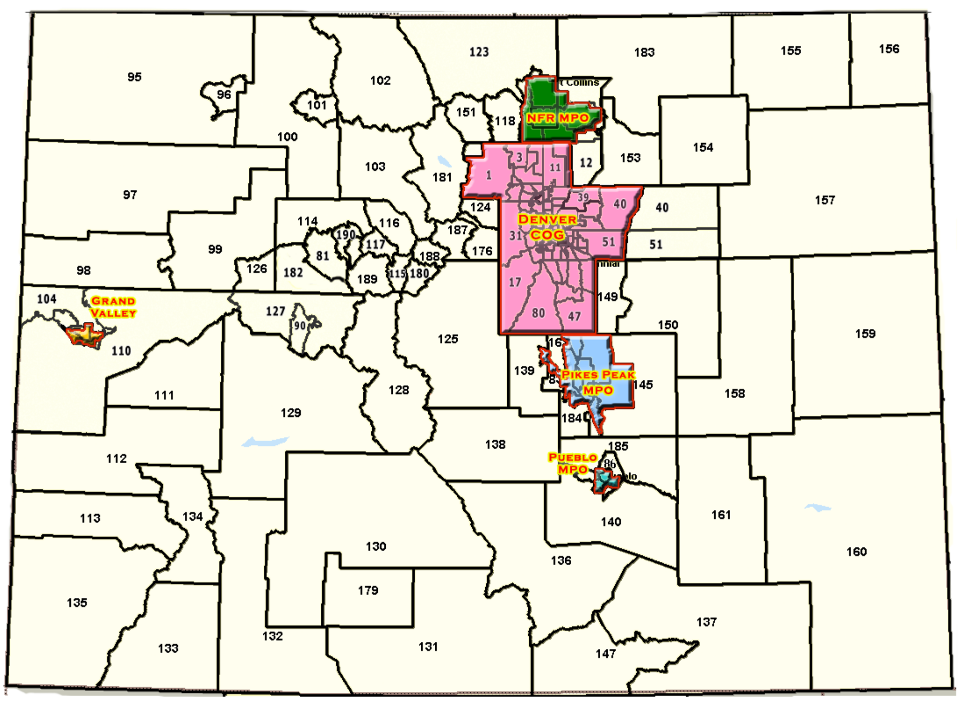
Exhibit 6-1: RMRA Zone System



The zone system of RMRA, as shown in Exhibit 6-1, is a combination of Colorado Metropolitan Planning Organization (MPO) zones for the urban areas, while for rural areas, it is predominantly county based. For both the MPO and county-based zones base year estimates were developed for population, income, and employment. These forecasts were compatible with MPOs' data, Colorado State Demography Office (Colorado SDO) and the Bureau of Economic Analysis (BEA). Zones are defined relative firstly to the rail network and secondly to the highway network. As zones move outward from populated centers, their size transitions from small to larger. For the purpose of describing the air traffic, some specific zones are designated for the airports. For example, Denver International Airport (DIA), the largest airport within the study area, has its own zone.

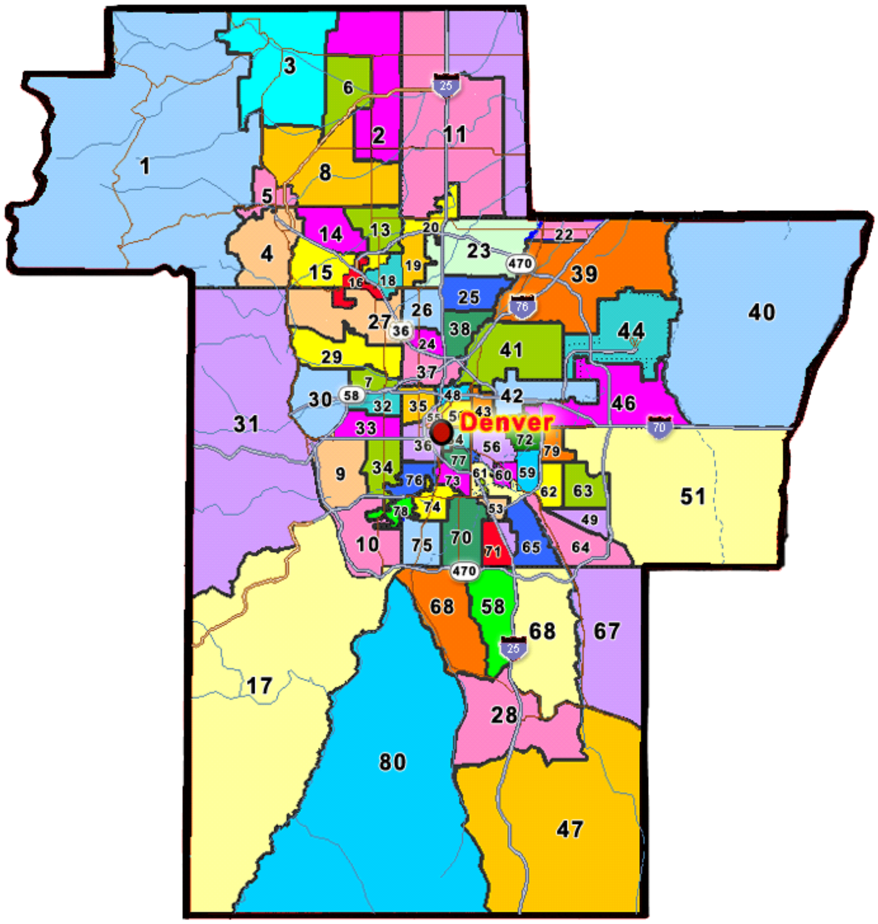
The networks and zone systems developed for the RMRA High-Speed Rail Feasibility Study were enhanced with finer zone detail in urban areas. These finer zones were based on the Traffic Analysis Zones (TAZ) for the five Colorado MPOs that are part of the study area. The whole zone system contains 194 zones within the study area boundaries and 178 within Colorado. 82 zones are based on Denver Regional Council of Governments (DRCORG) TAZ, 8 zones from North Front Range MPO TAZ, 8 zones from Grand Valley MPO TAZ, 5 zones from Pikes Peak MPO TAZ and 7 zones from Pueblo Area Council of Governments TAZ. Exhibit 6-1 shows the whole zone system (with the internal and external zones), while Exhibit 6-2 shows the zone system in Colorado only*. Exhibit 6-3 shows the zone system used for Denver area, which is an aggregation of the TAZ system of DRCOG.

Exhibit 6-2: Colorado Zone System Showing MPOs



* For different networks either "Full" or "Colorado only" zone systems were used in the RMRA study

Exhibit 6-3: DRCOG – Denver TAZ Based Zones

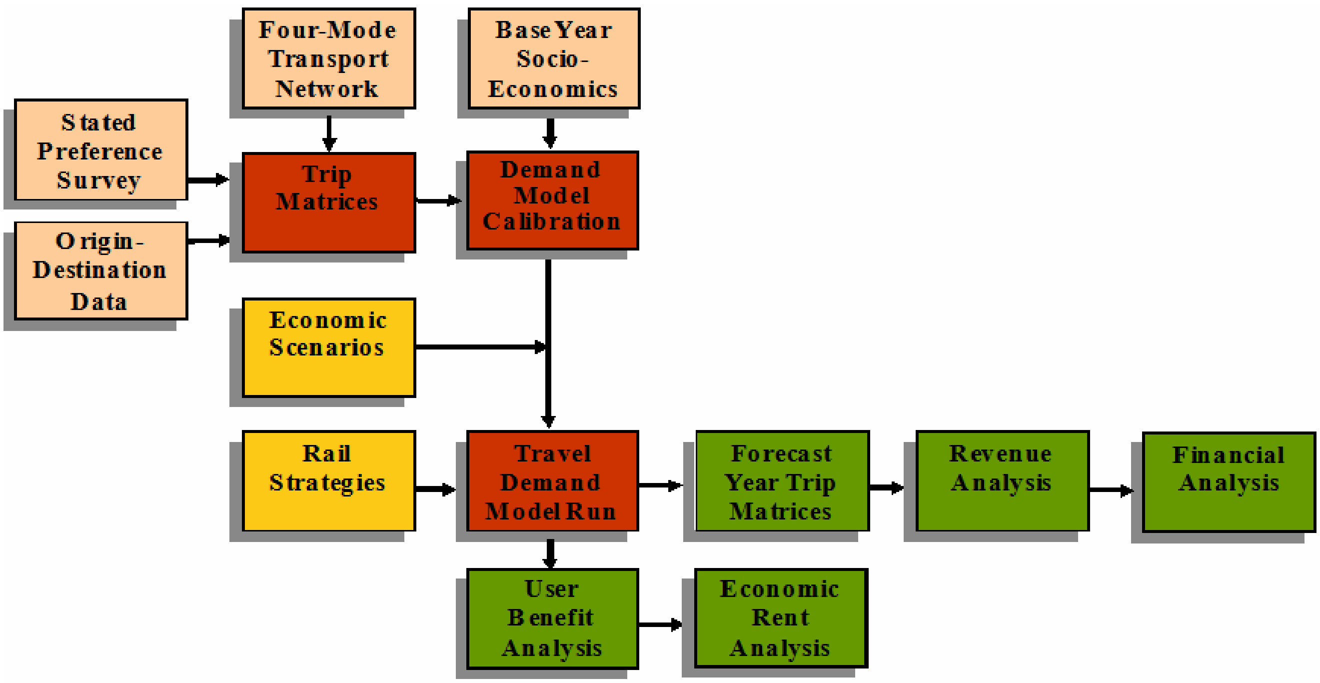


The zone system has been incorporated into the *COMPASS*™ model structure (see Exhibit 6-4), which includes four databases:

- Stated Preference Data
- Socioeconomic Database
- Origin-Destination Data
- Network Data

Each of these databases is described in the following sections of this chapter.

Exhibit 6-4: COMPASS™ Model Structure



6.2 Stated Preference Survey

Stated preference surveys provide critical insight into travel markets and travel behavior. To better understand the different trip modes, purposes, and seasonal patterns, stated preference surveys were conducted in different places and in different seasons to capture a representative sample for each type of traveler.

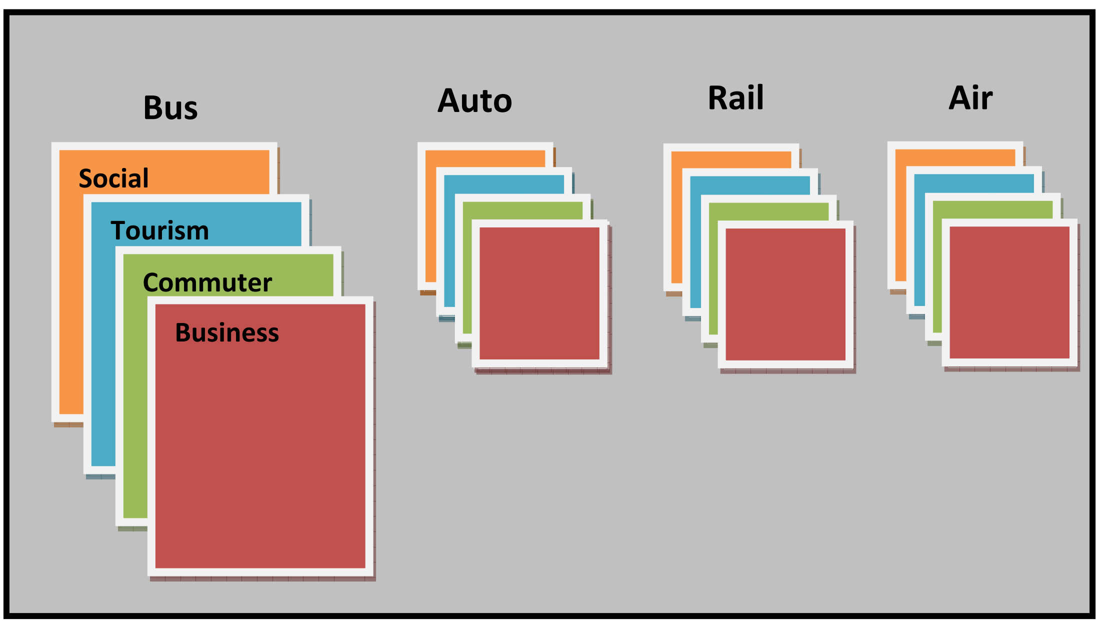
The purpose of conducting the surveys was to collect specific attitudinal data by interviewing travelers within the study region. The travelers were asked to identify how they value travel time and frequencies associated with particular modes of transportation. These values were then combined with other collected trip data and incorporated into the calibration process for the travel demand model. The calibration process adapts the model to the specific characteristics of the travel market within the RMRA study region.

6.2.1 Survey Methodology

Travel options in a stated preference survey enable respondents to consider the trade-offs among desirable travel attributes, such as time, comfort, cost, speed, and accessibility without regard to travel mode. Trade-offs included a range of service options that were presented in such a way as to induce the individuals to respond realistically without specifying a mode of travel. More specifically, stated preference surveys ask travelers to choose between a hypothetical cost and another value, such as travel time or service frequency. The choice the traveler makes demonstrates his or her preference between cost, time and other travel aspects of the rail mode. In addition to estimating the value of time and frequency, the stated preference surveys can also help to get the information that can be used to determine the trip purposes and trip modes and to evaluate origin destination flow.

The stated preference surveys for this study were conducted using a stratified or quota group sampling approach. The information collected from the respondents for a specific quota sampling category was then expanded to the overall quota sample population based on a mode and purpose basis (see Exhibit 6-5). Stratified or quota surveys, which are now widely used in commercial, political and industrial surveying, have the advantage of being relatively inexpensive to implement while providing expanded coverage and more representative results than a simple random survey.

Exhibit 6-5: Modes and Trip Purpose Basis of Stated Preference



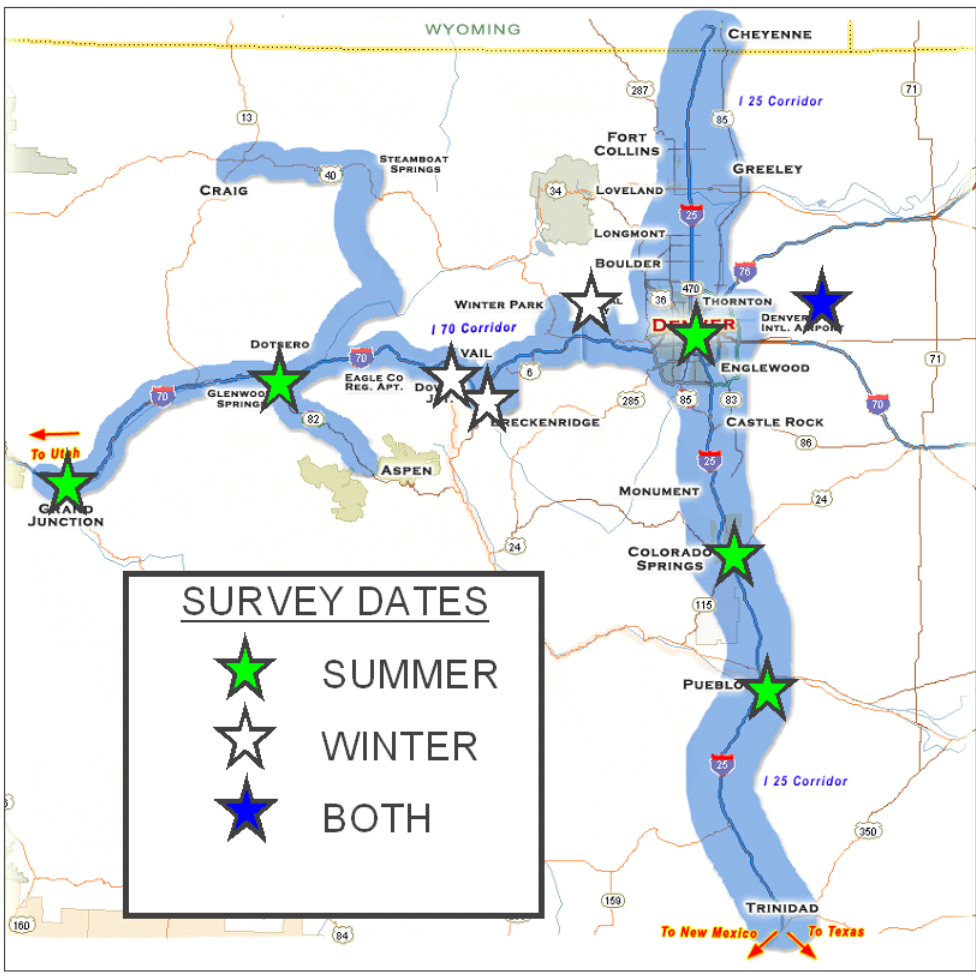
The study team developed surveys for each travel mode and purpose. Each survey collected information on an individual travel profile, origin and destination, trip purposes, demographics, as well as Stated Preference questions on values of time (VOT), values of service frequency (VOF), value of interchange and value of reliability. A minimum sample from each travel market segment (by mode and trip purpose) was required to ensure statistical confidence. Using the Central Limit

Theorem[1], it was determined that a minimum sample size of 20 to 40 participants ensures the statistical validity for each quota sample. For this study's stated preference surveys, most of desired quota targets were set at 80 or more interviews. An example of the sample survey form is shown in Appendix D.

6.2.2 Survey Implementation

Two sets of stated preference surveys were conducted at various locations within the study region in a manner designed to reach a broad sample of the potential users of an intercity passenger rail system. The first one was done in Fall 2008 and the second was done in Winter 2009. The fall survey was primarily targeted at the Colorado resident and non-seasonal tourism and the winter survey was targeted at the resorts trips and employee trip making. Exhibit 6-6 shows the locations of these surveys.

Exhibit 6-6: Locations of Surveys



1 The Central Limit Theorem states that the sampling distribution of the mean of any distribution with mean μ and variance σ^2 approaches a normal distribution with mean μ and variance σ^2/N as N the sample size increases. Spiegel, M.R., Theory and Problems of Probability and Statistics, NY McGraw Hill, pp. 112-113, 1992

Approximately 3,659 surveys were completed. The Exhibit 6-7 shows the target number of each sub-group by trip mode and trip purpose and the actual number of surveys received. Based on this Exhibit, most of groups attained their target values; ensuring the integrity of the sample frame. The surveys were conducted by using random walk face-to-face interview techniques. The surveys captured data from a broad mix of business travelers, tourists and resident leisure travelers.

Exhibit 6-7: The Target /Actual Number of Surveys

	Business	Commuter	Social	Tourist	Total
Rail	0 / 9	0 / 2	80 / 68	160 / 140	240 / 219
Air Access	80 / 391	80 / 13	80 / 433	80 / 480	320 / 1317
Bus	80 / 47	160 / 180	160 / 119	80 / 101	480 / 447
Auto	160 / 260	160 / 171	80 / 489	160 / 746	560 / 1666
Total	320 / 707	400 / 366	400 / 1109	480 / 1467	1600 / 3659

Air mode surveys were conducted at DIA both in winter and fall. The fall surveys targeted passengers flying directly to or from DIA and excluded connecting passengers, while the winter surveys focused on intrastate flights, such as to and from Colorado Springs, Aspen, and captured mostly connecting passengers.

The auto mode surveys were conducted at the Division of Motor Vehicles of Colorado Department of Revenue and its offices in the cities of Parker (Full Service Office, 17737 Cottonwood Drive), Colorado Springs (Full service office, Austin Bluffs Pkwy), Pueblo (Full service office, Abriendo Ave), Grand Junction (Full Service office, 6th St.) and Glenwood Springs (Full service office, Glenwood Springs Mall). In winter, surveys were carried out at the resort areas of Vail, Breckenridge, and Central City.

Rail mode surveys were conducted at the Amtrak stations before passengers boarding on trains. The surveyed stations included Denver Union Station, Grand Junction, and Glenwood Springs.

Bus mode surveys were conducted at stations of RTD, Greyhound and Front Range Express (FREX), which cover the both long and short distance bus trips.

6.2.3 Survey Demographic Characteristics

It was found in the survey that there were distinctly different travel and demographic differences on a modal basis. For example, among air passengers, about 30 percent are business trips, while only 4 percent of rail trips (Amtrak) are business trips, as shown in Exhibit 6-8.

Exhibit 6-8: Trip Purposes by Modes

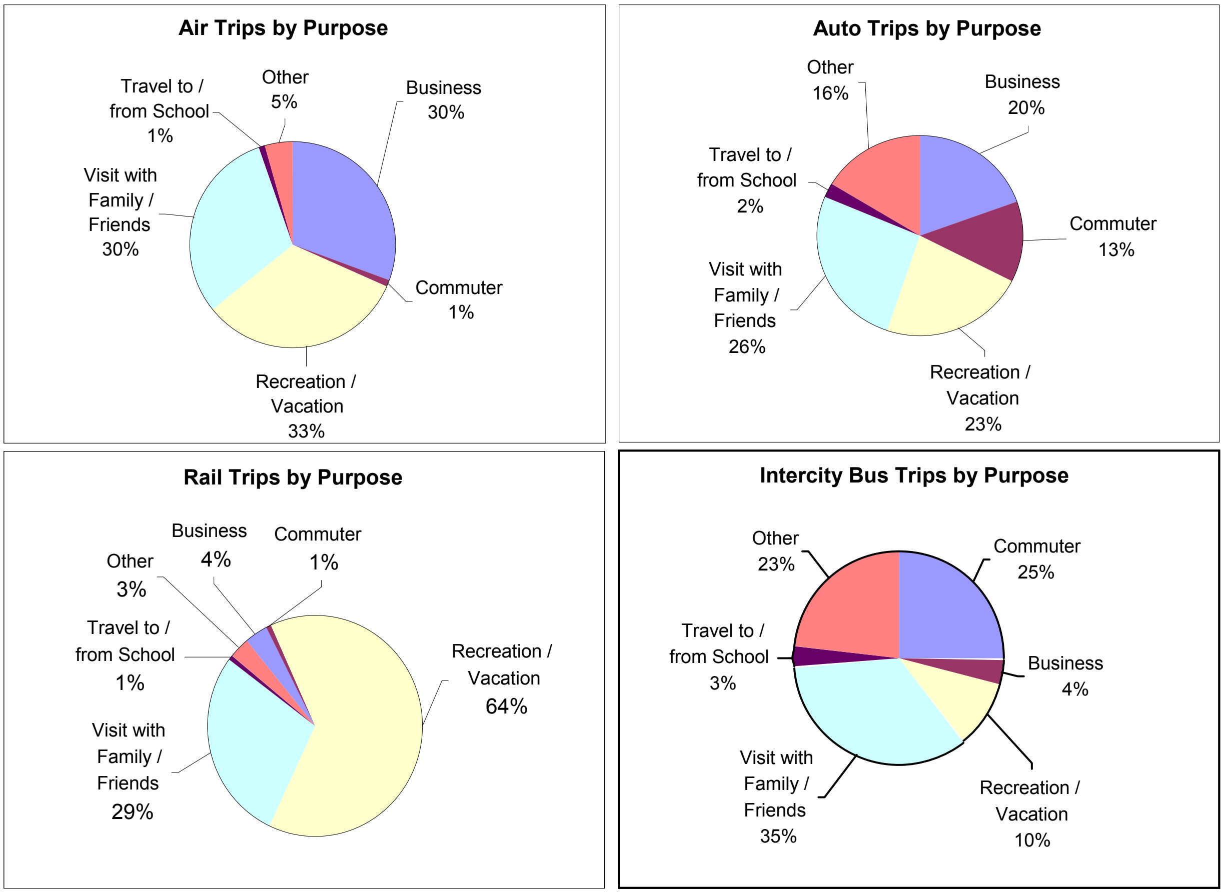
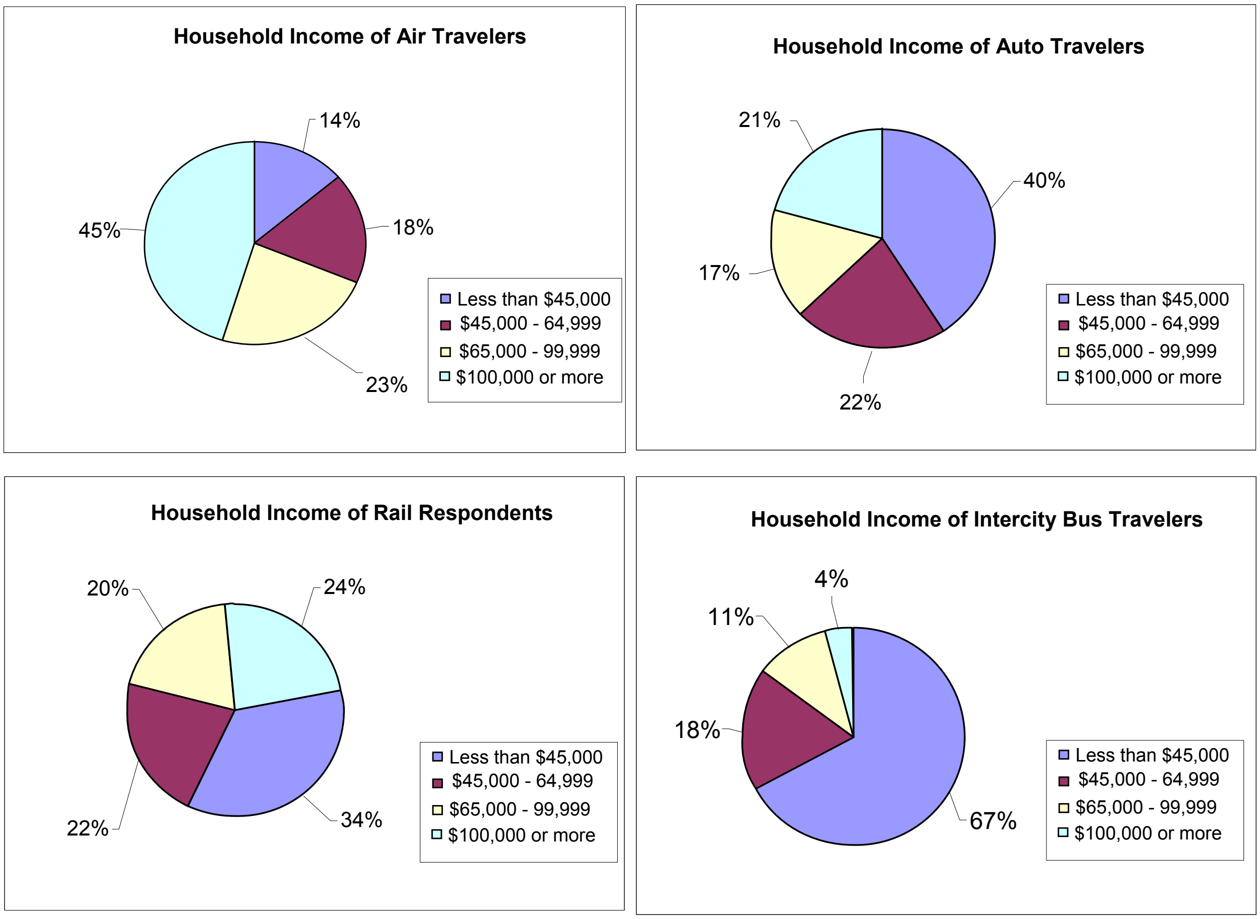


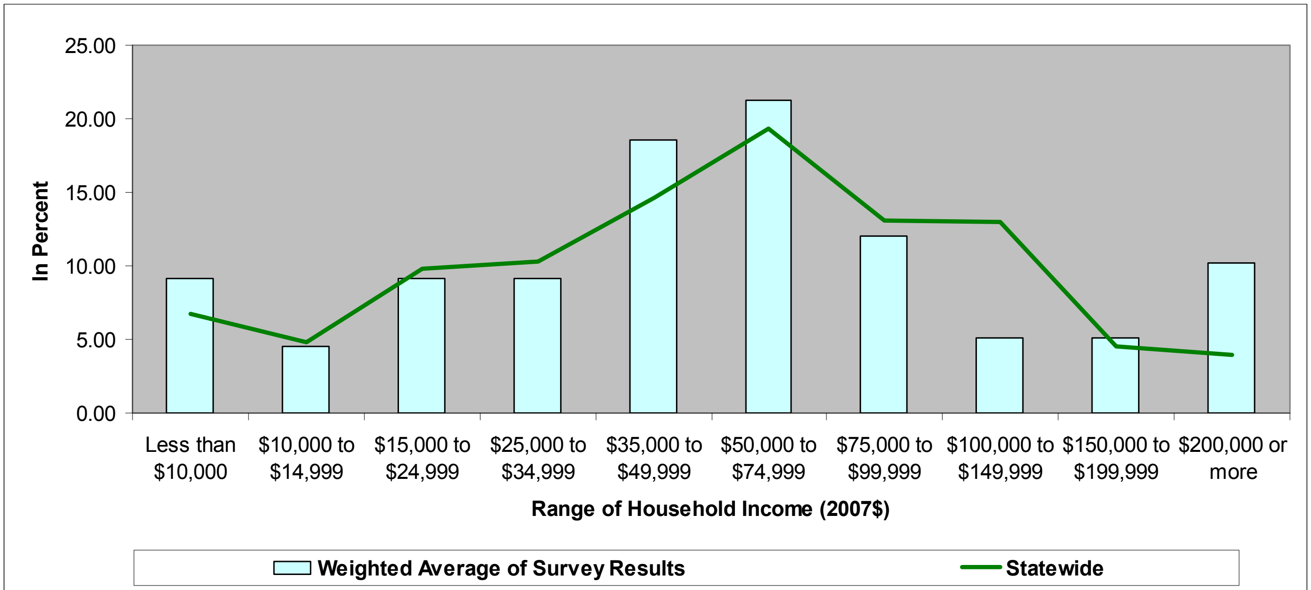
Exhibit 6-9: Household Income by Modes



Air passengers generally have the highest income, rail and auto passengers have the medium income while bus passengers have the lowest income (See Exhibit 6-9).

A comparison of the results of the stated preference survey household income data with the statewide data shows that the income distributions by mode are representative of statewide data (see Exhibit 6-10). A statistical T test shows the income distribution of the modal data from the survey (when combined appropriately by being weighted) is equivalent to the statewide distribution. This means that the database will be representative of statewide value of time. As a result, there was no need of further adjustments to make the data an effective representation of statewide values for VOT, VOF, etc.

Exhibit 6-10: Comparison of Household Income Distribution



Source: TEMS, Inc. and U.S. Census Bureau, 2005-2007 American Community Survey

6.2.4 Value of Time and Value of Frequency by Trip Purpose and Mode

Exhibit 6-11 and Exhibit 6-12 illustrate the different values of time and values of frequency expressed by four trip purposes in the various modes.

Exhibit 6-11: Value of Time by Trip Purpose and Mode ($/hour)

Mode	Trip Purposes			
	Business	Commuter	Tourism	Social
Bus	13.20	10.92	11.39	11.60
Rail	16.07	17.50	17.65	15.92
Auto	18.91	18.95	18.86	17.69
Air	48.69	35.73	33.34	34.69

Exhibit 6-12: Value of Frequency by Trip Purpose and Mode ($/hour)

Mode	Trip Purposes			
	Business	Commuter	Tourism	Social
Bus	6.79	6.27	7.08	6.22
Rail	12.88	10.00	14.65	13.31
Air	18.13	21.10	16.75	18.29

As shown in Exhibit 6-11 and Exhibit 6-12:

- The value of time and value of frequency of air mode are higher than those of other modes. The bus mode has the lowest value of time and value of frequency.
- The business traveler and commuters usually place higher values on travel time.
- Compared with other trip purposes, tourism and social trips have lower VOT and VOF.

6.2.5 Comparison with Other Studies

Exhibit 6-13: Comparison of VOT ($/Hour)

Mode	Colorado		Midwest Regional Rail Initiative		Cleveland Hub	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Air	48.69	34.59	55.12	27.56	79	31
Auto	18.91	18.50	22.58	15.86	26	19
Bus	13.20	11.30	N/A	9.66	16	11
Rail	16.07	17.02	25.22	18.61	33	16

Exhibit 6-13 provides a comparison of values of time by mode and trip purpose for this study with the values generated for the MWRRI and the Cleveland Hub Study. It is noted that values of time of business trips for this study are lower than those for the MWRRI and Cleveland Hub Study, but the pattern are similar: value of time for air mode is the highest followed by auto and rail while the values for bus are the lowest. Business trips have higher VOT, while non-business trips have lower VOT.

6.3 Socioeconomic Baseline and Forecasts

Forecasting travel demand between the model's zones required base year estimates and forecasts of three socioeconomic variables – population, employment and household income – for each of the RMRA model zones. To allow for assessment of the financial and operational feasibility of the system over its full life cycle, socioeconomic variables were forecasted through 2045.

The base year socioeconomic data and forecast for the study area were derived from the Bureau of Economic Analysis, Colorado State Demography Office, and MPOs. Since the official projections available are only to 2035, the projections after 2035 were made by trend extrapolation.

Using these sources, each zone was treated as an independent unit in the income, population and employment forecast. Given the different projections from various sources, three projection (High, Central, Low) scenarios are used. The forecast of ridership, revenue and other results will be different if different socioeconomic projection scenarios are used.

Exhibits 6-14 through 6-16 summarize the base year 2005 and projections of socioeconomic data (population, employment and income) for the study area.

Exhibit 6-14: Summary of Base and Projected Socioeconomic Data: Population (in Million)

Projection Scenarios	2005	2007	2010	2015	2020	2025	2030	2035	Ave. Annual Growth Rate 2005 - 2035
High Case	4.67	4.86	5.23	5.85	6.47	7.10	7.74	8.38	2.0%
Central Case	4.67	4.86	5.24	5.75	6.30	6.90	7.42	8.04	1.8%
Low Case	4.67	4.86	5.15	5.67	6.20	6.71	7.20	7.66	1.7%

Exhibit 6-15: Summary of Base and Projected Socioeconomic Data: Employment (in Million)

Projection Scenarios	2005	2007	2010	2015	2020	2025	2030	2035	Ave. Annual Growth Rate 2005 - 2035
High Case	2.35	2.48	2.72	3.11	3.43	3.69	4.00	4.27	2.0%
Central Case	2.35	2.48	2.72	3.05	3.34	3.59	3.84	4.11	1.9%
Low Case	2.35	2.48	2.69	3.02	3.30	3.50	3.73	3.92	1.7%

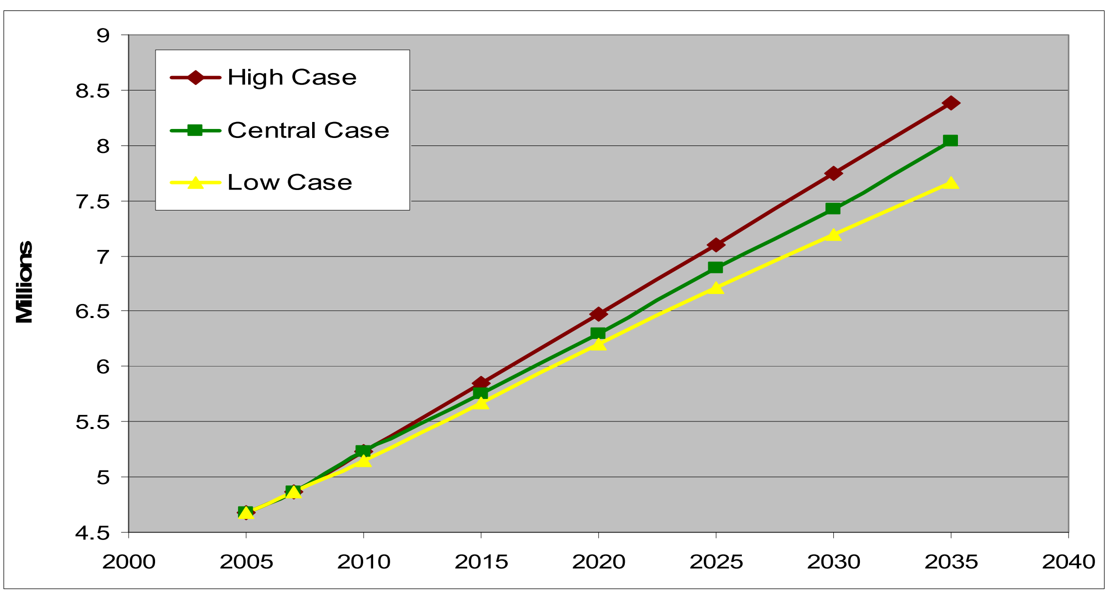
Exhibit 6-16: Summary of Base and Projected Socioeconomic Data: Average Household Income (in Thousand $2007)

Projection Scenarios	2007	2010	2015	2020	2025	2030	2035	Ave. Annual Growth Rate 2007 - 2035
High Case	68.483	73.87	80.03	84.31	87.59	91.31	95.04	1.2%
Central Case	68.483	72.45	78.17	81.25	84.36	87.39	90.55	1.0%
Low Case	68.483	71.46	72.48	74.92	77.23	79.42	81.58	0.6%

Note: future data adjusted for inflation and is in 2007 dollars

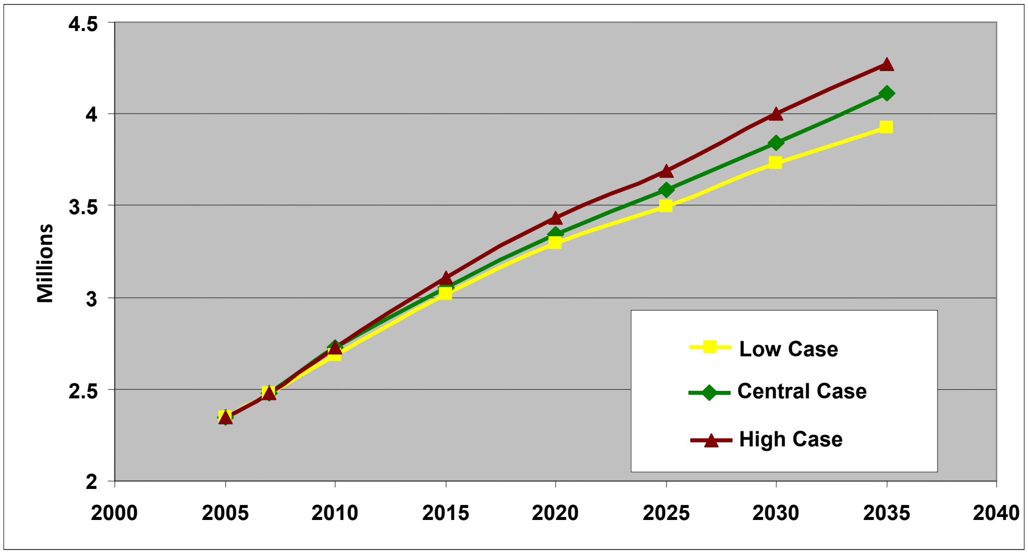
Exhibits 6-17 through 6-19 show that the population and employment in Colorado will increase rapidly, faster than household income. From 2007 to 2035 under central case, the population and employment are expected to increase by 65 percent and 66 percent due largely from immigration from the Midwest and California; at the same time the increase in household income is 32 percent. This suggests that the spending power of travelers will increase by 32 percent, and individuals will enjoy increased disposable income. Given these facts, socioeconomic growth will play an important role in the growth of traffic demand.

Exhibit 6-17: Colorado Population Projections



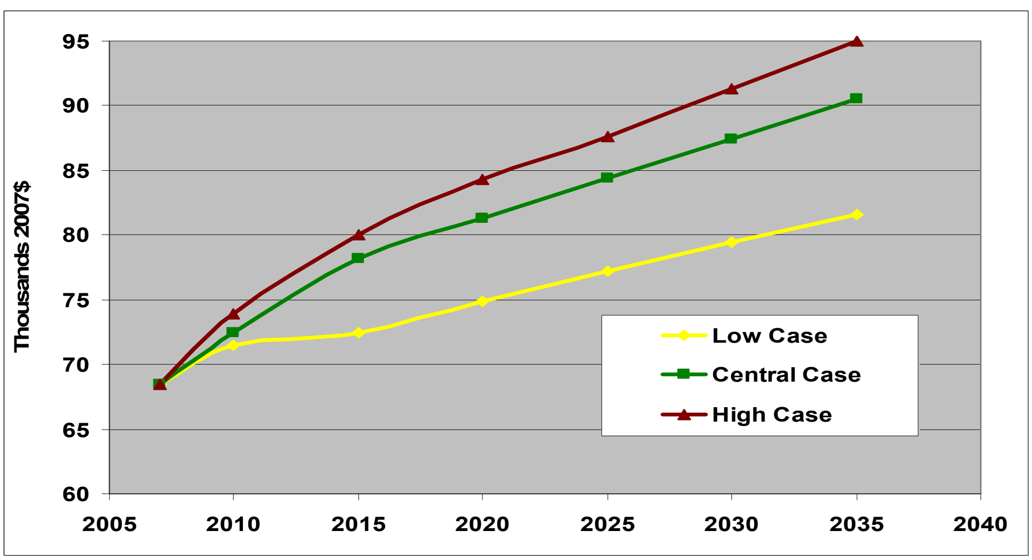
Source: BEA (www.bea.gov) , Colorado SDO (www.dola.state.co.us/demog/), DRCOG, Pikes Peak Area COG, North Front Range MPO, Grand Valley MPO and Pueblo Area COG.

Exhibit 6-18: Employment Projection



Source: BEA (www.bea.gov), Colorado SDO (www.dola.state.co.us/demog/), DDCOG, Pikes Peak Area COG, North Front Range MPO, Grand Valley MPO and Pueblo Area COG.

Exhibit 6-19: Household Income Projection



Source: BEA (www.bea.gov) and TEMS Inc.

6.4 Transportation Networks

In transportation analysis, travel impedance (i.e., the disabilities experienced by travelers) is measured in terms of cost and travel time. These variables are incorporated into the basic transportation network elements. Correct representation of the networks is vital for accurate forecasting. Basic network elements are called nodes and links. Each travel mode consists of a database comprised of zones, stations or nodes, and connections or links between them in the study area. Each node and link is assigned a set of attributes. The network data assembled for the study included the following attributes for all the zone links:

- For public travel modes (air, rail and bus):
  - Access/egress times and costs (e.g., travel time to a station, time/cost of parking, time walking from a station, time/cost of taking a taxi to the final destination, etc.)
  - Waiting at terminal and delay times
  - In-vehicle travel times
  - Number of interchanges and connection times
  - Fares
  - On-time performance
  - Frequency of service
- For private mode (auto):
  - Travel time, including rest time
  - Travel cost (vehicle operating cost)
  - Tolls

The auto network was developed to reflect the major highway segments within the study area. The Internal Revenue Service (IRS) Standard Mileage Rate was used to develop the auto network. The values provided by the IRS consist of an average cost of 40.5 cents per mile for Business and 13 cents per mile for Commuter, Tourism and Social travelers. The Business figure reflects the IRS estimate of the full cost of operating a vehicle because a business traveler is usually able to expense the full cost for the use of an auto. Other costs are set at a marginal cost, which reflects how most social travelers perceive what their car costs to operate.

Air network attributes contain a range of variables that include time and distances between airports, fares, on-time performance measures and connection times. Travel times and frequencies were derived from the Official Airline Guide (OAG). For travel time, the study team obtained the non-stop, shortest-path distance between airports. Airline fare information was provided by the official websites of major airlines (e.g. www.frontierairlines.com, www.southwest.com) serving airports in the study area.

Bus network attribute data such as fares, routes and schedules, were obtained from the carrier websites and schedule book (*e.g.*, Greyhound).

The rail network was developed using 2007 Amtrak schedules that provided travel times and distances for the routes within the study area (www.amtrak.com). Fare-by-mile information was also obtained from Amtrak and was applied to the corridors based on their respective average fare by mile.

6.5 Origin-Destination Data

The multi-modal intercity travel analysis developed from the *COMPASS*™ model required the collection of origin-destination (O-D) data describing annual passenger trips between zone pairs. For each O-D zone pair, the annual passenger trips were broken down by transportation mode (auto, air, rail and bus) and by trip purpose (*Business, Commuter, Tourism and Social*). The *COMPASS*™ model is described in the Appendix B.

Because the goal of the study was to evaluate intercity travel, the O-D data collected for the model reflected travel between zones (*i.e.*, between counties, neighboring states and major urban areas). Local travel (short distance trips under 55 miles) was excluded from the analysis, as they are not true intercity trips, and thus are not considered to be part of the potential intercity passenger rail market.

TEMS extracted and aggregated data from the sources shown in Exhibit 6-20 to estimate base year travel between city-pairs. Data was acquired by mode, and where necessary a simulation process was used to fill holes in the O-D matrix and to provide a distribution of trips to zones where the data was at the more aggregate level of the rail station, bus terminal or airport.

Exhibit 6-20: Sources of Total Travel Data by Mode

Mode	Data Source	Description	Data Enhancement Required
Rail	Amtrak Station Data	Station Passenger Volume	Access/Egress Simulation
Air	Denver International Airport	Airport-to-airport passenger volume	Access/Egress Simulation
Bus	Bus Schedules; National Transit Database	Counts to estimate bus load factors, simulate passenger volume	Access/Egress Simulation
Auto	MPO O-D tables and EIS[1] studies (I-70 PEIS[2] and I-25 North EIS)	MPO highway and urban traffic studies	Trip Simulation for Door-to-Door Movement

[1] EIS - Environmental Impact Statement
[2] PEIS - Programmatic Environmental Impact Statement

Access/egress simulation refers to the need to identify the final origin and destination zones for trips via rail, air and bus that were provided at a non-aggregate terminal level. Otherwise, all non-auto trips would appear to begin at the bus or rail terminal or airport zones. Distribution of access and egress trips to zones was accomplished by locating zone centroids at population centers in origin and destination zones, and then distributing trips to centroids using trip length data obtained from either the Stated Preference Survey, or the partial matrices provided by MPOs.

6.5.1 Rail Mode

Given the schedule of Amtrak and the capacity of trains, rail O-D trips were estimated by a simulation of trip volumes against generalized cost and socioeconomic parameters such as income, population and employment. The generalized cost data between zone centroids was obtained from the networks that were built on a mode and purpose base (see Section 6.4). The results were balanced against boarding and alighting data at Amtrak stations within the study area.

6.5.2 Air Mode

The airport-to-airport passenger volumes within the Colorado were extracted from an internal DIA report. Door-to-door O-D trips were estimated using an access/egress simulation that related travel volume by zone to generalized cost and socioeconomic factors.

6.5.3 Bus Mode

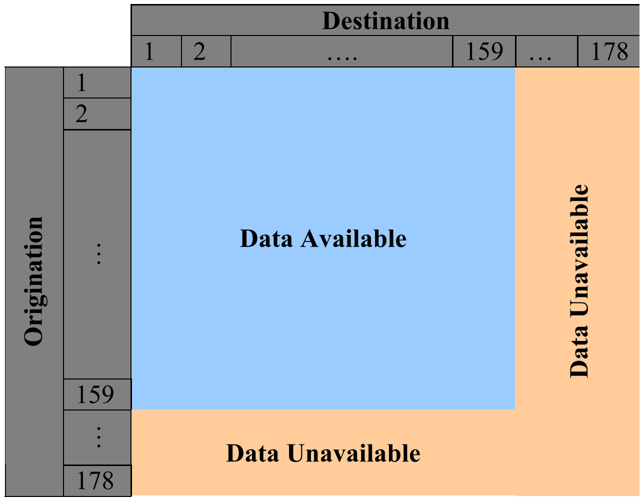
The I-70 PEIS and DRCOG have the trip tables for bus modes. An access/egress model similar to that used in rail mode was calibrated based on the trip tables and socioeconomic characteristics (e.g., population, employment and income) of the zones. This calibrated model was applied to other zones to get the trips for zones outside the I-70 PEIS and DRCOG area. The forecast results were checked against the schedules and capacities of Greyhound, RTD, FREX and other transit carriers.

6.5.4 Auto Mode

The O-D sources for auto mode include: the O-D trip tables provided by MPOs, and the O-D trip tables from I-70 PEIS and I-25 North EIS. The trips inside each MPO study area can be obtained from the trip tables of each MPO. The I-70 PEIS and I-25 North EIS cover most of the study area. The remaining trips outside these areas were estimated using a statistical relationship of trip volumes against generalized cost and socioeconomic factors established from the known zone pair O-D flows.

Exhibit 6-21 shows the coverage of existing intercity auto trips in Colorado. This exhibit shows the bulk of the zones, population and trips are covered by available data from five Colorado MPOs and EIS studies (e.g., 95 percent of trips). The missing 5 percent of trips were estimated using the relationship between zone pair trip volumes for the existing data, and the generalized cost and socioeconomic data for each zone. The estimated data combined with the existing data was then used to create a full base year trip matrix. Exhibit 6-22 summarizes the base year trips for each mode. The simulation to local zones was based on the same type of relationship used in the Total Demand Model. This relates the trips between zones to the generalized cost of travel between the zone pairs and the socioeconomic characteristics of the zone pair. See Appendix B.

Exhibit 6-21: Coverage of Existing Colorado Intercity Trips (> 55 miles)



	Total	Existing Data	Percentage Covered
Zones	**178**	**159**	**79.79%**
Population	**4.9 Million**	**4.6 Million**	**93.70%**
Trips per year	**100 Million**	**98 Million**	**95.5%**

Exhibit 6-22: Base Year Trips by Mode

Mode	Car	Bus	Air	Rail
Trips	100,200,000	2,960,000	150,503	52,000
Market Share	96.94%	2.86%	0.15%	0.05%

6.5.5 Model Validation

For auto trip data, validation was done by comparing the O-D trip matrices with the AADT of CDOT at five key segments in the I-70 and I-25 corridors. The five key segments are sufficient because less than 5 percent of original rail trips were generated outside the Ft. Collins to Denver to Pueblo, and DIA to Eagle Airport segments. As a result, the five key segments are sufficient to validate the relevant trips that will affect future demand forecast.

Exhibit 6-23 shows the comparison at the key locations along the I-70 and I-25 corridors. It can be seen that the base year modeled flows are close to the actual counts. The difference is mainly due to the distance between the position of milepost and the boundary of the zone defined by TEMS. The more distant the zone boundary is from the milepost, the more trips will be underestimated. This is because the farther the boundary is from the milepost, the more intra-zonal trips that are not included in the trip table. For air, bus and rail, the zonal trip volumes were balanced against the terminal (e.g., airport) volumes shown in the source data.

Exhibit 6-23: Comparison of CDOT AADT with *COMPASS*™ Estimate

Location	AADT	*COMPASS*™ Estimate	Difference	AADT MP to Zone Boundary
I-70: Idaho Springs	40,600	37,740	7.1%	1.69
I-70: EJMT	32,300	27,306	15.5%	2.41
I-70: Eagle	24,000	20,426	14.9%	2.56
I-25: Fort Collins	65,100	58,962	9.5%	2.18
I-25: Castle Rock	92,700	85,302	7.9%	1.46

6.6 Modeled Rail Network Strategies

As described in Chapter 5, rail ridership forecasts were developed for the six high-speed rail technology and route combinations. The six forecast technology strategies are described in Exhibit 6-24.

Exhibit 6-24: Alternative Rail Options Evaluated

Option	Route	Technology
79 mph	Existing Rail (I-25 only)	79-mph Diesel
110 mph	Existing Rail (I-25 only)	110-mph Diesel
125 mph	I-25 Greenfield/I-70 Right-of-Way	125-mph Maglev
150 mph	Existing Rail/Unconstrained I-70	150-mph Electric
220 mph	I-25 Greenfield/I-70 Right-of-Way	220-mph Electric
300 mph	I-25 Greenfield/I-70 Right-of-Way	300-mph Maglev

Schedule frequency and fare are two of the key inputs to the *COMPASS*™ model. The ridership forecasts presented in this chapter are based on the frequencies and fare levels identified in Exhibit 6-25 and were developed as described in Chapter 5. Fares were optimized to maximize the revenue yield.

Exhibit 6-25: Frequency and Fares of Options Evaluated

Option	Frequency (per day)	Fare (cents per mile)
79 mph	4	20
110 mph	8	28
125 mph	10	30
150 mph	12	32
220 mph	18	35
300 mph	24	38

6.7 Other Modeled Mode Network Strategies

For the purpose of analysis the air mode fares and frequencies were held constant due to the lack of information on future air service scenarios and the small intra-state, intercity market share of the air mode. Auto and bus were subject to two sets of limitations – congestion and gas prices, each described below.

6.7.1 Congestion

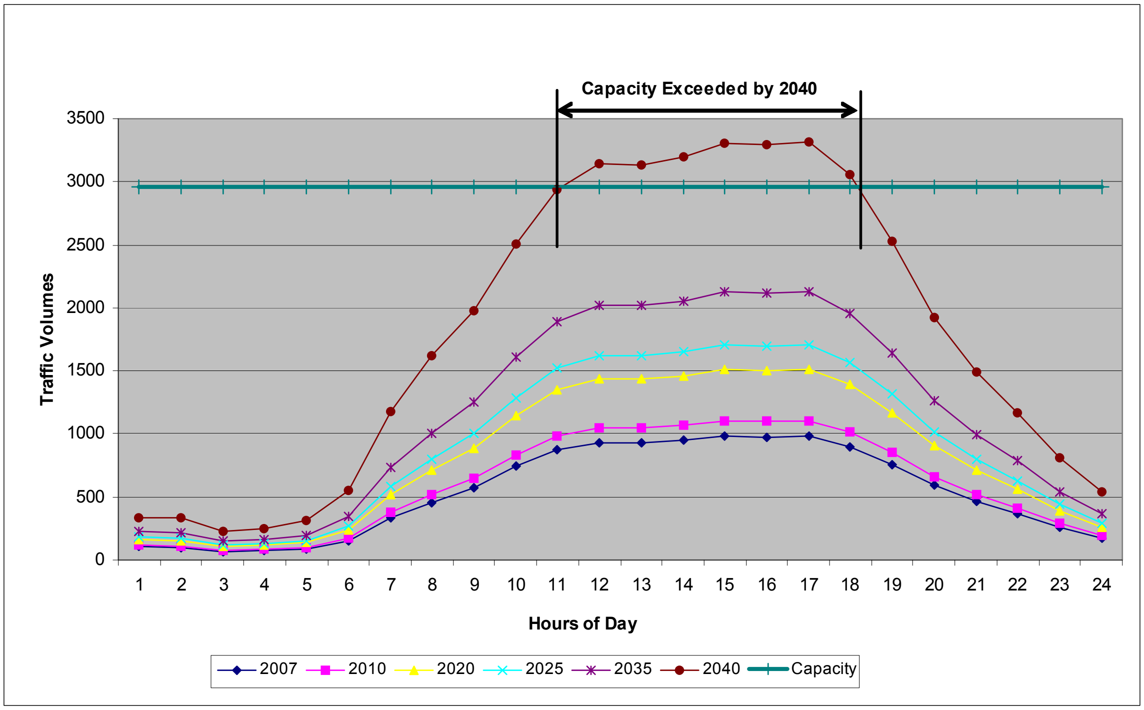
Like many other corridors in the U.S., the I-70 and I-25 corridors are subject to significant congestion. This is due to the growth in the region's economy and population. In the next thirty years, the region's population is likely to nearly double, and since highway construction will not increase at the same rate, highway congestion will increase. This will be largely for commuter and daily peak hour travel (Monday through Friday) in the I-25 corridor as might be expected for a multi-urbanized region such as I-25 corridor. However, the worst congestion will occur on weekends (Friday, Saturday and Sunday) in the I-70 corridor in response to its role as a tourist and recreational area serving both residents of the I-25 corridor and tourists from all over the US.

Exhibits 6-26 through 6-31 show how congestion is expected to evolve in both the I-70 and I-25 corridors. The hourly traffic volumes are calculated based on the peak hour volumes from I-70 PEIS and I-25 EIS, and hourly traffic volume distribution from CDOT.

Besides the locations shown in exhibits, the congestion analysis shows that by 2035 capacity will be exceeded for most of the day in both the I-70 and I-25 in many areas 100 miles from Denver such as Denver to Ft. Collins, Denver to DIA, and Denver to Colorado Springs.

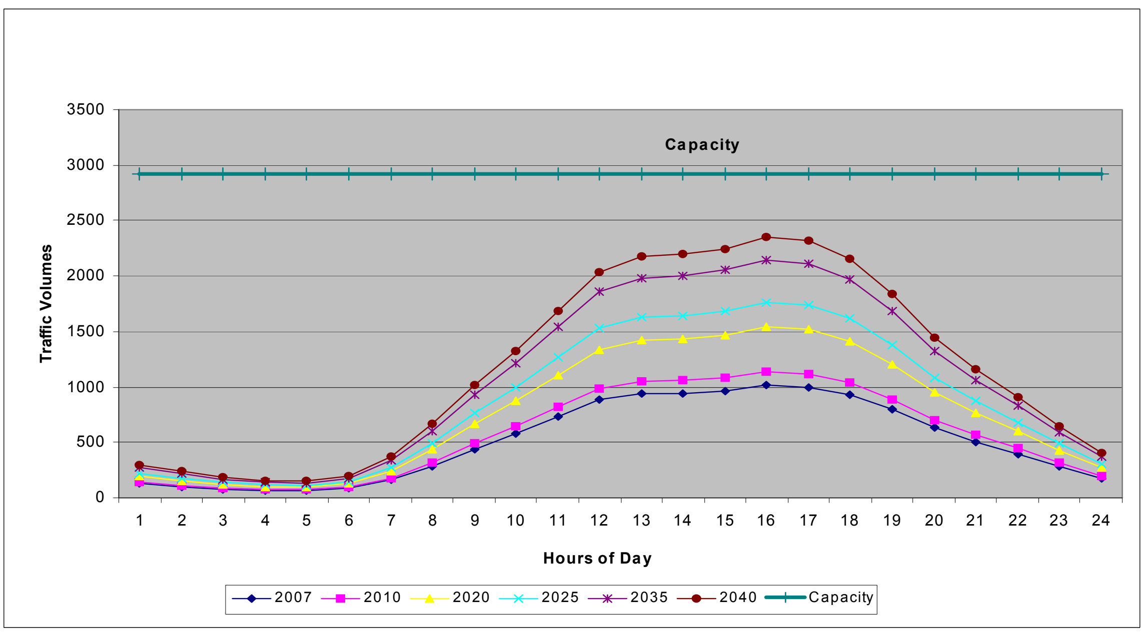
The analysis was made for weekday/weekends and summer and winter. The highway capacity manual volume delay functions were used to convert congestion into additional travel time. Capacity estimates were based on I-70 PEIS, I-25 EIS, and CDOT data.

Exhibit 6-26: I-70 Average Weekend Hourly Traffic Volumes Glenwood Springs to Eagle County Line Eastbound



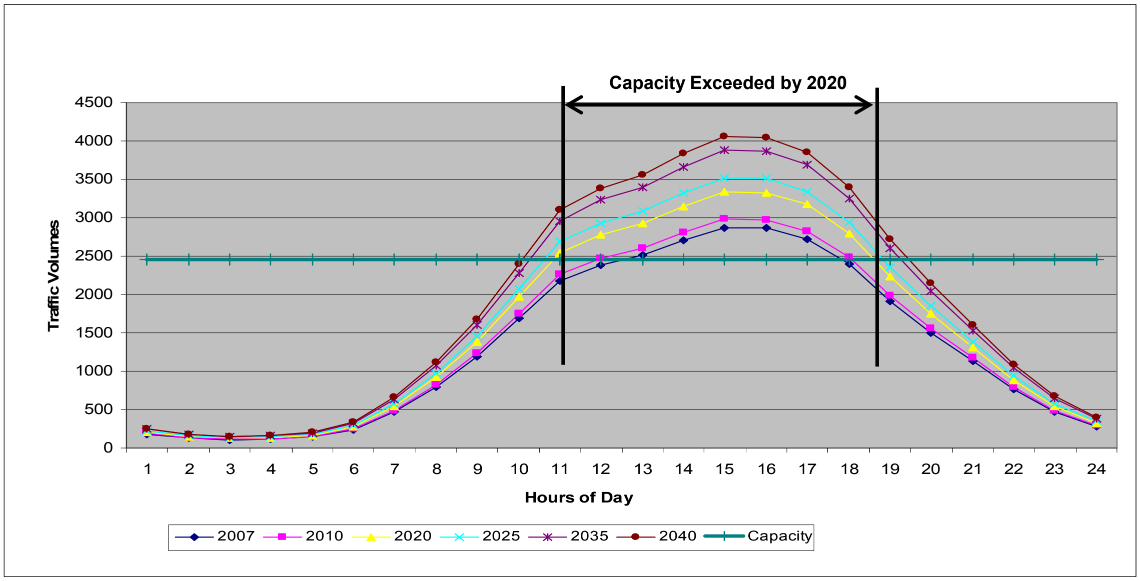
Source: I-70 PEIS and CDOT (www.dot.state.co.us)

Exhibit 6-27: I-70 Average Weekend Hourly Traffic Volumes Glenwood Springs to Eagle County Line Westbound



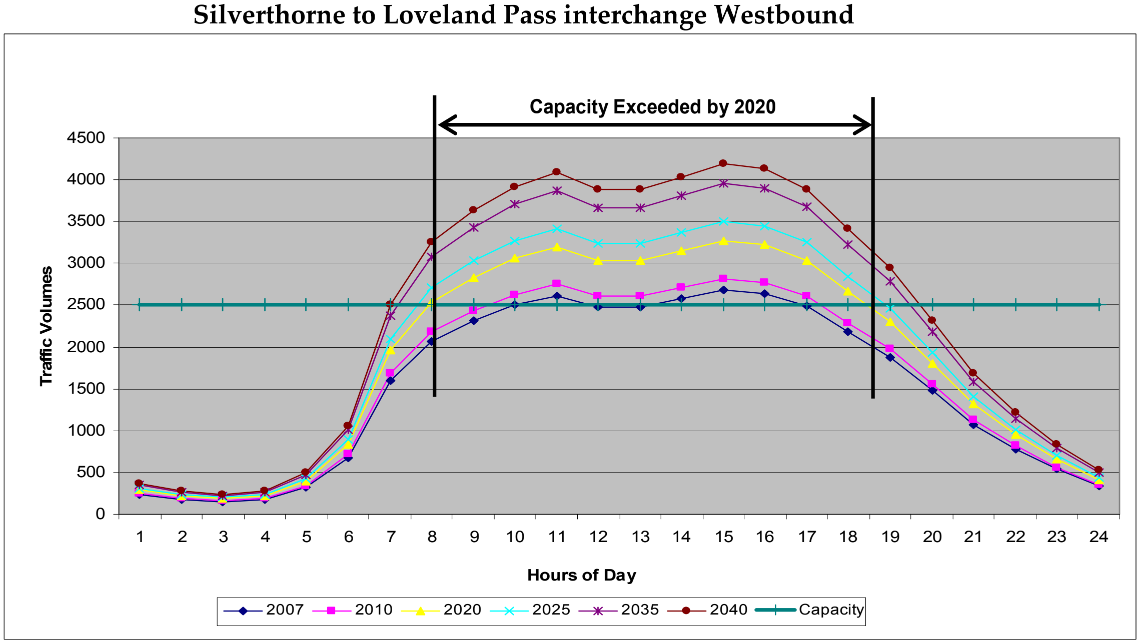
Source: I-70 PEIS and CDOT (www.dot.state.co.us)

Exhibit 6-28: I-70 Average Weekend Hourly Traffic Volumes Silverthorne to Loveland Pass Interchange Eastbound



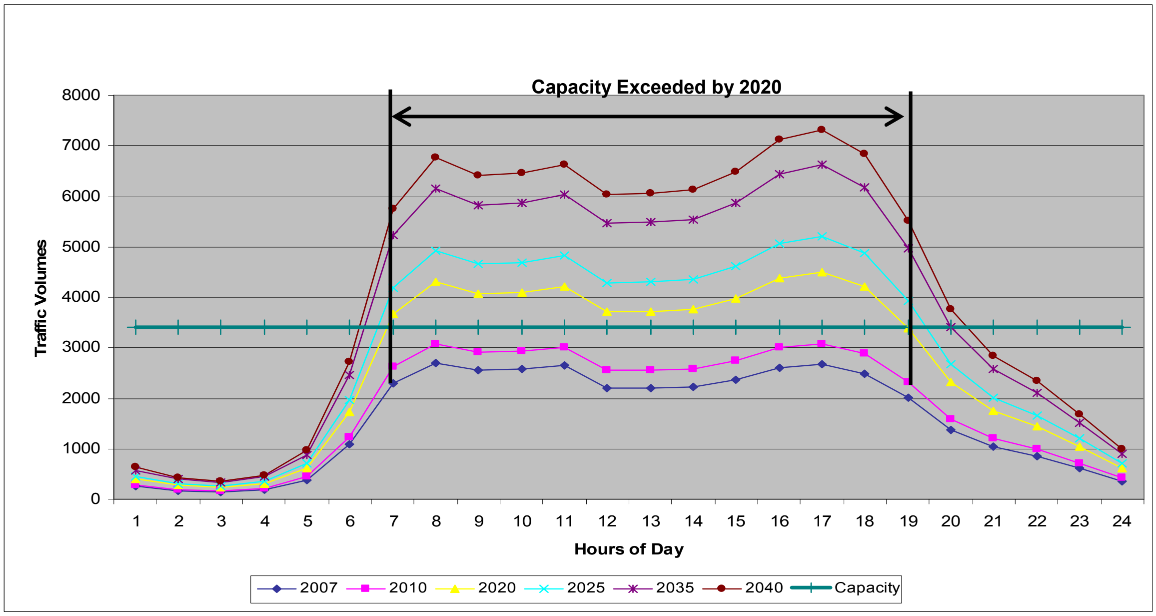
Source: I-70 PEIS and CDOT (www.dot.state.co.us)

Exhibit 6-29: I-70 Average Weekend Hourly Traffic Volumes Silverthorne to Loveland Pass interchange Westbound



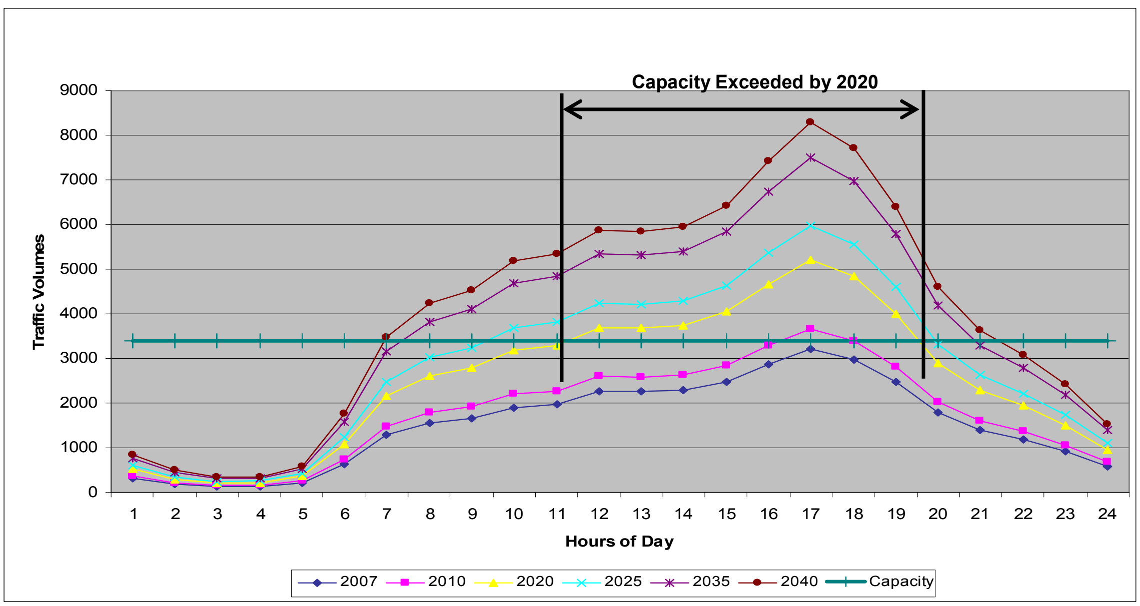
Source: I-70 PEIS and CDOT (www.dot.state.co.us)

Exhibit 6-30: I-25 Hourly Traffic Volumes Castle Rock-South of Plum Creek Parkway Northbound



Source: I-25 EIS and CDOT (www.dot.state.co.us)

Exhibit 6-31: I-25 Hourly Traffic Volumes Castle Rock-South of Plum Creek Parkway Southbound

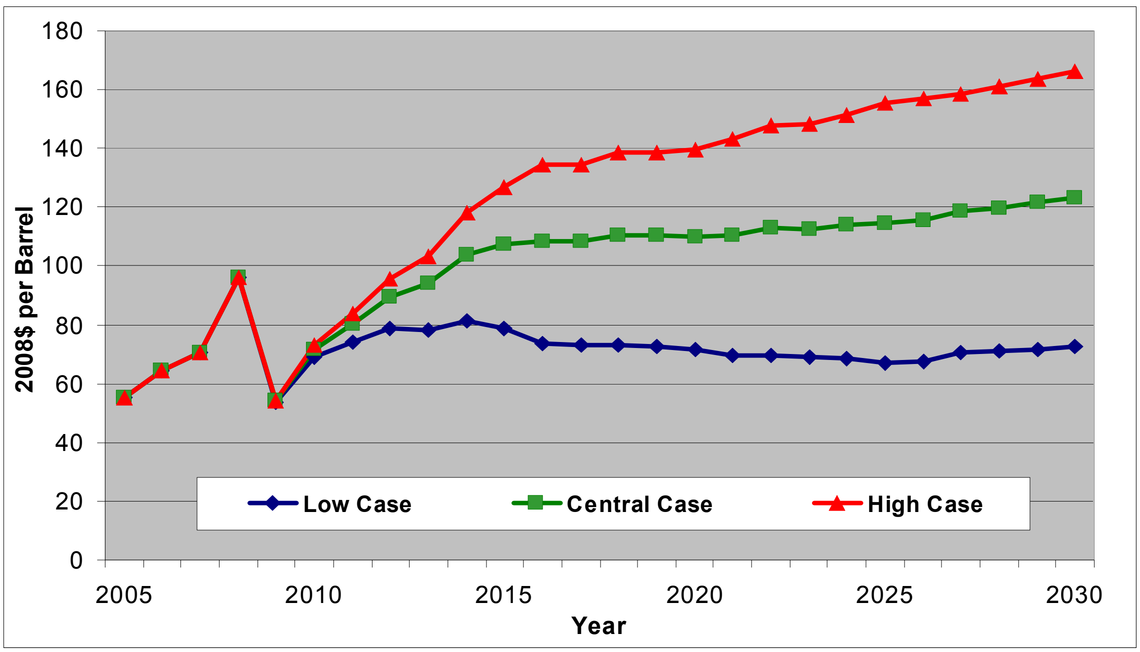


Source: I-25 EIS and CDOT (www.dot.state.co.us)

6.7.2 Gas Prices

A second crucial factor in the future role and attractiveness of the High-Speed Rail is the price of gas. Forecasts of oil prices from the Energy Information Agency suggest that oil price will return at least to $100 per barrel in the next five years and will remain at that level in real terms to 2030 and beyond. See Exhibit 6-32. The implication of this is a central case gas price of 4 dollars per gallon with a high case price of $5 per gallon and a low case price of $3 per gallon. Since gas is currently $2.50+ a gallon in a weak economy environment, $4 per gallon once the economy starts to grow again seems very realistic. Exhibit 6-33 shows the relationship of gas prices to oil acquisition cost from 1993 to 2008. It shows that gas prices rise directly with oil prices. As a result, gas prices are likely to rise as shown in Exhibit 6-34. This gives high, low and central scenarios for gas price to use in the Colorado traffic forecast.

Exhibit 6-32: U.S. Crude Oil Composite Acquisition Cost by Refiners - Historic Data and the Forecast



Source: Energy Information Administration (www.eia.doe.gov)

Exhibit 6-33: U.S. Retail Gasoline Prices as a Function of Crude Oil Prices (1993 –2008)[1]

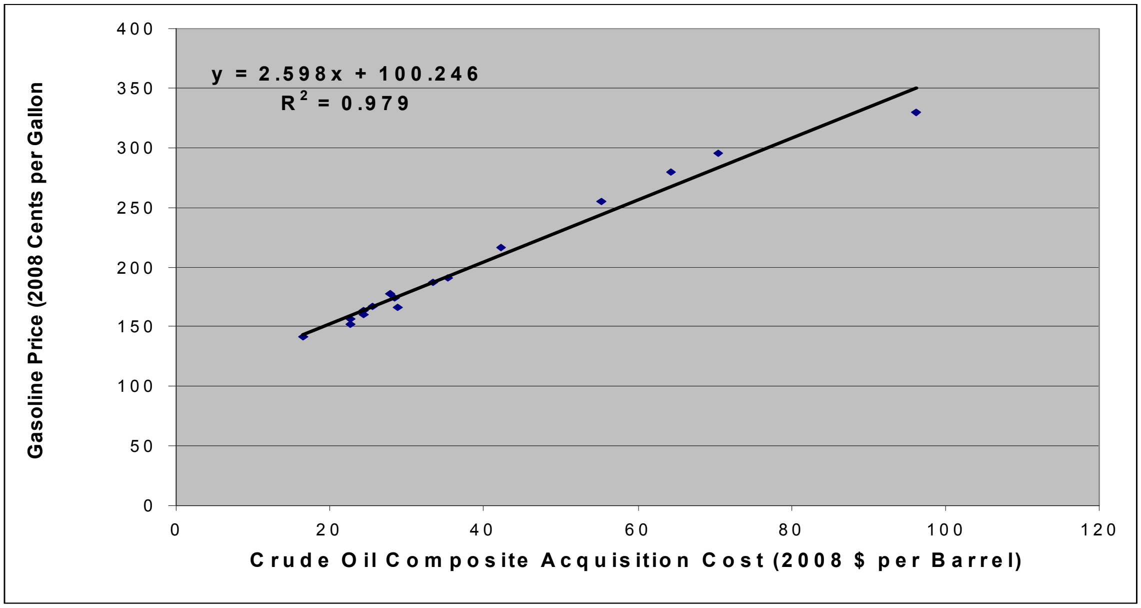
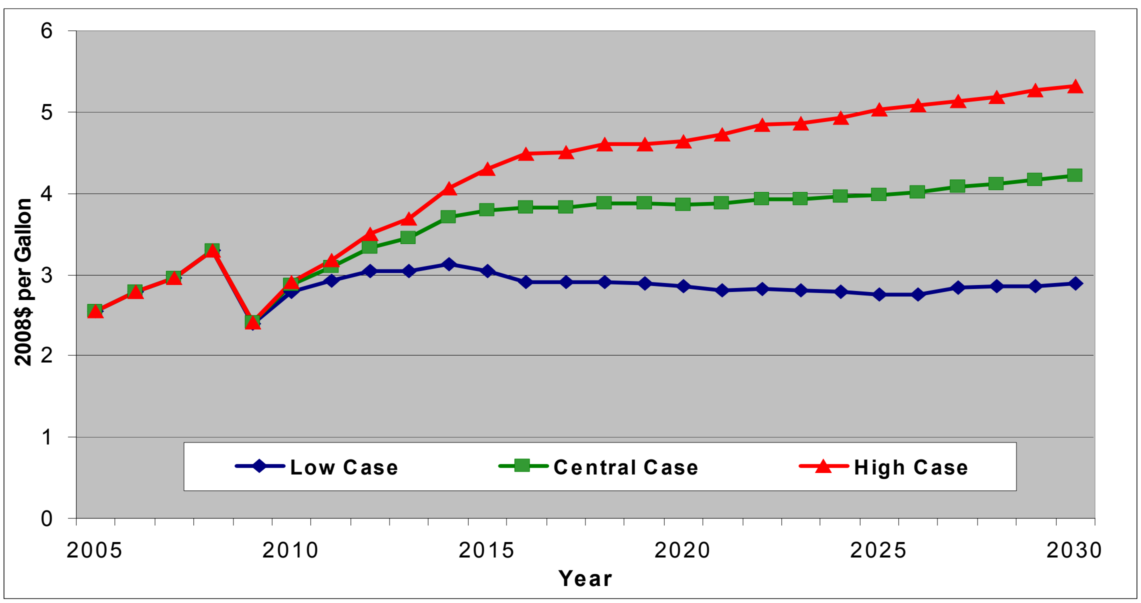


Exhibit 6-34: U.S. Retail Gasoline Prices - Historic Data and the Forecast



Source: TEMS, Inc. & Energy Information Administration (www.eia.doe.gov)

[1] Analysis developed by TEMS, Inc. for MARAD US DOT

6.8 High-Speed Rail Forecasts

6.8.1 Ridership Forecast

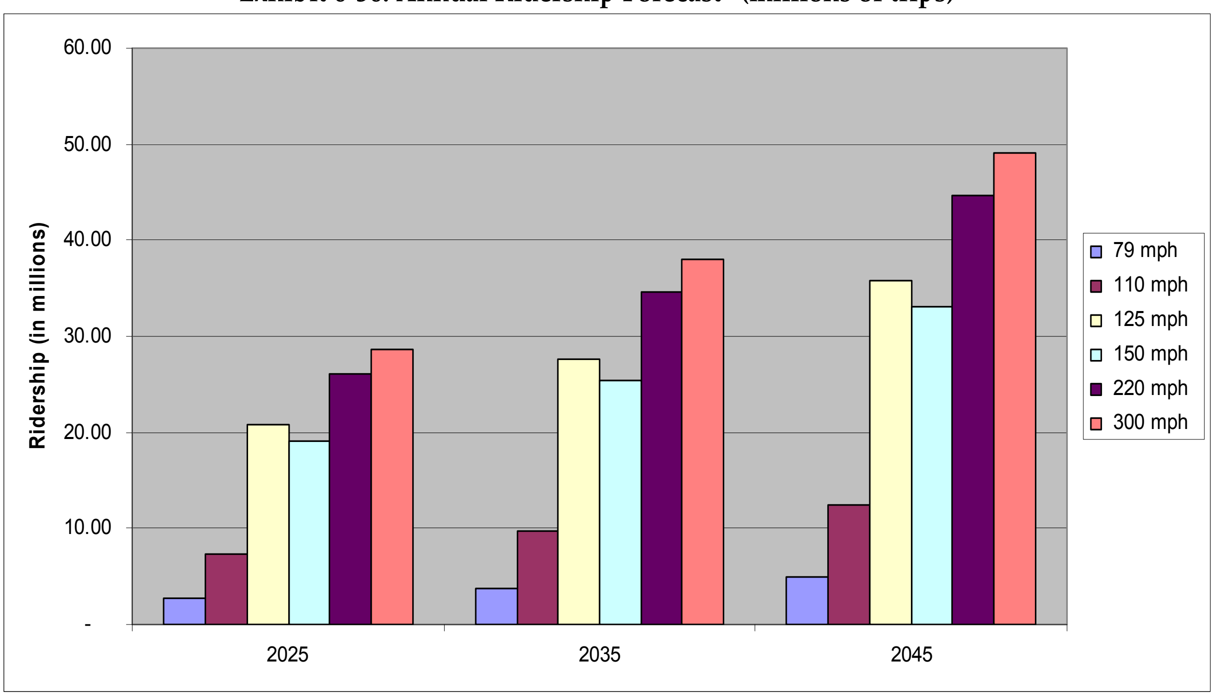
Exhibit 6-35 and Exhibit 6-36 portray the ridership forecast generated by each option associated with the frequencies and fares described above. 150-mph ridership is lower because it uses the existing, slower rail alignments on I-25 and west of Eagle; other high-speed technologies use greenfield alignments, which although more expensive, are faster and have better station locations.

Exhibit 6-35: Annual High-Speed Rail Ridership (millions of trips)

Technology	2025	2035	2045
79-mph diesel*	2.80	3.74	4.89
110-mph diesel*	7.27	9.64	12.50
125-mph maglev	20.74	27.57	35.79
150-mph EMU	19.13	25.42	33.00
220-mph EMU	26.05	34.53	44.72
300-mph maglev	28.64	37.97	49.17

*Ridership for I-25 corridor only; diesel powered equipment not compatible with I-70 corridor terrain.

Exhibit 6-36: Annual Ridership Forecast* (millions of trips)



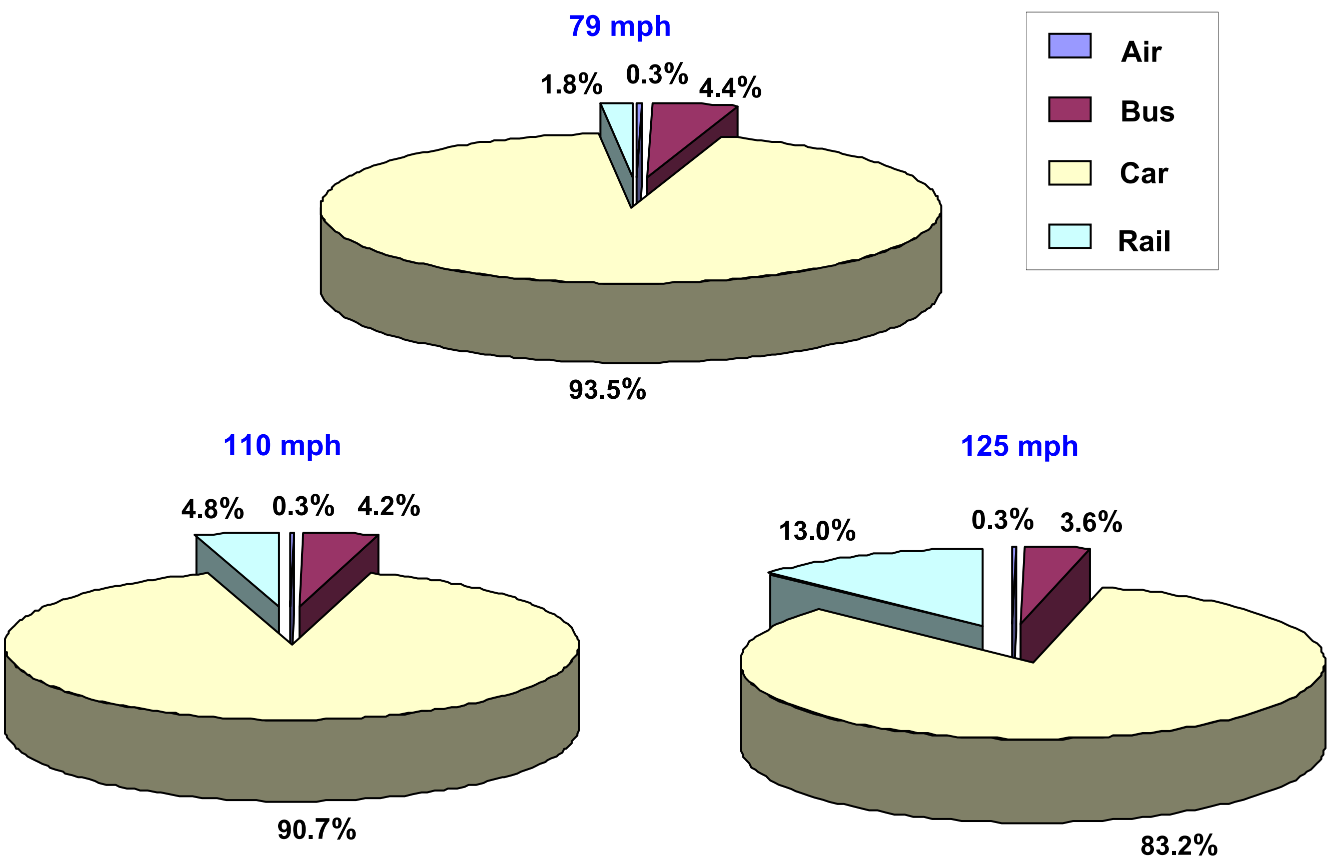
*79 and 110- mph technology only run at I-25 corridor since diesel powered equipment is not compatible with I-70 corridor terrain

As shown in Exhibit 6-36, the options with higher speed and frequency will produce more ridership even though their fares have been set at a higher level than the lower speed options.

6.8.2 Market Shares

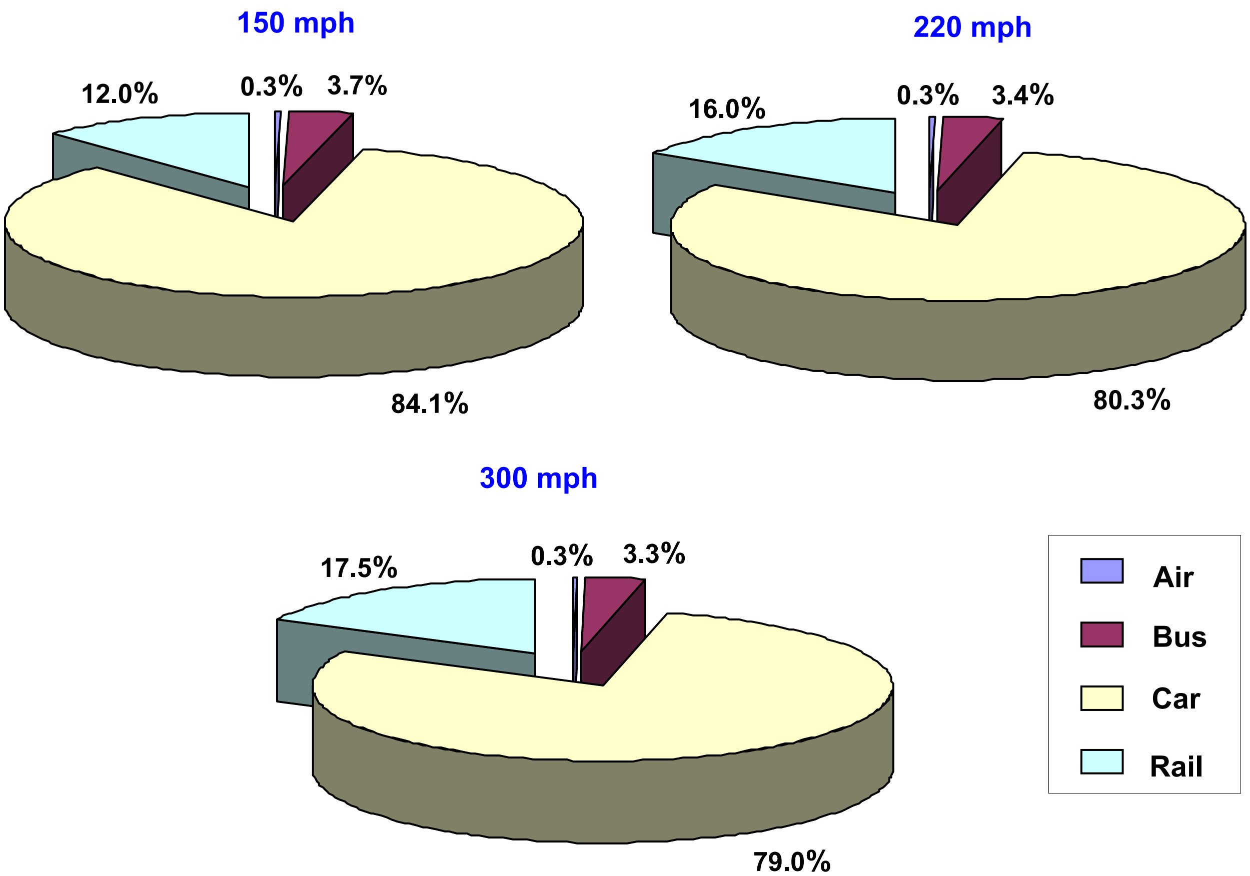
The estimates of the modal market shares of the different technology options were developed using the *COMPASS*™ model. Exhibit 6-37 and 6-38 show the market shares for each technology option for the year 2035 with central socioeconomic projections and central gas projections.

Exhibit 6-37: 79-mph, 110-mph, 125-mph Options – 2035 Market Share



Note: Based on central socioeconomic and central gas price projections

Exhibit 6-38: 150-mph, 220-mph, 300-mph Options – 2035 Market Share



Note: Based on central socioeconomic and central gas price projections

Based on the exhibits above, the auto mode dominates the I-70 and I-25 intercity travel market and has more than 80 percent of the market regardless of technology options. The air mode is the weakest among all the modes in the study area, remaining relatively constant across all alternatives, but the market share of auto and bus modes decreases significantly from 94 percent to 79 percent as rail speed increases; bus falls from 4.4 percent to 3.3 percent. This is because faster rail technologies tend to be more competitive against auto travel, and both auto and bus suffer from the increasing congestion and gas price. However, while auto continues to dominate the intercity market, the high-speed rail, especially the rail options with speeds more than 110 mph, attracts an increasingly bigger portion of the market from the auto mode. The higher the rail speed, the larger the proportion of the total travel market that will use rail.

6.8.3 Ridership Composition

Demand for high-speed rail consists of three components:

- **Natural demand** – the part of demand that is generated by demographic increase. As cities and villages grow, so does the demand for travel. As a result in travel demand forecasting there is a need to assess how population, employment and income will impact travel demand.
- **Diverted demand** – the part of demand that is transferred from one mode to another as service level or competition between the modes increases or changes. Since in this case, HSR is not present in the base case, and a very powerful new mode is being introduced, a significant level of diversion can be expected
- **Induced demand** – this is the part of demand that is generated because of improvement in the utility of travel. For example, better highways reduce the cost of traveling by automobile; hence extra trips are induced by the reduced travel time and cost. For example, the building of the interstate system generated a huge increase in automobile flows, as a result of the reduced time and cost of travel between cities. HSR induces extra trips because of its speed (compared to bus and auto), lower fares (compared to air), convenience (downtown to downtown and ease of access), and reliability (particularly on I-70, which suffers from up to 40 closures per year due to weather conditions.)

Each scenario with a different HSR technology will show different breakdowns of demand across the components noted above. Natural demand will remain the same, since there is no demographic change across the technologies, but its share appears to diminish because the overall traffic is higher when moving from a slow to a fast technology. The breakdown of demand is shown in Exhibit 6-39 and 6-40.

Exhibit 6-39: 79-mph, 110-mph, 125-mph Options – 2035 Ridership Breakdown

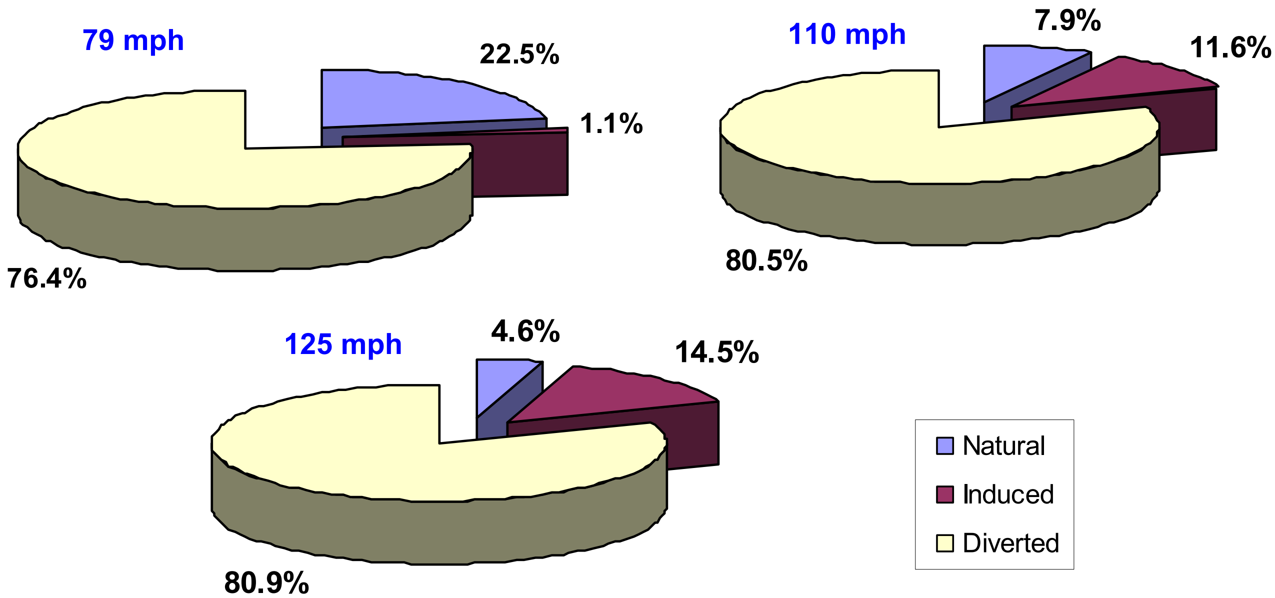
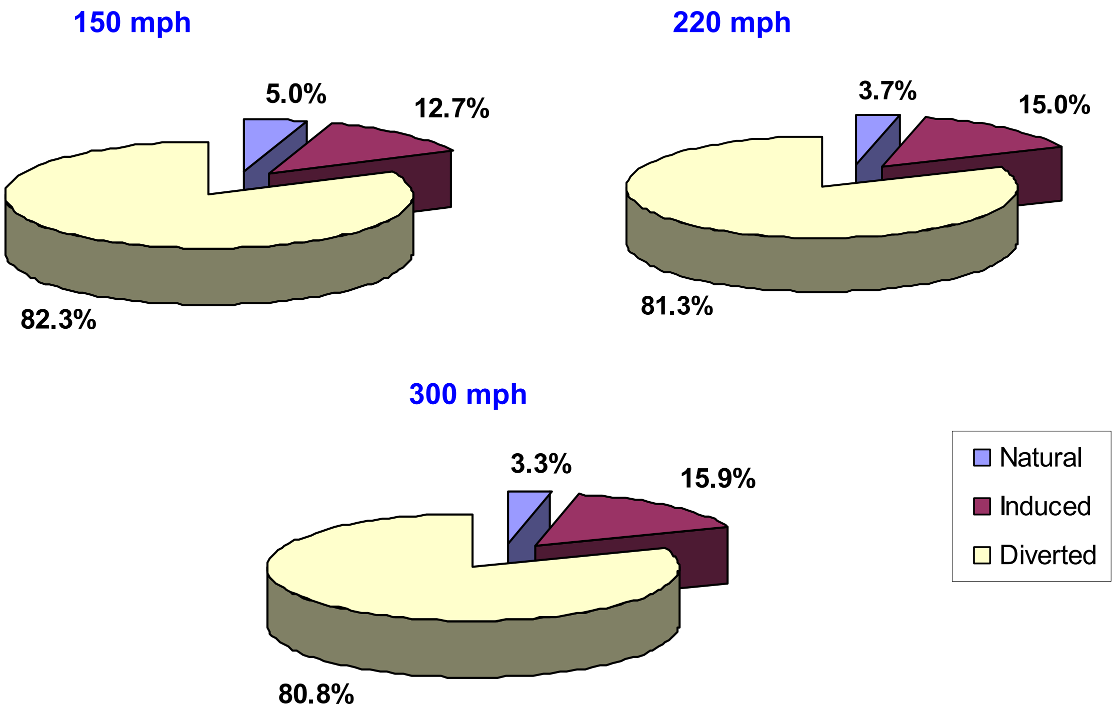


Exhibit 6-40: 150-mph, 220-mph, 300-mph Options 2035 Ridership Breakdown



As might be expected, diversion from other modes of travel is the largest contributing factor to rail ridership. These charts show that the level of induced demand increases from 110 mph to 300 mph, rising from 11.6 percent for the 110-mph option to 15.9 percent for the 300-mph option. This reflects the increasing attractiveness of higher speed options. Natural demand (i.e., demand generated by demographic) growth is fixed for all technologies, and it becomes a smaller and smaller portion of the total demand for rail, as speeds increase and the diverted and induced demand increase.

6.8.4 Revenue Forecast

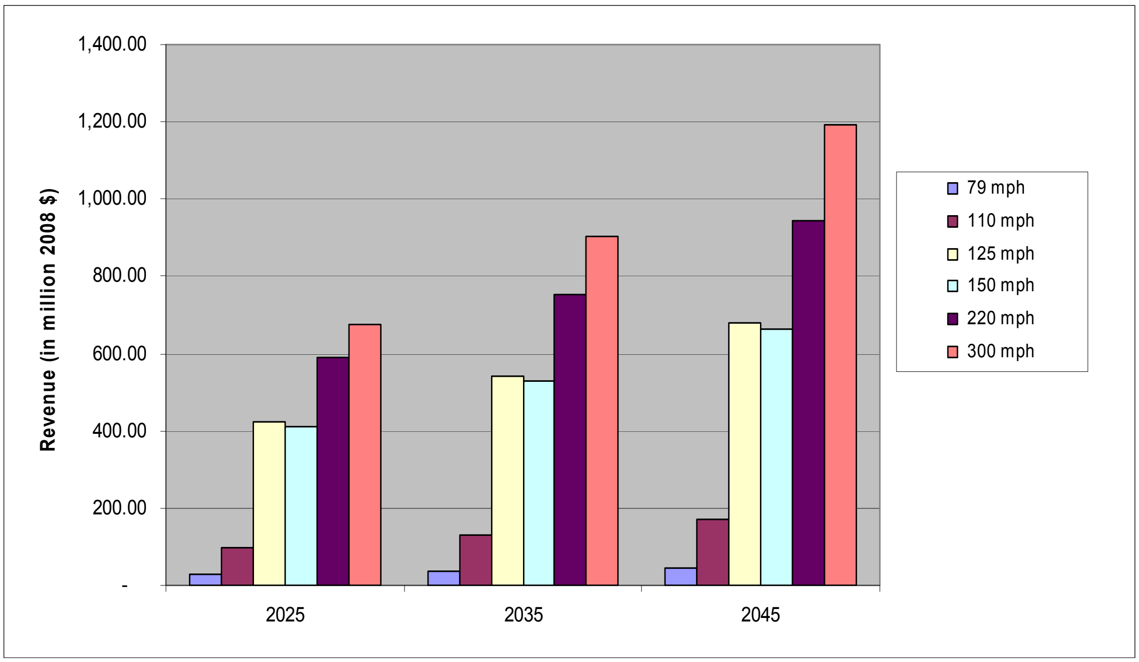
Exhibit 6-41 and Exhibit 6-42 provide the detailed revenue forecast for the year 2025, 2035 and 2045 for six technology options with central socioeconomic and central gas price scenarios. The higher speed options usually produce higher revenue. The only case where this does not happen is 150-mph train compared to 125-mph maglev; the 150-mph train has lower ridership and revenue than the 125-mph maglev because it is on the existing rail right-of-way rather than a greenfield route, which has a better alignment and provides higher speeds. On the greenfield route the 150-mph train would be faster than 125-mph maglev and hence would generate higher ridership.

Exhibit 6-41: Revenue Forecast by Option (Millions $2008)

Technology	2025	2035	2045
79-mph diesel*	$30.08	$36.45	$45.26
110-mph diesel*	$97.89	$130.07	$169.71
125-mph maglev	$421.46	$541.72	$679.98
150-mph EMU	$412.23	$529.75	$664.59
220-mph EMU	$588.32	$754.92	$946.00
300-mph maglev	$675.23	$905.41	$1,191.98

*Revenue for I-25 corridor only; diesel powered equipment is not compatible with I-70 corridor terrain.

Exhibit 6-42: Revenue Forecast (Millions $2008)



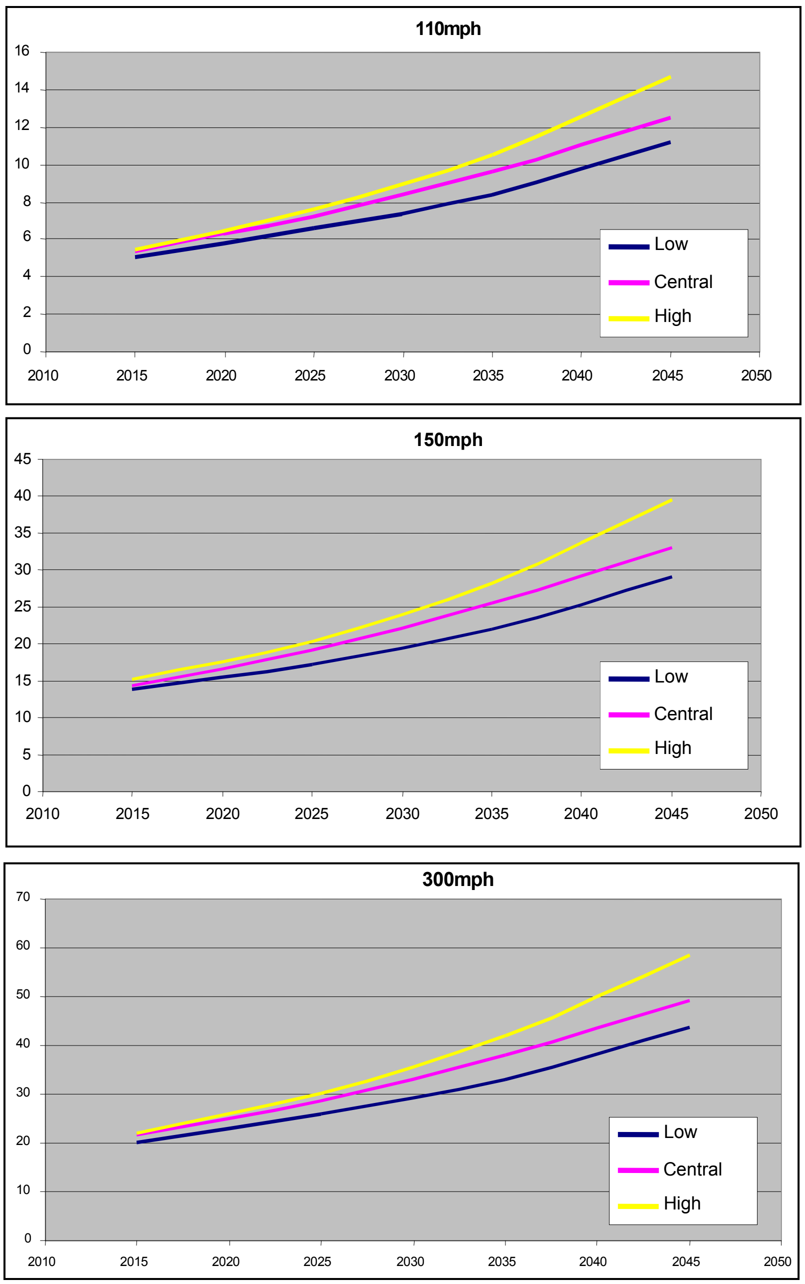
6.9 Sensitivity Analysis

A series of sensitivity analyses were done to test the forecast results in response to change of socioeconomic forecast, gas price and seasonal weekday/weekend congestion.

6.9.1 Socioeconomic Sensitivity

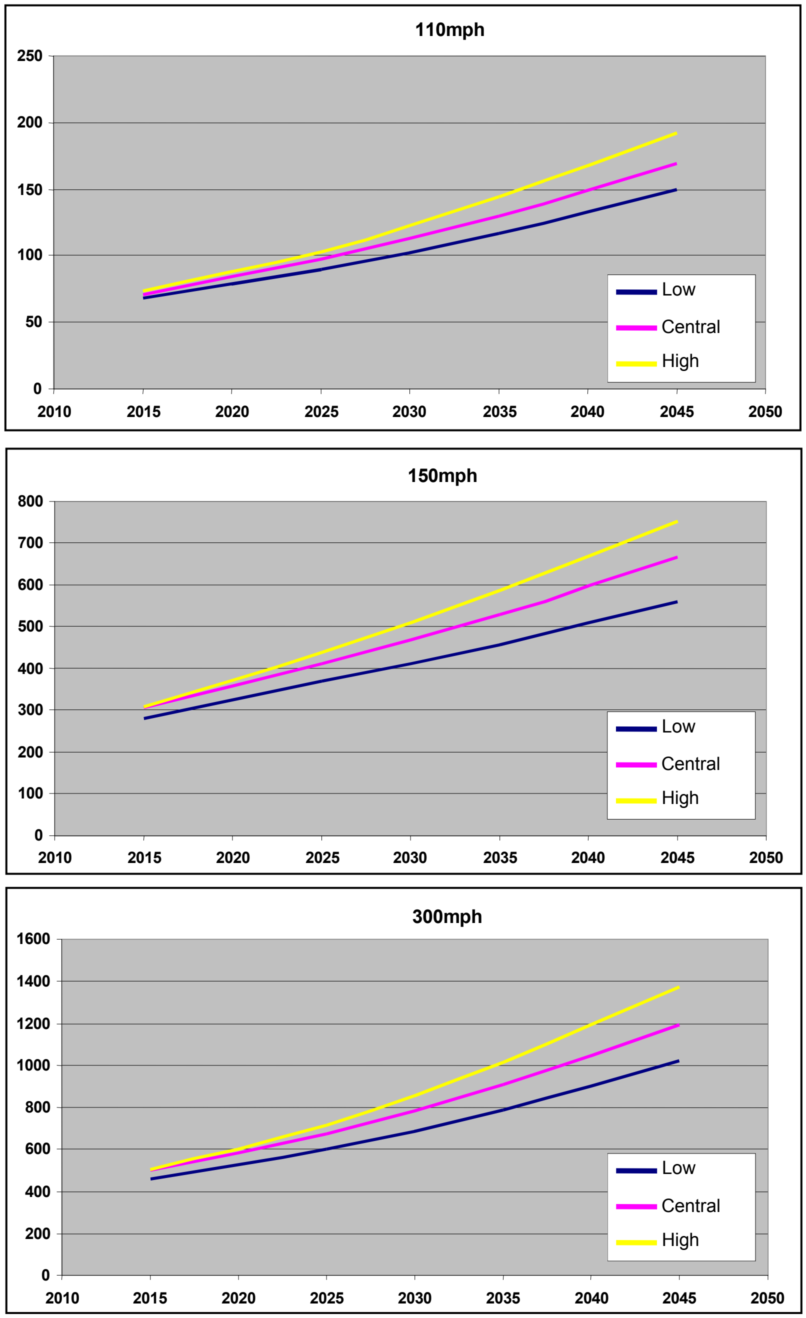
As mentioned in Section 6.3, socioeconomic (population, employment and income) forecasts create three scenarios: low, central and high. The ridership and revenue forecasts shown in Section 6.8 are based on the central forecast scenario (i.e., central population forecast, central employment forecast, and central income forecast). Sensitivity analysis was performed to show how the forecast model performs under different socioeconomic forecast scenarios. Exhibits 6-43 and 6-44 show ridership and revenue forecast for different socioeconomic projections.

Exhibit 6-43: Ridership vs. Socioeconomic Sensitivity Analysis (in millions)



It can be seen that by 2035 the impact of the lower and upper socioeconomic forecasts is to reduce ridership by 12 percent and increase revenue by 12 percent.

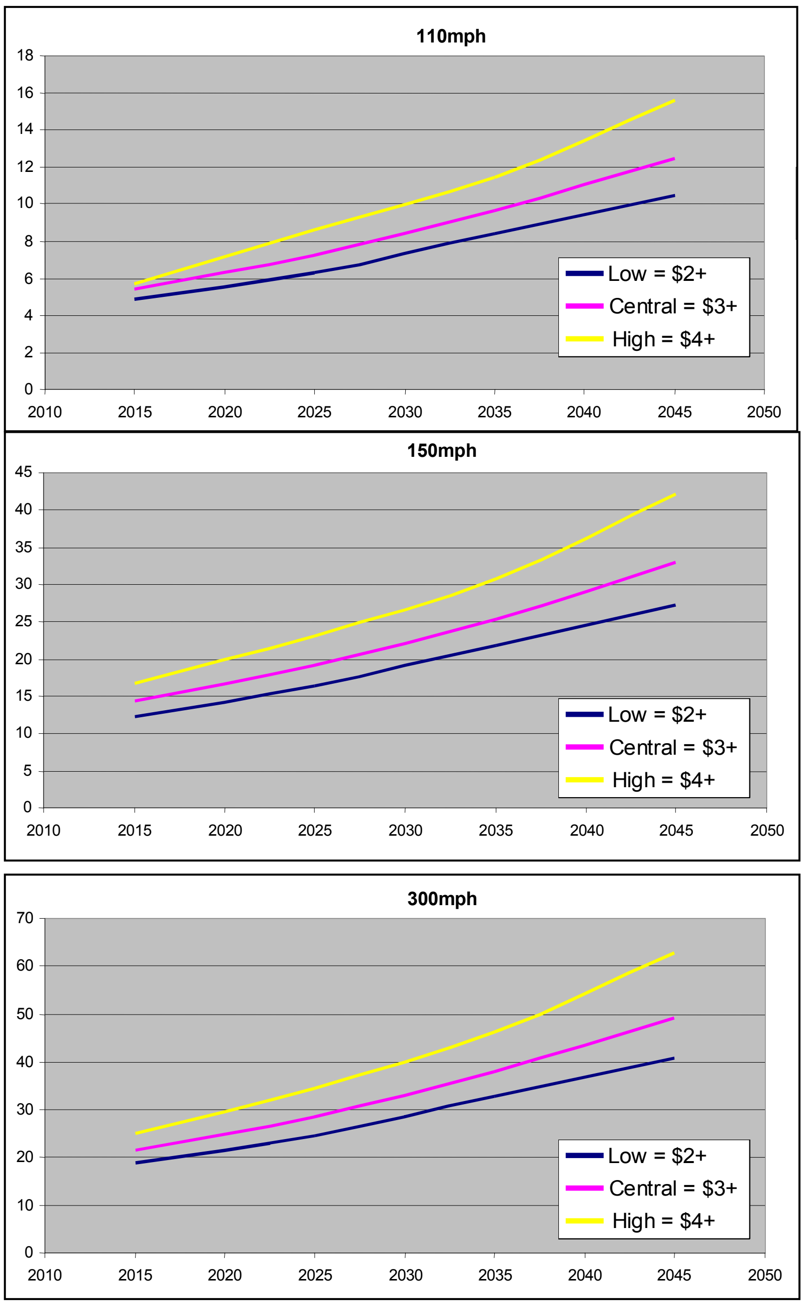
Exhibit 6-44: Revenue vs. Socioeconomic Sensitivity Analysis (Millions $2008)



6.9.2 Gas Price Sensitivity

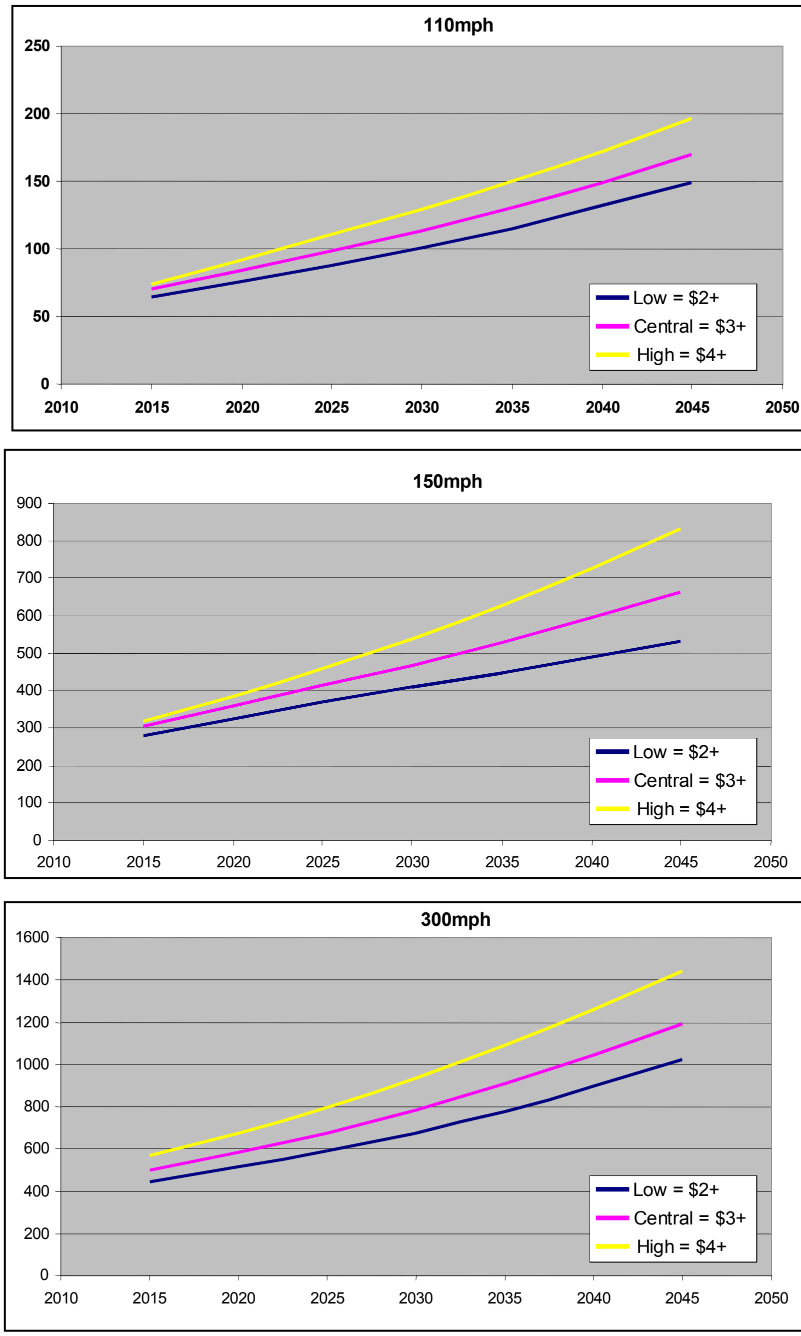
Gas price is an important factor when travelers make decisions on mode choice. As described in Section 6.7, like socioeconomic projection, the gas price projection in this study has three scenarios. Gas price sensitivity analysis was done to find how different gas price setting would affect the forecast of ridership and revenue. Exhibits 6-45 and 6-46 show the ridership and revenue forecast for different gas price projections.

Exhibit 6-45: Ridership vs. Gas Price Sensitivity Analysis (Central Socioeconomic Scenario)



It can be seen that the impact of high (low) gas prices is to raise (reduce) ridership in 2035 by 20-25 (13-18) percent, and revenue by 18-23 (13-18) percent, compared to central gas price scenario. The higher speed options are more affected by increasing gas prices as they become more and more attractive.

Exhibit 6-46: Revenue vs. Gas Price Sensitivity Analysis (Central Socioeconomic Scenario)



6.9.3 Seasonal and Weekday/Weekend Sensitivity

The trip generation rates and transportation network have different characteristics during winter, summer, weekend (Friday, Saturday, Sunday) and weekday (Monday, Tuesday, Thursday). For example, based on traffic counts from CDOT, higher traffic volumes are observed on weekends than on weekdays within the study area. The congestion situation in summer is usually worse that that in winter. Four cases (winter weekday, winter weekend, summer weekday, and summer weekend) were examined in this study. The O-D trip matrices and network were adjusted for each case based on the traffic counts and congestion change. See Exhibits 6-47 and 6-48.

Exhibit 6-47: Ridership of Seasonal Weekday/Weekend Comparison (millions of trips)

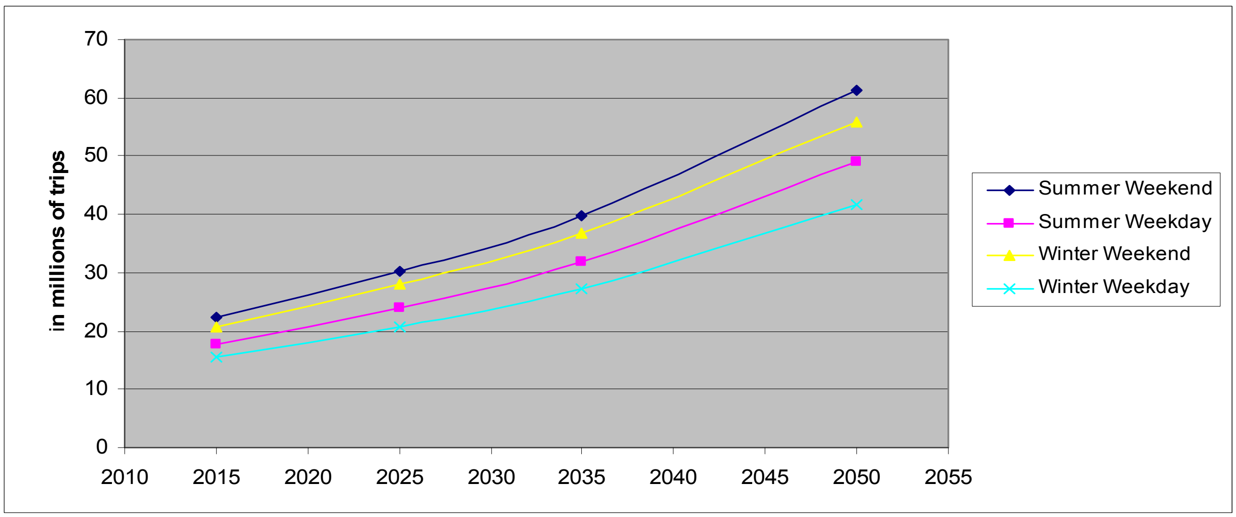
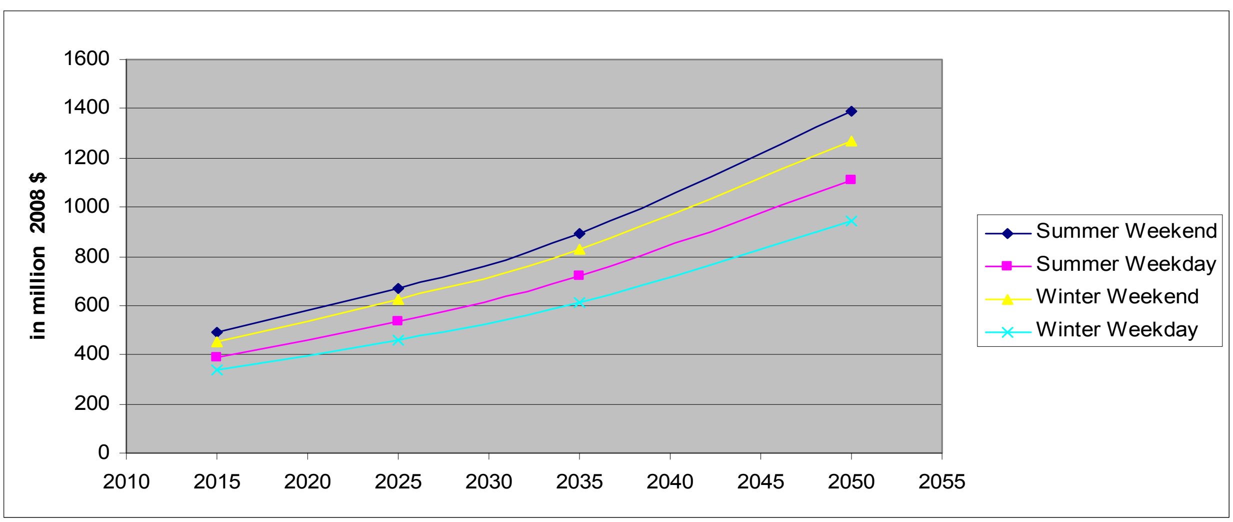


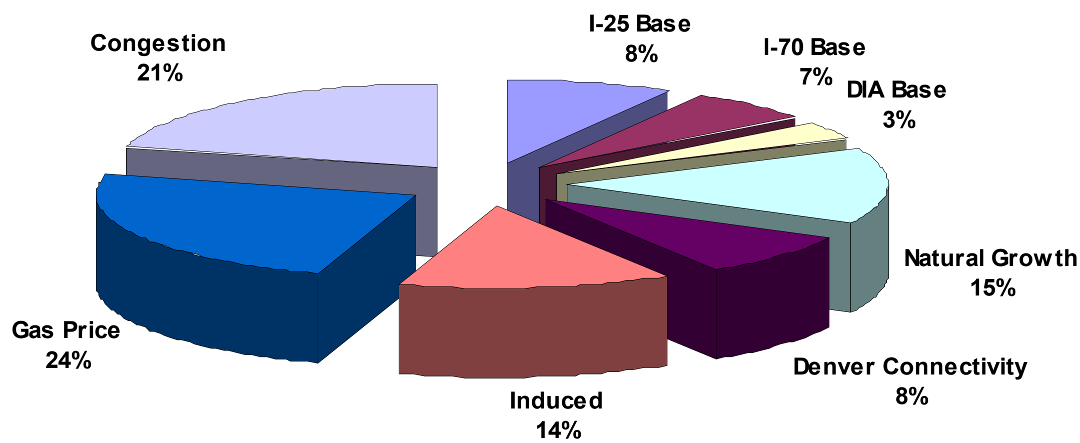
Exhibit 6-48: Revenues of Seasonal Weekday/Weekend Comparison (Millions $2008)



It can be seen that the highest traffic and revenues are generated by summer weekends. They are followed by winter weekends. Summer weekdays have less traffic and revenues than summer/winter weekends. And finally, the least volume of trips and revenues in the comparison is generated by winter weekdays. Seasonal and weekend/weekday analysis will help the design of operation plan of rail service to accommodate the changes on ridership.

Exhibit 6-49 shows the breakdown of demand due to key factors such as congestion, gas price, induced demand, Denver and DIA connectivity, and natural growth.

Exhibit 6-49: Key Components of Ridership Forecast



6.10 Validation

In order to check the accuracy and reliability of the forecast model in this study, the forecasted results are compared to those of two corridors: Northeast Corridor and California Corridor.

6.10.1 Northeast Corridor Comparison

To make a comparison of the Colorado forecasts with the high-speed rail service in the Northeast corridor an "apples-to-apples" analysis is needed. First, the Northeast Corridor (Washington to Boston)[1] has two train systems: Amtrak and commuter service (NJT, Long Island Railroad, MARC, Septa, Shore Line East, and MBTA), plus air service between the major cities. The Colorado corridors do not have commuter rail or air service, except DIA to Colorado Springs, Eagle, Steamboat and Aspen. In the Northeast Corridor air service carries almost as many passengers as Amtrak, while commuter service carries over 360 million passengers per year, of which at least ten percent could use parallel Amtrak service. As such, while Amtrak carried 13 million passengers in 2008, air

[1] The Future of the Northeast Corridor, The Business Alliance for Northeast Mobility. February 2009. http://www.rpa.org/pdf/RPANECfuture012309.pdf

doubled that number to 26 million and Amtrak plus air plus commuter is 49.7 million according to the Business Alliance for Northeast Mobility. To estimate the comparable 2008 number for Colorado, TEMS estimated the impact of reducing its 2025 forecast of 19 million trips (see Exhibit 6-35) by increasing fares from 40¢ to 60¢ per mile to match Amtrak fares, and taking out expected real gas price increases and socioeconomic impacts from the forecasts. Without these adjustments the 2008 Colorado trips would equal 2.8 million trips for its 150-mph service. These comparisons do not include adjusting for congestion, as it is considered that the Northeast Corridor probably has congestion similar to that on I-70 and I-25 in 2025. (Given the anticipated demographic growth in Colorado, it is not unreasonable to project Colorado travel conditions similar to those in other built-up urban areas such as NEC or even California.) The 2.8 million 2008 Colorado trips are 21.5 percent of the NEC Amtrak trips today, 10.7 percent of the Amtrak plus air trips, 7.6 percent of the Amtrak plus commuter rail trips, and only 5.6 percent of the Amtrak plus air plus commuter trips estimated by the Business Alliance for Northeast Mobility.

If the process is reversed and Northeast Corridor trips of 2008 are factored to 2025 by applying similar socioeconomic, gas price, and fare adjustments the Amtrak volume in 2025 will be 89 million trips, while the overall Northeast public transport market will have expanded to 341 million trips. Colorado's 19 million trips are only 5.6 percent of the NEC market. See Exhibit 6-50.

As a result it can be seen that Colorado forecast volumes under the same scenarios of increased gas, socioeconomic growth, and lower fares would be between 5-10 percent of those of the Northeast Corridor. This seems reasonable, given that the population of Colorado is only 11.5 percent of the Northeast corridor (i.e., 4.4 million, compared to the 40 million in the NEC (up to 50 miles from stations)).

Exhibit 6-50: "Apples-to-Apples" Comparison of North East Corridor – NEC [1] and Colorado[2] (1-25/I-70) (Ridership, million of trips)

	NEC Amtrak	NEC Amtrak+ Commuter	NEC Amtrak+ Air	NEC Amtrak+Air +Commuter	Colorado	
2008	13	36.7[3]	26[4]	49.7	2.8	2008
Socioeconomic increase gives 10 million trips	↓	↓	↓	↓	↑	Socioeconomic decrease gives (-2.13) million trips
2025	23	64.7	45.8	87.6	4.9	2025
[5]Gas Price increase gives 21 million trips	↓	↓	↓	↓	↑	[5]Gas Price Decrease gives (-4.78) million trips
2025	44.2	124.8	88.4	169	9.5	2025
[5]Fare decrease gives 45 million trips	↓	↓	↓	↓	↑	[5]Fare Increase gives (-9.56) million trips
2025 Forecast	89.1	251.6	178.2	340.7	19.1	
Colorado/NEC	21.5%	7.6%	10.7%	5.6%		

Notes:

(1) Congestion base and growth in NEC are assumed similar to Colorado. If Northeast Corridor highway congestion growth is faster than Colorado, Colorado percentage falls in relation to NEC. (The data source for NEC is: The Future of the Northeast Corridor, The Business Alliance for Northeast Mobility. February 2009. http://www.rpa.org/pdf/RPANECfuture012309.pdf)

(2). Source: *COMPASS*™ Model

(3) Assume 90% of commuter trip are short distant trips with trip length less than 55 miles.

(4) The total air market share is equal to rail (The Future of the Northeast Corridor, The Business Alliance for Northeast Mobility. February 2009. http://www.rpa.org/pdf/RPANECfuture012309.pdf)

(5) Based on Colorado elasticities from COMPASS™ Model (i.e., gas price impact is 24% of the estimated 19.1 million total trips for the corridor. See Exhibit 6-49.)

6.10.2 California Corridor Comparison

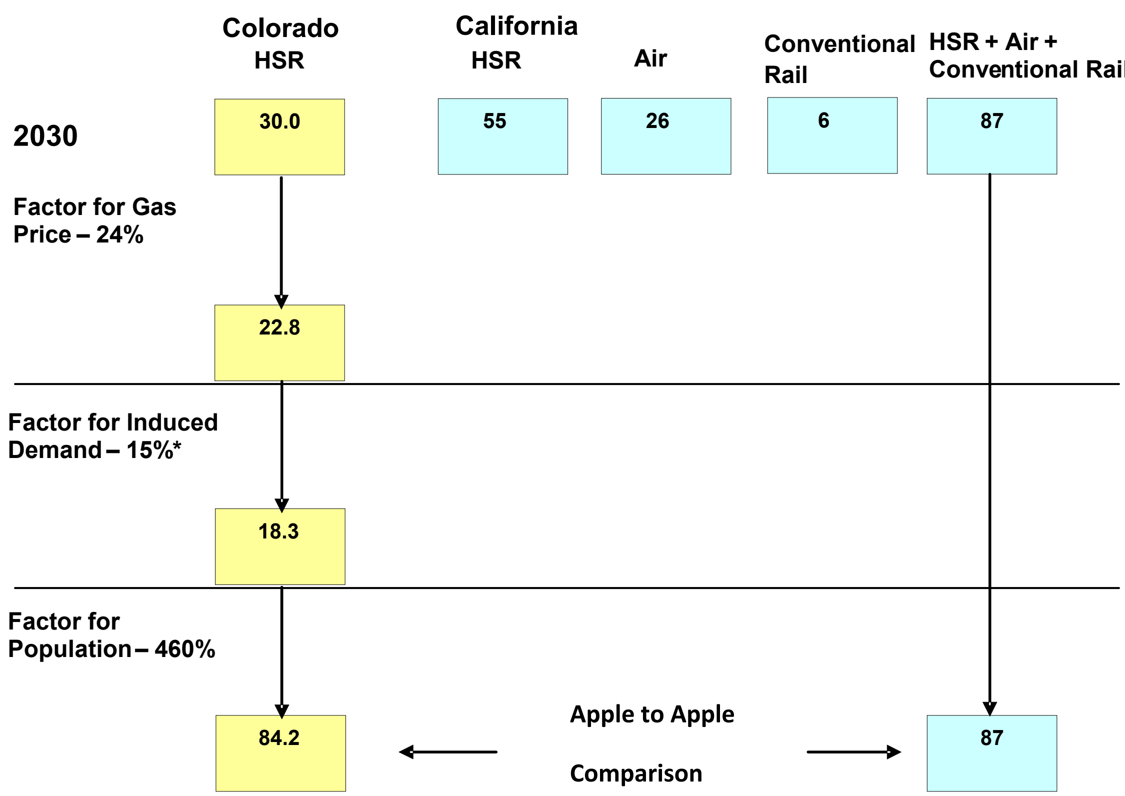
Another but perhaps less reliable comparison can be made with the California High Speed Rail Corridor. Its forecast for the 220-mph technology for its San Francisco, Sacramento, Los Angeles, San Diego market is 55 million trips in 2030[1]. In this corridor there is also extensive air service, 26 million trips in 2030, and conventional rail, 6 million trips in 2030. As a result, the corridor will have 87 million public mode trips in 2030.

In 2030 for the 220-mph option for Colorado the forecast is for 30 million trips of which 7.2 million trips are diverted trips due to the forecasted higher gas prices. Another feature of the Colorado forecast is 4.8 million trips due to an induced demand of 15 percent. The California forecast almost completely excludes induced demand. This is remarkable since most forecasters would anticipate a significant (10-20 percent induced demand for a new system that offers low fares (50 percent of air fare), and fast travel times (2.5 hours on the train compared to over 4 hours driving from San Francisco to Los Angeles). As such, for an apples-to-apples comparison the Colorado forecast needs to exclude induced demand. This would reduce the 2030 estimate to 18.3 million trips. If the 2030 population of Colorado is 7.5 million and the southern California area served by high-speed rail is 34.5 million, then the population ratio factor is 4.6. Using a 4.6 ratio, the trip forecast for Colorado if it had California's population is 84.3 million trips, whereas the California forecast is 87 million trips.

From this analysis it can be seen in Exhibit 6-51 that the Colorado forecast is very comparable to that of California.

[1] Ridership and Revenue Forecast of California High Speed Rail Project, Parsons Brinckerhoff, Cambridge Systematics and Systra (http://www.cahighspeedrail.ca.gov)

Exhibit 6-51: "Apples-to-Apples" Comparison of Colorado and California Public Mode Markets (Ridership, million of trips)



California/Colorado = 87/84.2 = 1.03

*Percentages are in each case applied to the base estimate.

Sources: *COMPASS*™ model and Ridership and Revenue Forecast of California High-Speed Rail Project, Parsons Brinckerhoff, Cambridge Systematics and Systra (www.cahighspeedrail.ca.gov)

6.11 Summary

The Colorado corridors that are the subject of RMRA study exhibit a very vigorous travel market, with extensive trip making along the I-25 and I-70 corridors in the region. The socioeconomic forecasts show a strong increase in population and employment in the following 30 years. Consequently, travel demand is expected to grow rapidly. Two Stated Preference surveys were conducted to estimate regional values of time and frequency, which are important inputs for *COMPASS*™ model. Trip information from a range of different sources was combined and checked to prepare the origin-destination trip matrices that define total annual zone-to-zone travel. Cost and travel time were incorporated into the network for all modes (auto, rail, bus, and air) and four purposes of travel (business, commuter, tourist, and social). The effects on travel due to gas prices and road congestion were analyzed. Six different technology options with different networks, travel time, fares and frequencies were evaluated and compared by *COMPASS*™ model. The ridership forecasts show the higher speed options will produce more ridership and revenue. Market share forecast shows that high-speed rail will attract a significant number of trips from other modes, especially from auto (80-90 percent). The high-speed train induced between 10 and 16 percent increase in regional travel due to the improvement in travel time, cost and frequency provided by the high-speed train. Sensitivity analyses were conducted to study how socioeconomic projection, gas price, and seasonal and weekday/weekend travel pattern affect the forecasts results. The forecasts were also compared with those of other corridors in the Northeast and California.

7 Operating Costs

This chapter describes the build-up of the unit operating costs that were used in conjunction with the operating plans for assessing the total operating cost of each option. It is important to note that this study encompasses a wide variety of both technology and route options. Six different kinds of train technologies were evaluated including:

- Four Rail Technologies
  - 79-mph Conventional Diesel
  - 110-mph High-Speed Diesel
  - 150-mph Electric Locomotive-Hauled High-Speed Rail
  - 220-mph Electric Multiple-Unit (Self Propelled) High-Speed Rail
- Two Maglev Technologies
  - 125-mph Colorado Maglev (Linear Induction Motor)
  - 300-mph Transrapid (Linear Synchronous Motor)

At least two alignment options were evaluated for each corridor, including:

- I-25 Corridor
  - Greenfield
  - Existing Rail
- I-70 Corridor
  - High Grade 7 percent (I-70 Right-of-Way)
  - Low Grade 4 percent (Unconstrained)

An essential requirement is to maintain the consistency of the costing basis across all technologies and route alignment options. For example, because the 7 percent High-Grade option requires more powerful trains than does the 4 percent Low-Grade option, it would be appropriate to reflect this in higher per-mile equipment and energy costs. An apples-to-apples comparison is needed so that:

- Costs that depend on the propulsion/speed should reflect legitimate differences between technologies and routes.
- Costs that do not depend on propulsion/speed should remain the same across all technologies and routes.

In this chapter the character of the operating plan and equipment that optimizes each option will be described together with its unit operating costs. Some additional details are contained in the earlier methodology report.

The costing framework that was originally developed for the Midwest Regional Rail System (MWRRS) was adapted for use in this study. Following the MWRRS methodology, nine specific cost areas have been identified.[1] As shown in Exhibit 7-1, variable costs include equipment maintenance, energy and fuel, train and onboard (OBS) service crews, and insurance liability. Ridership influences marketing, and sales. Fixed costs include administrative costs, station costs, and track and right-of-way maintenance costs. Signals, communications and power supply are included in the track and right-of-way costs.

Exhibit 7-1: Operating Cost Categories and Primary Cost Drivers

Drivers		Cost Categories
Train Miles	→	Equipment Maintenance Energy and Fuel Train and Engine Crews Onboard Service Crews
Passenger Miles	→	Insurance Liability
Ridership and Revenue	→	Sales and Marketing
Fixed Cost	→	Service Administration Track and ROW Maintenance Station Costs

Operating costs developed for this study are consistent with unit operating costs from other recent studies. These costs were fine-tuned, then applied to the train-miles, number of stations, passenger volumes and other cost factors developed specifically for this study. Cost factors that vary by train technology, such as fuel usage and equipment maintenance, were developed from discussions with manufacturers and/or users of the technology and/or by cost benchmarking from both public and confidential sources. The cost development approach was used to fine-tune those items with the greatest potential variability and impact on the bottom line. Some unit costs, such as those for 110-mph diesel operations, are consistent with MWRRS costs brought up to $2008 through application of

[1] This corridor has no planned feeder bus services for which the rail service is financially responsible, and the treatment of operator profit will be discussed in parallel to Service Administration.

appropriate inflation adjustments. Other costs such as those for electric rail systems or maglev were developed from primary sources for this analysis or based on previous studies.

Operating costs can be categorized as variable or fixed. As described below, fixed costs include both Route and System overhead costs. Route costs can be clearly identified to specific train services but do not change much if fewer or additional trains were operated.

- **Variable costs** change with the volume of activity and are directly dependent on ridership, passenger miles or train miles. For each variable cost, a principal cost driver is identified and used to determine the total cost of that operating variable. An increase or decrease in any of these will directly drive operating costs higher or lower.
- **Fixed costs** are generally predetermined, but may be influenced by external factors, such as the volume of freight tonnage, or may include a relatively small component of activity-driven costs. As a rule, costs identified as fixed should remain stable across a broad range of service intensities. Within fixed costs are two sub-categories:
    - **Route** costs such as track maintenance, train control and station expense that, although fixed, can still be clearly identified at the route level.
    - **Overhead or System** costs such as headquarters management, call center, accounting, legal, and other corporate fixed costs that are shared across routes or even nationally. A portion of overhead cost (such as direct line supervision) may be directly identifiable but most of the cost is fixed. Accordingly, assignment of such costs becomes an allocation issue that raises equity concerns. These kinds of fixed costs are handled separately.

Operating costs have been developed based on the following premises:

- Based on results of recent studies, a variety of sources including suppliers, current operators' histories, testing programs and prior internal analysis from other passenger corridors were used to develop the cost data. However, as the rail service is implemented, actual costs will be subject to negotiation between the passenger rail authority and the contract rail operator(s).
- Freight railroads will maintain the track and right-of-way that they own, but ultimately, the actual cost of track maintenance will be resolved through negotiations with the railroads. For this study a track maintenance cost model was used that reflects actual freight railroad cost data.
- Maintenance of train equipment will be contracted out to the equipment supplier.
- Train operating practices follow existing work rules for crew staffing and hours of service. Operating expenses for train operations, crews, management and supervision were developed through a bottoms-up staffing approach based on typical passenger rail organizational needs.

The costing framework has been validated with recent operating experience based on publicly available data from other sources, particularly the Northern New England Passenger Rail Authority's (NNEPRA) *Downeaster* costs and data on Illinois operations that was provided by Amtrak. It has been brought to a $2008 costing basis and additional cost categories, such as for electrification, have been added into the model.

As background, the MWRRS costing framework was developed in conjunction with nine states that comprised the MWRRS steering committee and with Amtrak. In addition, freight railroads, equipment manufacturers and others provided input to the development of the costs.

The original concept for the MWRRS was for development of a new service based on operating methods directly modeled after state-of-the-art European rail operating practice. Along with anticipated economies of scale, modern train technology could reduce operating costs when compared to existing Amtrak practice. In the original 2000 MWRRS Plan, European equipment costs were measured at 40 percent of Amtrak's costs. However, in the final MWRRS plan that was released in 2004, train-operating costs were significantly increased to a level that is more consistent with Amtrak's current cost structure. However, adopting an Amtrak cost structure for financial planning does not suggest that Amtrak would actually be selected for the corridor operation. Rather, this selection increases the flexibility for choosing an operator without excluding Amtrak, because multiple operators and vendors will be able to meet the broader performance parameters provided by this conservative approach.

The RMRA analysis has been conducted using 2008 constant dollars.

7.1 Variable Costs

These costs include those that directly depend on the number of train-miles operated. They include train equipment maintenance, train crew cost, fuel and energy, onboard service, and insurance costs.

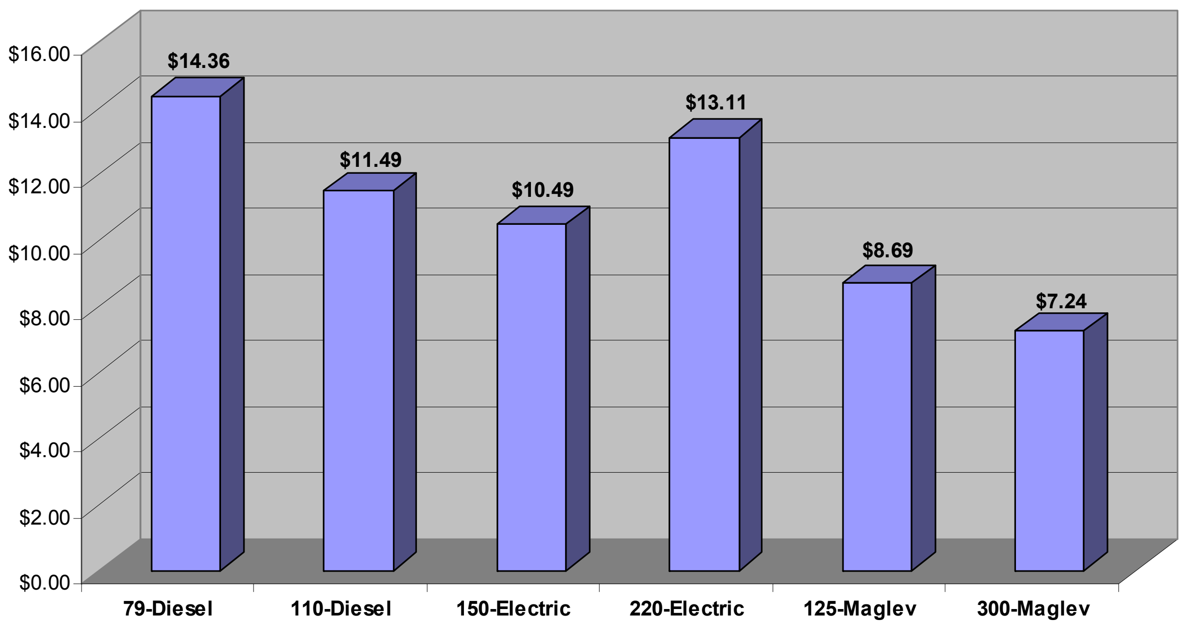
7.1.1 Train Equipment Maintenance

Equipment maintenance costs include all costs for spare parts, labor and materials needed to keep equipment safe and reliable. The costs include periodical overhauls in addition to running maintenance. It also assumes that facilities for servicing and maintaining equipment are designed specifically to accommodate the selected train technology. This arrangement supports more efficient and cost-effective maintenance practices. Acquiring a large fleet of trains with identical features and components, allows for substantial savings in parts inventory and other economies of scale. In particular, commonality of rolling stock and other equipment will standardize maintenance training, enhance efficiencies and foster broad expertise in train and system repair.

The MWRRS study developed a cost of $9.87 per train mile for a 300-seat train in $2002. This cost was increased to $11.49 per train mile in $2008. Available evidence suggests that the maintenance cost for an electric train should be about 9 percent cheaper per equivalent seat-mile than that of a diesel train leading to a unit cost of $10.49 per train-mile for the 150-mph locomotive-hauled electric train used on the 4 percent gradients. The higher-powered 220-mph electric train needed for 7 percent gradients will need more on-board electrical equipment, transformers and traction motors that increases its operating cost up to $13.11 per train-mile.

Equipment maintenance cost for Maglev vehicles were developed from information provided by Transrapid and other sources. Available data indicates that Maglev vehicle maintenance costs should be substantially lower than for conventional rail vehicles. However the 125-mph Colorado Maglev has the LIM motor on board the vehicle, which adds to the electrical complexity of that LIM vehicle as opposed to the Transrapid, which has the LSM motor in the guideway. The need for maintaining this additional on-board electrical equipment is reflected in a higher equipment cost for the 125-mph LIM vehicle as compared to the 300-mph LSM Transrapid. All equipment maintenance unit costs used for this evaluation are summarized in Exhibit 7-2.

Exhibit 7-2: Equipment Maintenance Cost per Mile ($2008)



7.1.2 Train and Engine Crew Costs

The train operating crew incurs crew costs. Following Amtrak staffing policies, the operating crew would consist of an engineer, a conductor and an assistant conductor and is subject to federal Hours of Service regulations. Costs for the crew include salary, fringe benefits, training, overtime and additional pay for split shifts and high mileage runs. An overtime allowance is included as well as scheduled time-off, unscheduled absences and time required for operating, safety and passenger handling training. Fringe benefits include health and welfare, FICA and pensions. The cost of employee injury claims under FELA is also treated as a fringe benefit for this analysis. The overall fringe benefit rate was calculated as 55 percent. In addition, an allowance was built in for spare/reserve crews on the extra board. Costing of train crews was based on Amtrak's 1999 labor agreement, adjusted for inflation to 2008.

Any intercity service needs the safety, fare collection and customer service functions performed by the on-board train crew. Regarding the train operator, it is equally possible to automate either a conventional rail system or a maglev, provided access to the right-of-way is equally controlled. Some previous maglev studies have proposed to eliminate staffing on-board trains and instead place their staffing in stations. This could be appropriate for an extremely high-volume, short-haul maglev such as might be found in urban transit corridors, but for a long haul, lower volume intercity application it is more appropriate to place personnel on board the trains rather than in the stations. Since the rail and maglev modes are equal in their ability to be automated, an "apples to apples" comparison of Rail versus Maglev options requires consistency in the train and station staffing assumptions.

Crew costs depend upon the level of train crew utilization, which is largely influenced by the structure of crew bases and any prior agreements on staffing locations. Train frequency strongly influences the amount of held-away-from-home-terminal time, which occurs if train crews have to stay overnight in a hotel away from their home base. Since train schedules have continued to evolve throughout the lifetime of this study and a broad range of service frequencies and speeds have been evaluated, a parametric approach was needed to develop a system average per train mile rate for crew costs. Such an average rate necessarily involves some approximation, but to avoid having to reconfigure a detailed crew-staffing plan whenever the train schedules change, an average rate is necessary and appropriate for a planning-level study.

For this study, an intermediate value of $4.58 per train mile was selected for 110-mph scenarios. This is a moderate level of crew cost that includes the need for some away-from-home layover. 79-mph scenarios cost $6.13 per train-mile because of poor crew utilization in these low-frequency scenarios. With trains operating less frequently there is less opportunity to return crews to their home base on the same day, leading to more split shifts and overnight layovers. The 220-mph scenarios used $4.28 per train mile, reflecting operating efficiencies related both to higher speeds and more frequent trains, both of which tend to reduce the need for away-from-home layovers.

7.1.3 Fuel and Energy

Both the ridership and operating cost models are based on fuel costs that were in effect during the base year of 2008 and that formed the basis of the demand model calibration. The assumed diesel fuel cost on the operating side is consistent with the level of gasoline prices that were assumed for development of the demand forecasts. The fuel price spikes of 2007 and 2008 show the difficulty of predicting short-term energy prices. However, economists are in more general agreement that long-term energy prices are only going in one direction: up.

A consumption rate of 2.42 gallons/mile was estimated for a 110-mph 300-seat train, based upon nominal usage rates of all three technologies considered in Phase 3 of the MWRRS Study. Assuming $2.52 a gallon for diesel fuel per a recent RTD study, this translates into a cost of $6.10 per train mile, roughly doubling the cost of diesel fuel as compared to the earlier MWRRS study.

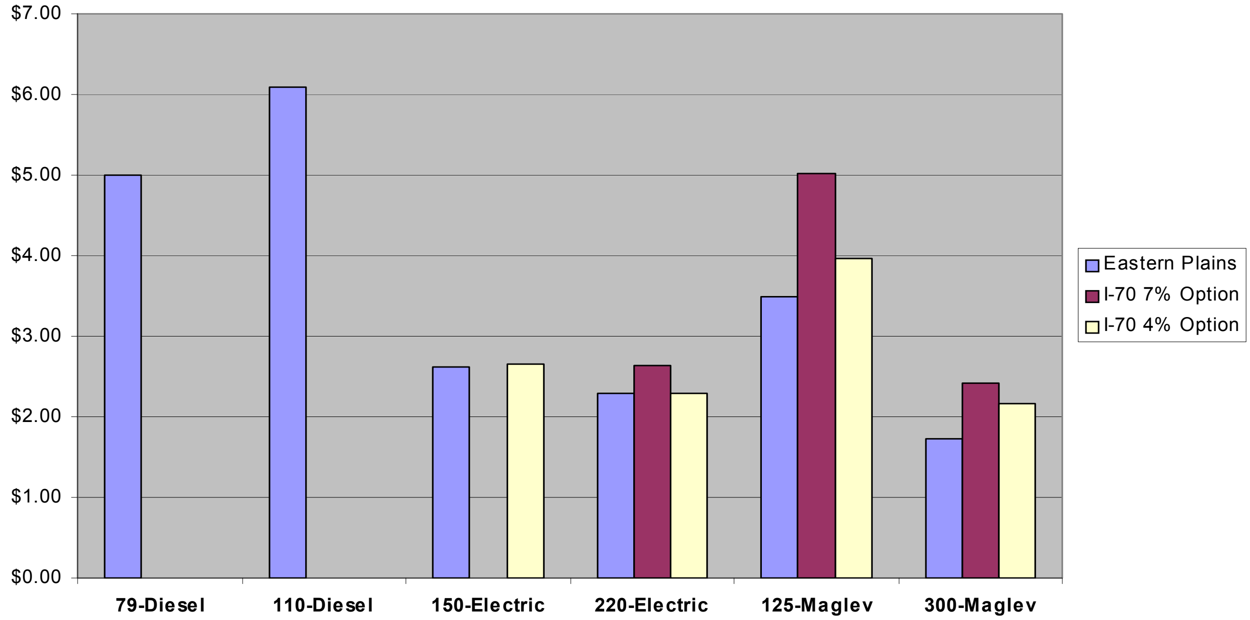
However, electric traction has an advantage over diesel since it can be powered from any energy source, not just petroleum-based fuel. Even taking typical peaking demands into account, electric energy is typically less expensive than diesel fuel. The comparable cost for the 150-mph locomotive-hauled electric train was just $2.61 per train mile as compared to $6.10 for the diesel. The 220-mph electric multiple unit is even more efficient at $2.29 per train mile when operating on the I-25 corridor in the eastern plains. All electric costs include the Peak Usage charge, which for electric rail systems is significant, usually doubling the overall electric cost.

For costing electric train or maglev operations in the mountains, an allowance must be made for energy recapture during regenerative braking. That is, some of the energy used going uphill can be turned back into electricity going downhill, and fed back into the overhead electric wire. Clearly more energy will be used overall due to operation on heavy grades, but the ability to regenerate power offsets at least a part of the added cost.

Both electric trains and maglev vehicles have the ability for regenerative braking. However they are not equally efficient at doing it. Rail vehicles tend to be the heaviest, but their traction motors have a very high electrical efficiency because of the small air gap. LSM maglev vehicles are very light compared to rail vehicles and have good electrical efficiency as well. However, LIM maglev vehicles such as the proposed Colorado Maglev have additional weight due to having the linear motor on board the vehicle; additionally the electrical efficiency of LIM propulsion is only in the 70 percent range for LIM as opposed to mid-90 percent for LSM and high-90 percent for rail. As a result, the LIM vehicle wastes a lot of electrical energy both going uphill and downhill, turning that energy into heat.

This result is shown in Exhibit 7-3 where the 220-mph electric train has a cost of $2.63 per mile for operating in the mountains, only slightly more than for operating on level ground, due to this vehicle's high efficiency in regenerative braking mode. The 300-mph maglev has a slightly lower cost of $2.42 per mile, although the LSM propulsion is slightly less efficient in recapturing energy, the maglev vehicle is much lighter, so it consumes less energy overall. However, the 125-mph LIM maglev costs $5.02 per mile in mountainous territory, approximately double the energy consumption of either the electric train or LSM maglev, due to the poor electrical efficiency of the LIM drive.

Exhibit 7-3: Energy and Fuel - Cost per Mile ($2008)



7.1.4 Onboard Services (OBS)

Onboard service (OBS) costs are those expenses for providing food service onboard the trains. OBS adds costs in three different areas: equipment, labor and cost of goods sold. Equipment capital and operating cost is built into the cost of the trains and is not attributed to food catering specifically. Small 200-seat trains cannot afford a dedicated dining or bistro car. Instead, an OBS employee or food service vendor would move through the train with a trolley cart, offering food and beverages for sale to the passengers.

The goal of OBS franchising should be to ensure a reasonable profit for the provider of on-board services, while maintaining a reasonable and affordable price structure for passengers. The key to attaining OBS profitability is selling enough products to recover the train mile related labor costs. If small 200-seat trains were used for start-up, given the assumed OBS cost structure, even with a trolley cart service the OBS operator will be challenged to attain profitability. However, the expanded customer base on larger 300-seat trains can provide a slight positive operating margin for OBS service. 400-seat electric trains should provide a comfortable positive profit margin for the OBS operator.

Because the trolley cart has been shown to double OBS revenues, it can result in profitable OBS operations in situations where a bistro-only service would be hard-pressed to sell enough food to recover its costs. While only a limited menu can be offered from a cart, the ready availability of food and beverages at the customer's seat is a proven strategy for increasing sales. Many customers appreciate the convenience of a trolley cart service and are willing to purchase food items that are brought directly to them. While some customers prefer stretching their legs and walking to a bistro car, other customers will not bother to make the trip.

The cost of goods sold is estimated as 50 percent of OBS revenue, based on Amtrak's route profitability reports. Labor costs, including the cost of commissary support and OBS supervision, have been estimated at $2.38 per train mile for 110-mph service, declining to $1.66 per train mile because of better crew utilization in the 220-mph scenario. This cost is generally consistent with Amtrak's level of wages and staffing approach for conventional bistro car services. However, this Business Plan recommends that an experienced food service vendor provide food services and use a trolley cart approach.

A key technical requirement for providing trolley service is to ensure the doors and vestibules between cars are designed to allow a cart to easily pass through. Since trolley service is a standard feature on most European railways, most European rolling stock is designed to accommodate the carts. Although convenient passageways often have not been provided on U.S. equipment, the ability to support trolley carts is an important equipment design requirement for the planned service.

7.1.5 Insurance Costs

Liability costs were estimated at 1.3¢ per passenger-mile, the same rate that was assumed in the earlier MWRRS study brought to $2008. Federal Employees Liability Act (FELA) costs are not included in this category but are applied as an overhead to labor costs.

The Amtrak Reform and Accountability Act of 1997 (§161) provides for a limit of $200 million on passenger liability claims. Amtrak carries that level of excess liability insurance, which allows Amtrak to fully indemnify the freight railroads in the event of a rail accident. This insurance protection has been a key element in Amtrak's ability to secure freight railroad cooperation. In addition, freight railroads perceive that the full faith and credit of the United States Government is behind Amtrak, while this may not be true of other potential passenger operators. A recent General Accounting Office (GAO) review[2] has concluded that this $200 million liability cap applies to commuter railroads as well as to Amtrak. If the GAO's interpretation is correct, the liability cap may also apply to potential Colorado rail franchisees. If this liability limitation were in fact available to potential franchisees, it would be much easier for any operator to obtain insurance that could fully indemnify a freight railroad at a reasonable cost. It is recommended that the Rocky Mountain Rail Authority seek qualified legal advice on this matter.

[2] See: http://www.gao.gov/highlights/d04240high.pdf

7.2 Fixed Route Costs

This cost category includes those costs that, while largely independent of the number of train-miles operated, can still be directly associated to the operation of specific routes. It includes such costs as track maintenance, which varies by train technology, and station operations.

7.2.1 Track and Right-of-Way Costs

Currently, it is industry practice for passenger train operators providing service on freight-owned rights-of-way to pay for track access, dispatching and track maintenance. The rates for all of these activities will ultimately be based upon a determination of the appropriate costs that result from negotiations between the parties. The purpose here is to provide estimates based on the best available information; however, it is important to recognize that this study is a feasibility-level analysis and that as the project moves forward, additional study and discussions with the railroads will be needed to further refine these costs. Both capital and operating costs will be estimated.

To accommodate passenger trains, Colorado rail corridors would need a substantial increase in capacity. Once constructed, these improvements will need to be maintained to FRA standards required for reliable and safe operations. The costing basis assumed in this report is that of *incremental* or *avoidable* costs. Avoidable costs are those that are eliminated or saved if an activity is discontinued. The term *incremental* is used to reference the change in costs that results from a management action that increases volume, whereas *avoidable* defines the change in costs that results from a management action that reduces volume.

The following cost components are included within the Track and Right-of-Way category:

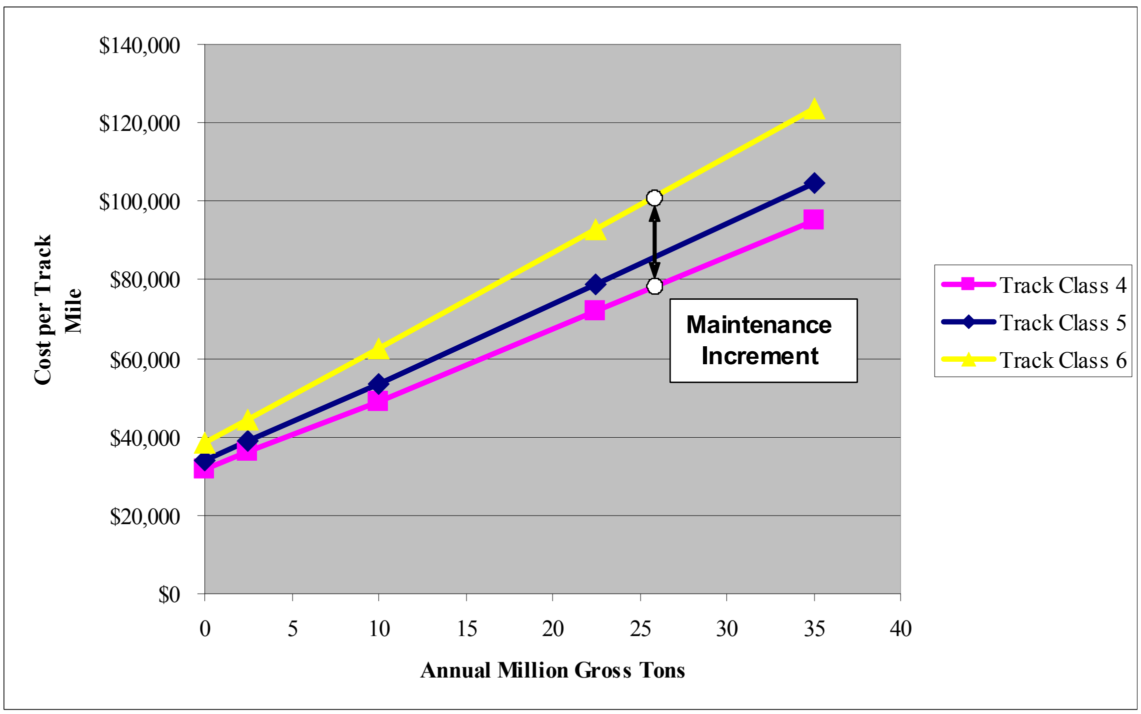
- **Track Maintenance Costs.** Costs for track maintenance are estimated based on Zeta-Tech's January 2004 draft technical monograph *Estimating Maintenance Costs for Mixed High-Speed Passenger and Freight Rail Corridors*.[3] Zeta-Tech costs have been adjusted for inflation to $2008. However, Zeta-Tech's costs are conceptual and are still subject to negotiation with the freight railroads.
- **Dispatching Costs and Out-of-Pocket Reimbursement.** Passenger service must also reimburse a freight railroad's added costs for dispatching its line, providing employee efficiency tests and for performing other services on behalf of the passenger operator. These costs are included as an additive to Track and Right-of-Way Maintenance costs.
- **Costs for Access to Track and Right-of-Way.** Access fees, particularly train mile fees incurred as an operating expense, are specifically excluded from this calculation. Any such payments would have to be calculated and negotiated on a route-specific and railroad-specific basis. Such a calculation would have to consider the value of the infrastructure

[3] Zeta-Tech, a subsidiary of Harsco (a supplier of track maintenance machinery) is a rail consulting firm who specializes in development of track maintenance strategies, costs and related engineering economics.

improvements made to the corridor for balancing up-front capital with ongoing operating payments.[4]

Exhibit 7-4 shows the conceptual relationship between track maintenance cost and total tonnage that was calibrated from the earlier Zeta-Tech study. It shows a strong relationship between tonnage, FRA track class (4 through 6, corresponding to a 79-mph to 110-mph track speed) and maintenance cost. At low tonnage, the cost differential for maintaining a higher track class is not very large, but as tonnage grows, so too does the added cost. For shared track, if freight needs only Class 4 track, the passenger service would have to pay the difference, called the "maintenance increment", which for a 25 MGT line as shown in Exhibit 7-4, would come to about $25,000 per mile per year. The required payment to reimburse a freight railroad for its added track cost would be less for lower freight tonnage, more for higher freight tonnage.

Exhibit 7-4: Track Maintenance Cost Function (in $2002)



Please note that Exhibit 7-4 shows that the cost of shared track depends strongly on the level of *freight* tonnage, since the passenger trains are relatively lightweight and do not contribute much to the total tonnage, In fact, following the Zeta-Tech methodology, the "maintenance increment" is calculated based on *freight tonnage only*, since a flat rate of $1.56 per train mile as used in the Zeta-Tech report was already added to reflect the direct cost of added passenger tonnage regardless of

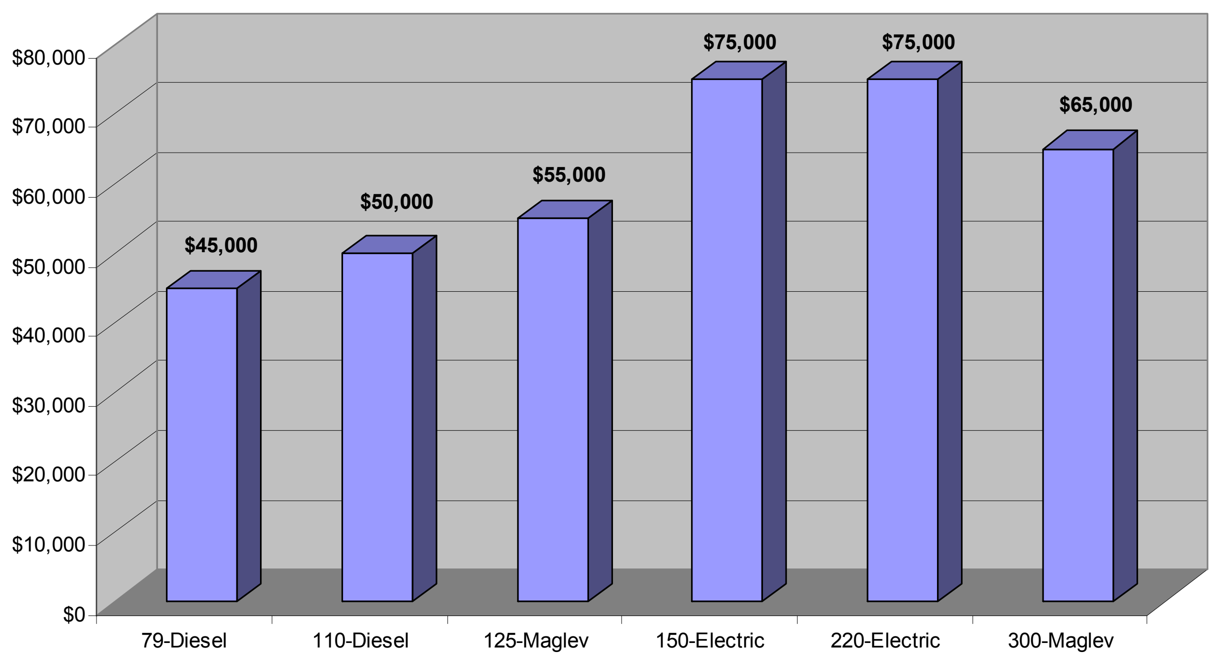
[4] For 110-mph service, the level of infrastructure improvements to the corridor called for in this study should provide enough capacity to allow superior on-time performance for both freight and passenger operations

track class. This cost, which was developed by Zeta-Tech's TrackShare® model, includes not only directly variable costs, but also an allocation of a freight railroad's fixed cost. Accordingly, it complies with the Surface Transportation Board's definition of "avoidable cost." An allowance of 39.5¢ per train-mile was added for freight railroad dispatching and out-of-pocket costs.

The same cost function shown in Exhibit 7-4 can also be used for costing dedicated passenger track. With dedicated track, the passenger system is assumed to cover the entire cost for maintaining its own track. (Freight would then have to reimburse the passenger operator on a car-mile basis for any damage it causes to the passenger track.) Because passenger train tonnage is very low however, it can be seen that the cost differential between Class 4, 5 and 6 track is very small. Adjusting Zeta-Tech's $2002 costs shown in Exhibit 7-4 up to $2008, the average annual cost per track-mile for maintaining dedicated Class 4 track is about $45,000; the cost for Class 6 track rises to $50,000. Adding $25,000 per track-mile for overhead electric catenary, the overall maintenance cost rises to about $75,000 per track mile per year.

According to the data furnished by Transrapid, maglev infrastructure should cost less to maintain than an equivalent rail guideway. Compared to $75,000 per track mile for electrified railroad, the 300-mph Transrapid guideway is estimated to cost only $65,000 per mile per year to maintain. Since the 125-mph maglev guideway with LIM propulsion is much simpler than Transrapid's LSM guideway (which has extensive electrical coils in the track) the 125-maglev guideway cost was reduced to $55,000 per mile. These results in terms of guideway maintenance cost are summarized in Exhibit 7-5.

Exhibit 7-5: Guideway Maintenance – Cost per Track Mile ($2008)



In addition to an *operating* component of track maintenance cost (which is shown in Exhibit 7-4) the track cost methodology also identifies a *capital* cost component. For track maintenance:

- *Operating costs* cover expenses needed to keep existing assets in service and include both surfacing and a regimen of facility inspections.
- *Capital costs* are those related to the physical replacement of the assets that wear out. They include expenditures such as for replacement of rail and ties, but these costs are not incurred until many years after construction. In addition, the regular maintenance of a smooth surface by reducing dynamic loads actually helps extend the life of the underlying rail and tie assets. Therefore, capital maintenance costs are gradually introduced using a table of ramp-up factors provided by Zeta-Tech (Exhibit 7-6). A normalized capital maintenance level is not reached until 20 years after completion of the rail upgrade program.

Exhibit 7-6: Capital Cost Ramp-Up Following Upgrade of a Rail Line

Year	% of Capital Maintenance	Year	% of Capital Maintenance
0	0%	11	50%
1	0%	12	50%
2	0%	13	50%
3	0%	14	50%
4	20%	15	75%
5	20%	16	75%
6	20%	17	75%
7	35%	18	75%
8	35%	19	75%
9	35%	20	100%
10	50%		

For development of the Business Plan, only the operating component of track maintenance cost is treated as a direct operating expense. Capital maintenance costs are incorporated into the Financial Plan and into the Benefit Cost analysis. Because these capital costs do not start occurring until rather late in the project life, usually they have a very minor effect on the Benefit Cost calculation. These costs can be financed using direct capital grants or from surplus operating cash flow. The latter option has been assumed in this study. Accordingly, maintenance capital expenses only reduce the net cash flow generated from operations; they do not affect the operating ratio calculations.

7.2.2 Station Operations

A simplified fare structure, heavy reliance upon electronic ticketing and avoidance of a reservation system will minimize station personnel requirements. Station costs include personnel, ticket machines and station operating expenses.

- Staffed stations will be assumed at major stations. All stations were assumed open for two shifts. The cost for the staffed stations includes eight positions at each new location, costing $600,000 per year, in $2008.
- The cost for unstaffed stations covers the cost of utilities, ticket machines, cleaning and basic facility maintenance, costing $75,000 per year, in $2008. (These costs are also included in the staffed station cost.) Volunteer personnel such as Traveler's Aid, if desired could staff these stations.

This stations cost is practically independent of the number of trains operated or their speed, so running the largest number of trains at the highest speed possible generates the best economies of scale. The exact number of stations depends on the route alignment options that are ultimately selected for the system, but total station costs for the full system are likely to fall in the range of $12-14 million annually.

7.3 System Overhead Costs

The category of System Overhead largely consists of Service Administration or management overheads, covering such needs as the corporate procurement, human resources, accounting, finance and information technology functions as well as call center administration. A stand-alone administrative organization appropriate for the operation of a corridor system was developed for the MWRRS and later refined for the Ohio Hub studies. This organizational structure, which was developed with Amtrak's input and had a fixed cost of $8.9 million plus $1.43 per train-mile (in $2002) for added staff requirements as the system grew. Inflated to $2008, this became $10.3 million plus $1.53 per train mile.

However, the Sales and Marketing category also has a substantial fixed cost component for advertising and call center expense, adding another $2.7 million per year fixed cost, plus variable call center expenses of 66¢ per rider, all in $2008.[5] Finally, credit card and travel agency commissions are all variable: 1.8 percent and 1 percent of revenue, respectively. Therefore, the overall financial model for a Stand-alone organization therefore has $13.0 million ($10.3 + $2.7 million) annually in fixed cost for administrative, sales and marketing expenses. In addition, the system operator was allowed a 10 percent markup on certain direct cost items as a contribution to operator profit.

For operations that are too small to support their own stand-alone management structure, a benchmarking exercise concluded that an allocation share of $5 per train-mile contribution to fixed costs would be adequate under most circumstances, until the corridor system grows to a point where it is large enough that it can start supporting its own stand-alone administrative cost structure.

[5] In the MWRRS cost model, call center costs were built up directly from ridership, assuming 40 percent of all riders call for information, and that the average information call will take 5 minutes for each round trip. Call center costs, therefore, are variable by rider and not by train-mile. Assuming some flexibility for assigning personnel to accommodate peaks in volume and a 20 percent staffing contingency, variable costs came to 57¢ per rider. These were inflated to 66¢ per rider in $2008.

7.4 Key Cost Results

An apples-to-apples comparison of maglev to rail cost has concluded, based on the best available information, that propulsion-dependent operating costs for a 300-mph maglev would be generally lower than that for a rail system; these include energy, vehicle maintenance and guideway maintenance costs. Other maglev costs were treated as equivalent to a rail system, including Administration, Train and On Board Crew, Stations and Insurance costs.

Exhibit 7-7 shows the total annual operating cost breakdown for the full system options. Each technology option has a particular route alignment structure associated with it as defined in Chapter 3, and operating plan as described in Chapter 5.

Exhibit 7-7: Total Annual Operating Cost Breakdown by Technology

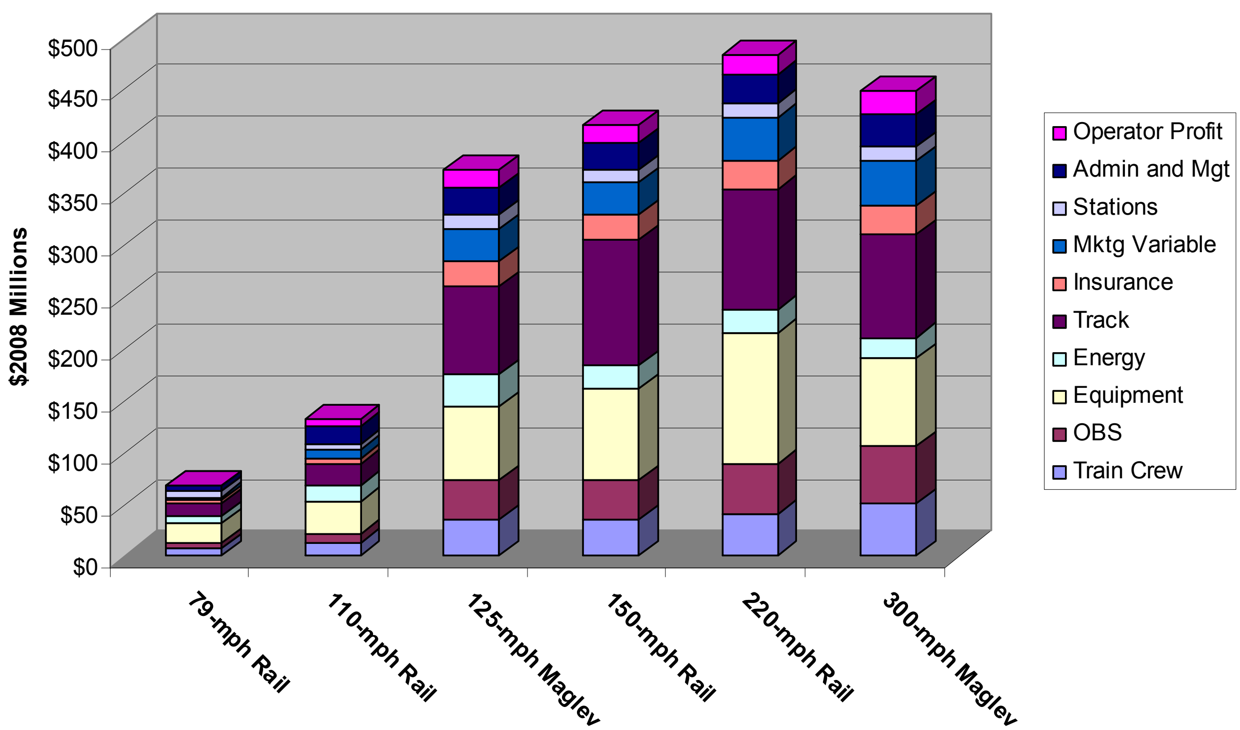
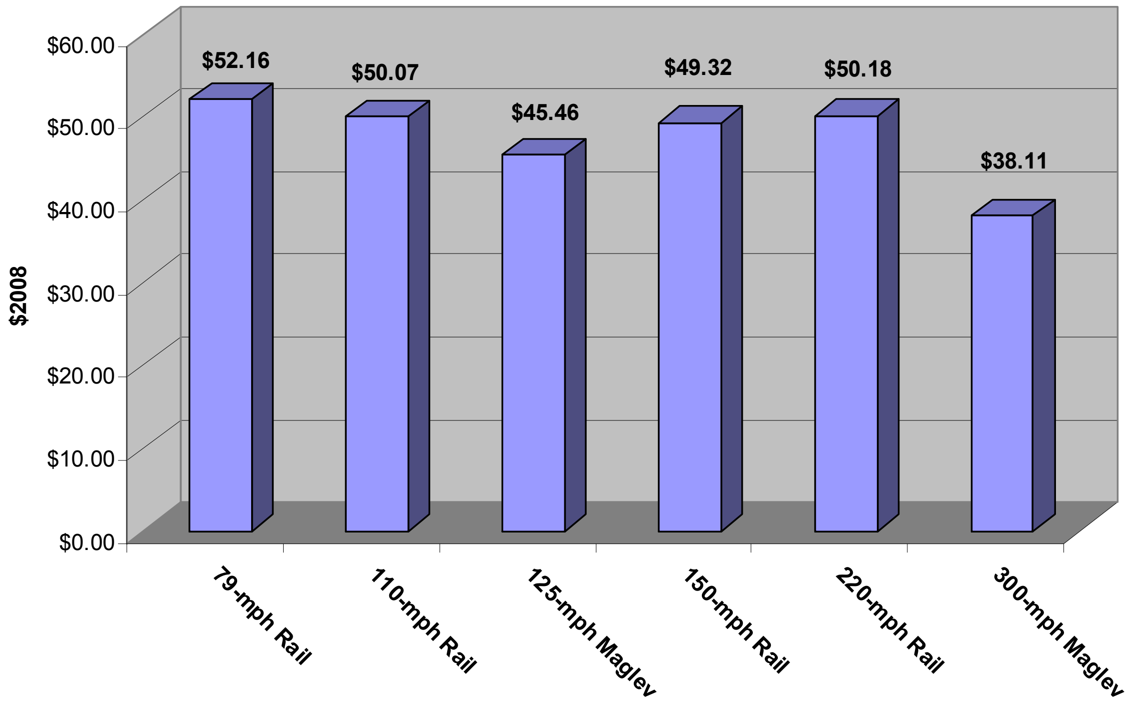


Exhibit 7-8 shows the average cost per train mile. It shows that maglev options tend to have slightly lower average costs than do the rail options. Rail costs are all remarkably close to $50 per train-mile. The 220-mph electric train however, has a much higher earning capacity than does the 110-mph diesel train because it is a larger train and because it goes faster, the 220-mph train can support a higher revenue yield per passenger-mile. This explains one of the main reasons why higher speed systems tend to produce better financial operating results than do lower speed systems.

Exhibit 7-8: Average Cost per Train Mile by Technology



8 Capital Costs

8.1 Introduction

The study team conducted an engineering assessment of infrastructure needed in cooperation with the RMRA, freight railroads, Colorado DOT and in coordination with both the FasTracks and Colorado Freight Rail Relocation (R2C2) studies. Towards the end of this chapter, vehicle costs are estimated based on the Operating Plan developed in Chapter 5 to develop the total Capital cost of the project.

The engineering assessment provides an evaluation of the current condition of the proposed highway, greenfield, and railroad right-of-way alignments; identifies improvements to existing rail lines needed to support the 79/110/150-mph passenger service scenarios; and develops estimates for new greenfield alignments for the 220-mph and 300-mph options. The engineering assessment is presented in Chapter 3 of this report.

In addition to the engineering assessment, the capital costing methodology identifies rolling stock (equipment) costs and land costs. Land costs are presented separately, as a placeholder for access to railroad rights-of-way and for procurement of additional privately owned property where required to construct new passenger rail infrastructure.

The engineering assessment and its findings and recommendations are preliminary and have not been discussed in detail with the railroads. As discussed earlier, the Study is at a feasibility level, the project is un-funded and formal negotiations with the railroads have not been initiated. Future Engineering Assessments require considerably more discussion to ensure railroad concurrence. Final design concepts and recommended capital plans depend on detailed operations and capacity analyses, design coordination and in-depth discussions with the freight railroads. As the project moves beyond the feasibility phase, railroad involvement and coordination become increasingly important.

The engineering assessment was conducted at a feasibility level of detail and accuracy. Exhibit 8-1 highlights the levels of accuracy associated with typical phases of project development and engineering design. A low level of accuracy is associated with the evaluation of project feasibility; while the highest level of accuracy is achieved during final design and production of construction documents. The RMRA Feasibility Study is only the first step in the project development process. As shown in Exhibit 8-1, the level of accuracy typically associated with a Feasibility Study is +/- 30 percent. It had been suggested that a 30 percent contingency be added to these costs to reflect a worst-case scenario. However, the error range already covers this contingency. The cost estimate is intended to be a mid-range projection with equal probability of the actual cost moving up or down.

Exhibit 8-1: Engineering Project Development Phases and Levels of Accuracy Development

Development Phases	Approximate Engineering Design Level*	Approximate Level of Accuracy**
Feasibility Study	0%	+/- 30% or worse
Project Definition/Advanced Planning	1-2%	+/- 25%
Conceptual Engineering	10%	+/- 20%
Preliminary Engineering	30%	+/- 15%
Pre-Final Engineering	65%	+/- 15%
Final Design/Construction Documents	100%	+/- 10% or better

*Percent of *Final Design*. **Percent of actual costs to construct.
Table prepared by Quandel Consultants, LLC

8.2 Engineering Assessment

The first step in the Engineering Assessment is to divide each corridor into segments. Route segments for existing railroad rights-of-way generally begin and end at major railroad control points or rail stations. For greenfield alignments, segments begin and end at station points. Typical corridors are divided into three to five route segments. Field inspections of the corridors have been conducted. Chapter 3 and the *Existing Conditions Report* highlight the findings of the field inspections.

A systematic engineering planning process was used to conduct the engineering assessment using the five basic costing elements that were defined in Chapter 3:

- Guideway and Track Elements
- Structures – Approaches, Flyovers, Bridges and Tunnels
- Systems
- Crossings
- Stations and Maintenance Facilities

Three auxiliary costing elements have been defined in the chapter as follow:

- Right-of-Way and Land
- Vehicles
- Professional Services & Contingencies

The engineering assessment was based on these eight costing elements. In addition to the field inspections and extensive work with GIS and railroad track charts, the assessment included a thorough review of the alignment studies and estimated costs presented in the I-70 Mountain Corridor Programmatic Environmental Impact Study. Sato Associates, the prime consultant for the

Mountain Study, was extremely helpful in understanding the details concerning the PEIS alignment for the rail alternative and the estimated infrastructure costs associated with the rail alternative. Although the PEIS alignment was used in segments of the I-70 corridor, the capital costs were estimated as part of this Feasibility Study. The PEIS capital cost estimates were within a reasonable range of the Feasibility Study estimates when adjusted for inflation.

8.3 Development of Unit Construction Capital Costs

8.3.1 Base Set of Unit Costs

The study team developed unit costs in 2008 dollars for the design and construction of high-speed passenger rail and maglev infrastructure on a series of previous planning projects. Initially the unit costs were applied to planned construction in the Midwest to implement the Midwest Regional Rail Initiative. Later the costs were applied to capital cost estimates for high-speed rail in Florida, Ohio, Minnesota and California.

The base set of unit costs addresses typical passenger rail infrastructure construction elements including: roadbed and trackwork, systems, facilities, structures, and grade crossings.

The unit costs have been evaluated by peer panels, freight railroads and contractors. The values have been found to be reasonable for developing the capital costs under normal contractor bidding procedures and under railroad force account agreements for construction. It should be noted that in two cases the costs have not been sufficient, specifically:

- DBOM procurement, where the contractor takes on large future operating risks and seeks to front load the risk in the initial construction.
- Rail alignments constructed in narrow highway medians under congested urban traffic.

The unit costs were developed and evaluated in the period between January 2000 and June 2002. Two questions must be considered in applying these costs to high-speed rail planning in Colorado:

1. Relative Costs: Are the costs reasonable for rail construction in Colorado considering local costs of materials and labor?
2. Cost Escalation: How should the costs be escalated from the nominal June 2002 values to current values considering the historical changes in construction costs?

A variety of indices are employed to monitor construction costs throughout the United States. However, no publicly available index exists for rail construction. In addition, relatively few recent examples of completed intercity passenger rail construction are found. This is especially true for high-speed applications.

8.3.2 Relative Costs

The *Engineering News Record* tracks a Building Cost Index (BCI) and a more general Construction Cost Index (CCI) in major cities and averages the values to produce national indices. It is reasonable to assume that the CCI is a better indicator of regional cost differences for a transportation project than the BCI. The CCI is calculated as the sum of 200 hours of local (union) common labor including fringes plus the local cost of 1.128 tons of Portland cement plus the national average price of 25cwt of fabricated structural steel. The CCI's from 1990 to 2008 indicate that construction costs in Denver have typically been 20-30 percent lower than national construction costs, and 25-40 percent lower than the average of costs in the Midwest. There is however, considerable variability in the Midwest costs between cities: for example, Kansas City has had an even lower CCI than Denver over the period.

To some extent, the construction cost of relatively specialized products and systems is independent of local regional costs. In the case of railroad construction, the costs of key materials such as rail, concrete ties and signal equipment are relatively uniform throughout the country. Similarly, the cost of skilled labor and mechanized track laying systems will be similar in all locations. These factors tend to diminish the regional construction cost differences.

8.3.3 Cost Escalation

Many State DOTs prepare periodic highway construction cost indices based on the tabulated bid prices of earthwork, asphalt pavement, concrete pavement, structural concrete, reinforcing steel and structural steel to assemble a composite index tied to base year costs in 1987. The State of Washington publishes the indices for the states of Washington, California, Colorado, Oregon, South Dakota, Utah and an FHWA composite. (The FHWA discontinued preparing the composite index in 2006). This data cannot be used to compare the absolute costs of highway construction among states, but may be used to compare the price trends. Comparing the indices over the 6 year period from 2002 to 2008, the Colorado index has outpaced the others, increasing by a factor of 2.21 compared to an average of 1.91 for the six states.

The Bureau of Labor Statistics prepares a variety of monthly, national Producer Price Indices, which are often used for escalation cost adjustments in construction projects. Two such indices may be suitable for our application, the Highway and Street Construction Index (PCUBHWY) and the Other Heavy Construction Index (PCUBHVY). A computation of escalation from June 2002 to January 2009 using either index yields similar results (HWY=51%, HVY=44%), but as the highway index is heavily influenced by the costs of petroleum products such as asphalt, it is reasonable to assume that the Other Heavy Construction Index is more suitable for our purpose.

8.3.4 Unit Price Adjustment

Based on the available data, it is reasonable to believe that the June 2002 unit costs developed for the Midwest can be adjusted downward for use in Colorado during the same time period. Considering the regional CCI difference and the relative uniformity of railroad material prices, an adjustment factor of 0.85 is reasonable.

While the BLS PPI suggests a national escalation factor of 1.44 for the period, the coincident Colorado DOT highway cost escalation factor of 2.21 is significant and suggests that construction cost escalation in Colorado exceeds that represented in the BLS value. The State of Colorado DOT has attributed much of the highway cost escalation to a regional shortage of Portland cement and high worldwide demand for asphalt, petroleum products and steel.

While the cost of rail construction is energy intensive due to the requirement for extensive grading to achieve desirable grades and curves, it is less so than highway construction, which uses petroleum products such as asphalt as a construction material. While a precise methodology for discounting the observed Colorado highway cost inflation does not exist, it is reasonable to believe that the regional escalation factor for rail construction over the period lies somewhere between the BLS PPI value of 1.44 and the CDOT value of 2.21. An average of the two values yields 1.825. The *Unit Price Regional and Escalation Analysis* is included in Appendix F.

Therefore the unit cost adjustment value considering regional cost differences and inflation from June 2002 to December 2008 is computed as follows:

Colorado Unit Cost (2008) = MWRRI Unit Cost (2002) x 0.85 x 1.825

8.3.5 Unit Capital Costs for Colorado – Steel Wheel/Steel Rail

<u>Trackwork and Land Acquisition</u>

The FRA requires that passenger trains operating on the general railroad system comply with stringent crashworthiness standards. Neither the FRA nor the Federal Highway Administration (FHWA) has addressed requirements for mode separation of high-speed passenger rail equipment operating in close proximity to highway traffic. Similarly, the FRA has not developed general rules for non-compliant passenger equipment operating in railway corridors adjacent to freight rail tracks. For the purposes of defining requirements necessary to proceed with the study and in order to develop planning level capital costs, it has been assumed that highway traffic and adjacent high-speed vehicles will be separated by concrete barriers. On tangent highway and track segments, there exists a small probability that automotive vehicles will leave the highway. Thus, protection against highway traffic incursions into the high-speed rail median would be provided using NCHRP Report 350 Level 5 highway concrete barrier walls. In curved median segments, where accidents are more likely, we have planned for NCHRP Level 6. It is anticipated that high-speed rail systems in the freight rail corridors will be separated by at least 25 ft between track centers, minimizing any need for physical protection. Chain link fencing will be provided throughout the system in all corridors to prevent the intrusion of trespassers and animals. These planning assumptions may be subject to modification as a result of federal or state rule making.

Land acquisition costs for right-of-way owned and controlled by the railroad industry is always an issue when attempting to introduce new passenger rail service. Since its inception, Amtrak has had the statutory right to operate passenger trains over freight railroad tracks and rights-of-way. When using freight tracks, Amtrak is required to pay only avoidable costs for track maintenance along with some out-of-pocket costs for dispatching[1].

Amtrak's payments do not include any access fee for the use of a railroad's tracks or its rights-of-way. Amtrak's federal statutory right-of-access has never required such a payment, and therefore, Amtrak avoids paying a fee or "rent" for occupying space on privately held land and facilities.

In the case of the RMRA high-speed rail routes, Colorado Department of Transportation has already begun a discussion with the freight railroads on the development of a bypass for Denver, Colorado Springs, and as far south as Pueblo and Trinidad. (See the *CDOT Rail Relocation Implementation Study, Jan. 2009*). While these discussions are still embryonic, there is clearly a case for providing a negotiated swap of right-of-way with one or perhaps both of the freight railroads.

While the RMRA may choose a different course, the final determination of what a Colorado passenger rail system will pay host freight railroads for use of their tracks and rights-of-way will ultimately be accomplished through negotiations.

This study assumes that a cost for access based on estimated across-the-fence land values would be included as part of the up-front capital expense, and would be used to purchase the rights to use the underlying railroad rights-of-way for the passenger service. It is assumed that railroads would receive this compensation in cases where the construction of a dedicated high-speed passenger track is on their property. If new track cannot be constructed within the existing railroad rights-of-way, then this cost would fund the possible acquisition of adjacent property.

Elsewhere land will need to be purchased directly from land owners. Where highway rights-of-way were used, the study assumed that right of way or air rights access would be granted by Colorado Department of Transportation at no cost to the rail system.

The outright purchase of land is not the only method whereby railroads could receive compensation for access to railroad rights-of-way. Commuter rail development provides examples of various types of payments for access rights. Some of these projects involved the purchase of the railroad rights-of-way while others provide up-front capital improvements in return for access to a railroad's tracks. The actual methods of payment remain to be determined during negotiation, and may depend on the importance of the track to the freight railroad as well as the level of capital to be invested by the passenger rail authority.

[1] However, these payments do not cover all of the freight railroads' incremental costs associated with dispatching Amtrak's passenger trains. Railroad costs increase due to delays caused by Amtrak's tightly scheduled trains. Track capacity constraints and bottlenecks create unreliable conditions where train delays often become unavoidable. While federal regulations give passenger trains dispatch priority, railroad dispatchers often encounter congestion where it becomes difficult to control traffic and adhere to Amtrak's timetables. In some cases, Amtrak will offer the railroads a payment to provide on-time passenger train performance. On heavily used line segments, however, these incentive payments only partially compensate a railroad for the costs of increased delay, and some railroads simply refuse to accept incentive payments. On lightly used lines, the economic rationale for making these payments is questionable since passenger trains cause very little delay on such tracks.

One area of possible concern is the freight railroads' ability to retain operating control over their rights-of-way. Whenever transit systems have paid full price to acquire a freight rail line, as on some commuter rail projects, the transit agencies have assumed operating control over the property. However, this study has assumed that the freight railroads would retain dispatching control over these rights-of-way. The railroads would have the right to use the increased capacity provided by the passenger system for its high-speed freight services.

For budgetary purposes, this study assumes an over-the-fence methodology for appraising the maximum value of railroad rights-of-way. To estimate land values, two land uses alongside each corridor are identified:

- Rural (e.g., farmland),
- Urban (e.g., high density residential, commercial, and industrial areas)

The value of a 50-foot wide right-of-way was established for each land use and the total land cost of the railroad corridor was estimated. Urban land rates were used in mountain resort areas such as Vail and Avon that have very high real estate prices. In the case of Vail no additional land cost needed to be assumed because the proposed rail alignment would be elevated over the existing I-70 highway alignment, thus was assumed to be granted to the project in that specific location.

Right-of-way cost was developed for the greenfield alternatives using the conceptual alignments and general land use designations. A 100 foot right-of-way was assumed. Where the alignment falls within an existing publicly-owned right-of-way, such as a highway or street alignment, no cost to the project for that particular right-of-way has been assumed. Where the geometric requirements take the alignment outside of the public right-of-way, impacted parcels were evaluated and a square foot quantity calculated. A unit cost per acre was developed in conjunction with other studies.

Exhibit 8-2 shows the unit cost for track work and land acquisition in 2008 dollars by project element.

Exhibit 8-2: Unit Capital Costs, Track work and Land Acquisition, in $2008

Item No.	Description	Unit	Unit Cost (Thousands of $2008)
1.1	HSR on Existing Roadbed (Single Track)	per mile	$1,174.90
1.2	HSR on Existing Roadbed (Double Track)	per mile	$2,350.00
1.3	HSR on New Roadbed & New Embankment (Single Track)	per mile	$1,765.30
1.4	HSR on New Roadbed & New Embankment (Double Track)	per mile	$3,163.90
1.5	HSR Double Track on 15' Retained Earth Fill	per mile	$16,711.30
1.6	Timber & Surface w/ 33% Tie replacement	per mile	$262.70
1.7	Timber & Surface w/ 66% Tie Replacement	per mile	$391.60
1.8	Relay Track w/ 136# CWR	per mile	$418.90
1.9	Freight Siding	per mile	$1,079.10
1.10	Passenger Siding	per mile	$1,628.10
1.11	NCHRP Class 6 Barrier (on curves)	lineal ft	$1.30
1.12	NCHRP Class 5 Barrier (on tangent)	lineal ft	$0.20
1.13	Fencing, 4 ft Woven Wire (both sides)	per mile	$60.30
1.14	Fencing, 6 ft Chain Link (both sides)	per mile	$181.00
1.15	Fencing, 10 ft Chain Link (both sides)	per mile	$207.10
1.16	Decorative Fencing (both sides)	per mile	$466.20
1.17	Drainage Improvements (cross country)	per mile	$78.10
1.18	Drainage Improvements in Median or along highway	per mile	$624.70
1.19	Land Acquisition Urban and Resort (100' of ROW)	per mile	$386.90
1.20	Land Acquisition Rural (100' of ROW)	per mile	$129.00
1.21	#33 High-Speed Turnout	each	$672.00
1.22	#24 High-Speed Turnout	each	$532.40
1.23	#20 Turnout Timber	each	$146.70
1.24	#10 Turnout Timber	each	$81.60
1.25	#20 Turnout Concrete	each	$294.60
1.26	#10 Turnout Concrete	each	$139.60
1.27	#33 Crossover	each	$1,344.10
1.28	#20 Crossover	each	$590.00
1.29	Elevate & Surface Curves	per mile	$68.60
1.30	Curvature Reduction	per mile	$465.00
1.31	Elastic Fasteners	per mile	$97.00

Structures: Approaches, Flyovers, Bridges, and Tunnels

A complete inventory of bridges has been developed for each existing rail route from existing track charts. For estimating the cost of new bridges on either green field alignments or along existing rail beds, conceptual engineering plans were used for a bridge to carry either single or double tracks over highways, streams, valleys, and rivers. Some bridges require rehabilitation on the abutments and superstructure. This type of work includes pointing of stone abutment walls, painting of bridges, and replacement of bearings. Many of the major bridge cost estimates will be estimated only as placeholders, which will be subject to more detailed engineering analysis in the future.

Rail route alternatives through the Rocky Mountains require a significant amount of tunneling to maintain operable grades, avoid areas prone to rock falls and avalanches, and to provide the shortest routes. Several tunnel configurations were considered. For this study, a two bore tunnel with cross passages is used for long and deep tunnels, whereas a single bore tunnel is used where the length is 1000 feet or less. Tunneling costs lie within the $20-73 thousand per linear foot range cited in Appendix G, where the higher cost was from the long undersea English Channel tunnel; but the estimates in Exhibit 8-3 are considered more appropriate benchmarks for the probable cost of Colorado tunnels. Exhibit 8-3 details the unit costs in 2008 dollars.

Exhibit 8-3: Unit Capital Costs, Structures in $2008

Item No.	Description (Bridges-under)	Unit	Unit Cost (Thousands of $2008)
2.1	Four Lane Urban Expressway (Rail over Highway)	each	$5,720.80
2.2	Four Lane Rural Expressway (Rail over Highway)	each	$4,762.40
2.3	Two Lane Highway (Rail over Highway)	each	$3,613.50
2.4	Rail (New Rail over Existing Rail)	each	$3,613.50
2.5	Minor river	each	$958.40
2.6	Major River	each	$9,581.60
2.7	Double Track High (50') Level Bridge	per LF	$14.40
2.8	Rehab for 110	per LF	$16.60
2.9	Convert open deck bridge to ballast deck (single track)	per LF	$5.50
2.10	Convert open deck bridge to ballast deck (double track)	per LF	$11.10
2.11	Single Track on Flyover/Elevated Structure	per LF	$5.00
2.12	Single Track on Approach Embankment w/ Retaining Wall	per LF	$3.50
2.13	Double Track on Flyover/Elevated Structure	per LF	$8.00
2.14	Double Track on Approach Embankment w/ Retaining Wall	per LF	$6.50
2.15	Ballasted Concrete Deck Replacement Bridge	per LF	$2.50
2.16	Land Bridges	per LF	$3.10
2.17	Four Lane Urban Expressway (Highway over Rail)	each	$2,469.40
2.18	Four Lane Rural Expressway (Highway over Rail)	each	$3,465.60
2.19	Two Lane Highway (Highway over Rail)	each	$2,251.60
2.20	Rail (Existing Rail over New Rail)	each	$7,229.40
2.21	Two Bore Long Tunnel	route ft	$44.00
2.22	Single Bore Short Tunnel	lineal ft	$25.00

Systems

The capital cost estimates for this study include costs to upgrade the train control and signal systems. Unit costs for system elements are shown in Exhibit 8-4. Under the 79-mph scenario, capital costs include the installation of Centralized Train Control (CTC) with interlockings and electric locks on industry turnouts and a PTC overlay suitable for operation at that speed. Under the 110-mph or higher speed scenarios, the signal improvements include the added costs for a vital PTC signal system.

Most U.S. railroads that allow or provide passenger and freight service operate under manual control with wayside signals. Centralized traffic control or CTC signaling is provided on busy corridors including Amtrak's Northeast Corridor. FRA requires that passenger service exceeding 79 mph operate with cab signaling/automatic train protection or automatic train stop to provide protection against operator errors. In addition, FRA is currently sponsoring demonstration projects to develop a universal communications based train control system, known as positive train control or PTC. New high-speed passenger service will include sophisticated signal systems to comply with FRA mandates and provide safe, reliable operations. Such signal systems include train borne components and wayside equipment such as track circuits, switch operators, and wayside detectors for protection against intrusion, high water, hot bearings and dragging equipment.

Modern signal systems rely on digital communication systems for data transmission using radio, fiber optic cables or a combination or the two. In addition, the communication system provides radio for operations, supervisory control and data acquisition for power systems, passenger station public address, etc. Wayside space must be provided for ducts and enclosures to house signal and communication components.

Electrified high-speed rail options require traction power substations and distribution facilities. It is assumed that the existing Colorado electrical grid and generating facilities contain sufficient capacity to support an electrified rail system. Similarly, the electric utility is expected to provide substations, transmission equipment and connections to the utility network with such costs covered in the utilization charges. As such, it is assumed that the electric utility would amortize the costs for bringing power to the substations, so the costs of modifications to the utility's grid are not included in the electrification cost estimate. Neither has the potential benefit from the electric utilities' potential ability to use the rail or maglev right-of-way for power transmission been assessed. (Such joint development could largely offset the utility's cost for connecting the rail or maglev system into the power supply.) Typical requirements for electrification include substations at 25 mile intervals and distribution conductors. In the case of electrified rail systems, overhead catenary conductors provide power to the train pantograph and the rails serve as return conductors. The catenary conductors are supported by poles and cross arms spaced at roughly 100-150 foot intervals. The catenary system contact wire is generally located 17.5 to 23 ft above the top of the rail. Additional electrical clearance or high voltage insulation is required to overhead bridge structures.

Exhibit 8-4: Unit Capital Costs, Systems, in $2008

Item No.	Description	Unit	Unit Cost (Thousands of $2008)
3.1	Signals for Siding w/ High-Speed Turnout	each	$1,500.30
3.2	Install CTC System (Single Track)	per mile	$216.50
3.3	Install CTC System (Double Track)	per mile	$355.00
3.4	Install PTC System	per mile	$171.00
3.5	Electric Lock for Industry Turnout	each	$121.90
3.6	Signals for Crossover	each	$828.20
3.7	Signals for Turnout	each	$473.30
3.8	Signals, Communications & Dispatch	per mile	$1,539.70
3.9	Electrification (Double Track)	per mile	$3,079.50
3.10	Electrification (Single Track)	per mile	$1,539.70

Crossings

The treatment of grade crossings to accommodate 110-mph operations on existing rail is a major challenge to planning a high-speed rail system. Highway/railroad crossing safety plays a critical role in future project development phases. A variety of devices were considered to improve safety including roadway geometric improvements, median barriers, barrier gates, traffic channelization devices, wayside horns, fencing and the potential closure of crossings. Greenfield routes were developed with grade separations at street and roadway crossings. Exhibit 8-5 details the unit costs for highway and railroad grade crossings. Chapter 4 contains additional information concerning the crossing costs.

Exhibit 8-5: Unit Capital Costs, Crossings, in $2008

Item No.	Description	Unit	Unit Cost (Thousands of $2008)
4.1	Private Closure	each	$98.20
4.2	Four Quadrant Gates w/ Trapped Vehicle Detector	each	$582.10
4.3	Four Quadrant Gates	each	$340.80
4.4	Convert Dual Gates to Quad Gates	each	$177.50
4.5	Conventional Gates single mainline track	each	$196.40
4.6	Conventional Gates double mainline track	each	$242.60
4.7	Convert Flashers Only to Dual Gate	each	$59.20
4.8	Single Gate with Median Barrier	each	$213.00
4.9	Convert Single Gate to Extended Arm	each	$17.70
4.10	Precast Panels without Roadway Improvements	each	$94.70
4.11	Precast Panels with Roadway Improvements	each	$177.50

Station/Maintenance Facilities

Passenger stations include platforms, escalators/elevators and other circulation elements, passenger ticketing and waiting facilities, lighting security, and station administration facilities.

The terminal stations may require four tracks for passenger boarding, train layover and light maintenance.

A maintenance facility with sufficient capacity to service the fleet is required. The facility must provide space and equipment to service the rolling stock and maintain the track structure and systems. Storage tracks can be expanded as the fleet grows. Sophisticated component repair may be subbed out to contract shops. It is anticipated that the maintenance facility for a non-electrified system will be less sophisticated than that of an electrified rail system. Exhibit 8-6 shows the unit costs for types of stations, terminals, and maintenance facilities

Exhibit 8-6: Unit Capital Costs, Railroad Station/Maintenance Facilities, in $2008

Item No.	Description	Unit	Unit Cost (Thousands of $2008)
5.1	Full Service - New - Low Volume - 500 Surface Park	each	$5,000.00
5.2	Full Service - Renovated - Low Volume- 500 Surface Park	each	$4,000.00
5.3	Terminal - New - Low Volume - 500 Surface Park	each	$7,500.00
5.4	Terminal - Renovated - Low Volume - 500 Surface Park	each	$6,000.00
5.5	Full Service - New- High Volume - Dual Platform - 1000 Surface Park	each	$10,000.00
5.6	Terminal - New- High Volume - Dual Platform - 1000 Surface Park	each	$15,000.00
5.7	Maintenance Facility (non-electrified track)	each	$80,000.00
5.8	Maintenance Facility (electrified track)	each	$100,000.00
5.9	Layover Facility	lump sum	$10,000.00

8.3.6 Unit Costs for Colorado – Maglev

Magnetic Levitation Technology Systems

Capital costs were developed for two types of magnetic levitation technologies as follows:

- High-speed magnetic levitation (LSM) technology, represented by the German TransRapid system with speeds from 250 to 300 mph. The system will be constructed in new, fully grade separated corridors and will not share right-of-way with the freight railroads.
- Urban magnetic levitation (LIM) technology, represented by Japanese CHHST, with speeds up to 125 mph. The system will be constructed in new; fully grade separated corridors and will not share right-of-way with the freight railroads.

For the purposes of this study, the only difference in unit costs between the two types is the systems unit costs as further detailed below.

Right-of-Way Costs

Maglev right-of-way costs were developed for each alternative using the conceptual routes. A 100-foot-wide right-of-way was assumed. Where the route fell within an existing public right-of-way, such as highway, street, or rail, no cost to the project for that particular right-of-way is assumed. Where the geometric requirements for Maglev take the route of the public right-of-way, the costs were determined for either rural or urban area. Units costs are based on a per mile basis using average values of $10,750 per acre for rural and $32,000 per acre for urban land acquisition. The unit costs on a per mile basis are shown in Exhibit 8-7. This unit cost estimate is based only on the current conceptual routes and will change as the project development progresses.

Exhibit 8-7: Unit Capital Costs, Right-of-Way, in $2008

Description	Unit	Unit Cost (Thousands of $2008)
Land Acquisition Rural	Mile	$129.0
Land Acquisition Urban	Mile	$ 387.0

Guideway and Track Elements

Maglev guideway costs were developed for at-grade, aerial and bridge structures and tunnels. The guideway system is comprised of a concrete and/or steel guideway to support the vehicles, stator packs, power rails, low-speed switches and high-speed switches. The types of guideways and tunnel sections used in this estimate are detailed Chapter 4 of this report. All civil engineering costs associated with the construction of the guideways are included in the unit costs

A unit cost of $3,400 per lineal foot is used for at-grade guideways. A unit cost of $6,600 per lineal foot is used for Type A aerial structures. A unit cost of $8,800 per lineal foot is used for the Type B aerial structure. Type B is a straddle-bent aerial structure needed to carry the guideway over public roadways and other obstacles encountered on the alignment. The unit cost for these guideways includes an allowance of 15 percent for special guideways required for project elements such as crossovers between guideways and tail structures at end stations for storage of train sets in off-peak hours.

A unit cost of $25,800 per lineal foot is used for the bridge structure required to carry the guideway over deep valleys and major rivers.

A unit cost of $33,600 per lineal foot is used for a Type A tunnel section consisting of two tunnels for the guideway. A unit cost of $44,800 per lineal foot is used for a Type B tunnel section consisting of two tunnels and a service/relief tunnel. Appendix G is a technical memorandum, *Rail Tunnel*

Evaluation that was prepared as a guide for this study. Exhibit 8-8 summarizes the unit costs for guideway and track elements.

Exhibit 8-8: Unit Capital Costs, Maglev Guideway & Track, in $2008

Description	Unit	Unit Cost (Thousands of $2008)
At Grade Guideway	LF	$3.4
Aerial Guideway Type A (Low)	LF	$6.6
Aerial Guideway Type B (High)	LF	$8.8
Bridge	LF	$25.8
Tunnel Type A (Single Bore)	LF	$33.6
Tunnel Type B (Dual Bore)	LF	$44.8

Systems

Propulsion, control and communication systems include civil structures for substations and cable trenches; propulsion blocks; propulsion equipment for low, medium, and high power; motor windings; wayside equipment; propulsion maintenance equipment; operation control subsystems for communication and data collection, and associated civil structures. A unit cost of $18,368,000 per mile, as shown in Exhibit 8-9, is used to estimate the cost of the very high-speed maglev.

Exhibit 8-9: Unit Capital Costs, Maglev Systems, in $2008

Description	Unit	Unit Cost (Thousands of $2008)
Propulsion, Command & Control Systems	Mile	$18,368
Power Distribution	Mile	$1,389

Power distribution unit costs were determined by a review of similar costs for the FRA demonstration projects. The unit cost used for this project is $1,389,000 per mile for very high-speed systems.

The sum of the Propulsion, Command & Control Systems and the power unit costs is approximately $19.7 Million per mile for very high-speed systems using liner synchronous motor (LSM) technology. The systems costs for the urban maglev is approximately $7.7 Million per mile based on information provided by Sandia National Laboratories during the development of the I-70 Mountain Programmatic Environmental Study.

Maintenance Facilities

Maintenance facilities and storage yards include the construction and all equipment necessary to properly maintain the fleet of vehicles. The size of the maintenance facility is related to the size of the maglev fleet needed for this program. The unit cost of $3,080,000 per section (or car) of a maglev train set for this study is determined by averaging the cost of the maintenance facilities for Baltimore- Washington and the Pittsburgh projects adjusted to year 2008 dollars.

Exhibit 8-10: Unit Capital Costs, Maglev Maintenance Facilities in $2008

Description	Unit	Unit Cost (Thousands of $2008)
Maintenance Facilities	Sections	$3,080

Stations and Parking

Stations and Parking Facilities include platforms, circulation, lighting, security measures and all auxiliary spaces. Space is provided for ticket sales, passenger information, station administration, baggage handling and commercial space. Exhibit 8-11 provides unit costs for various station types.

Exhibit 8-11: Unit Capital Costs, Stations & Parking in $2008

Description	Unit	Unit Cost (Thousands of $2008)
Full Service - New - Low Volume - 500 Surface Park	each	$5,000
Full Service - Renovated - Low Volume- 500 Surface Park	each	$4,000
Terminal - New - Low Volume - 500 Surface Park	each	$7,500
Terminal - Renovated - Low Volume - 500 Surface Park	each	$6,000
Full Service - New- High Volume - Dual Platform - 1000 Surface Park	each	$10,000
Terminal - New- High Volume - Dual Platform - 1000 Surface Park	each	$15,000

8.4 Other Costs

8.4.1 Contingency

Contingency costs were added as an overall percentage of the total construction cost. Contingencies are an allowance added to the estimate of costs to account for items and conditions that cannot be realistically anticipated. The contingency is expected to be needed as the project develops. The contingency is estimated at 30 percent of the construction cost elements. This contingency included 15%+ for design contingency and 15%+ for construction contingency.

8.4.2 Professional Services and Environmental

The project elements included in the Professional Services category are design engineering, program management, construction management and inspection, engineering during construction, and integrated testing and commissioning. For a project of this size, an overall program manager with several section designers is needed to provide conceptual engineering, preliminary engineering, environmental studies, geotechnical engineering, final engineering and engineering during construction. Field and construction management services and integrated testing services and commissioning of various project elements also are required. Professional services and other soft costs required to develop the RMRA project have been estimated as a percentage of the estimated construction cost and are included in the overall cost estimates as a separate line item. These costs include, as a percentage of construction cost:

- Design engineering and related studies 10%
- Insurance and Bonding 2%
- Program Management 4%
- Construction management and inspection 6%
- Engineering services during construction 2%
- Integrated Testing and Commissioning 2%
- Erosion Control and Water Quality Mgt 2%

8.4.3 Placeholders

The capital costs include allocation for special elements (placeholders) as conservative estimates for large and/or complex engineering projects that have not been estimated on the basis of unit costs and quantities. Placeholders provide lump sum budget approximations based on expert opinion rather than on an engineering estimate and are shown in the unit costs as lump sum items. Placeholders are used where detailed engineering requirements are not fully known. These costs will require special attention during the project development phase. The following list highlights some of the key placeholder costs that are assumed in this analysis. Cost details are shown on the detailed sheets in Appendix E:

- Costs for new stations in densely built-up urban areas, including Denver Union Station improvements
- Major tunnel improvements
- Rail capacity expansion
- Maintenance and layover facilities

8.5 Infrastructure Capital Costs

As route segments were examined in the field, general concepts were developed and assumptions made regarding the capacity and operational improvements needed to accommodate future passenger operations. The primary objective was to conceptualize infrastructure improvements that would improve fluidity and enhance the reliability of both passenger and freight rail operations.

In order to account for the interactive analysis needed to optimize the trade-off of capital costs with operational consideration, the study corridors were further segmented to allow for a mix and match scenario that was driven by technology consideration. Civil engineering quantities were developed for each segment using the results of the field inspections combined with data derived from GIS and railroad track charts. Infrastructure capital cost estimates by segment were prepared for each study corridor for steel wheel/steel rail, very high-speed maglev and urban maglev. Segments were identified for existing rail routes and constrained and unconstrained greeenfield routes. The following summarizes the key results of the initial screening of alternatives. The full screening process is described in Chapter 9. For the purpose of this screening, a set of capital costs were developed for each route/alignment option, or Representative Route as described in Chapter 4. The detailed cost estimates by segment are in Appendix E.

Infrastructure costs, shown in Exhibit 8-12, were developed for upgrading the existing rail lines in the I-25 corridor to 79-mph and 110-mph standards. Infrastructure costs for either 79 mph or 110 mph were thought to be practically identical, due to the need for heavy freight capacity mitigation in the I-25 corridor which requires extensive use of dedicated passenger infrastructure, regardless of speed. The only real difference is in vehicles, which have a lower cost in the 79-mph option, due primarily to the lower level of service offered and corresponding fewer number of vehicles that would need to be purchased.

Exhibit 8-12: Incremental Rail in I-25 Upgrade Costs

Capital Costs by Route and Technology (Billions $2008)

Existing Rail I-25	79 mph	110 mph
Infrastructure	$3.57	$3.57
Vehicle	$0.18	$0.28
Total	$3.75	$3.85

Capital Cost per Mile (Millions $2008)

Existing Rail I-25	79 mph	110 mph
Miles	347.50	347.50
Capital Cost per Mile	$10.78	$11.08

Infrastructure costs, shown in Exhibit 8-13, were developed for both electric rail options (150 mph and 220 mph) and for maglev options (125 mph and 300 mph.) All of these costs were developed for the full RMRA network including service to Grand Junction, Aspen, Craig and Black Hawk in the west, and to Cheyenne and Trinidad in the north and south. It can be seen that development of either of the two Maglev options would cost substantially more than would the rail options. As shown in Exhibit 8-13, a maglev system would cost two to three times that of a comparable rail system for only a few minutes difference in running time performance. This is because curves and the relatively short distances between stations fundamentally limit train performance, and maglev systems guideway structures are much more expensive than railroad guideway structures.

Exhibit 8-13: High-Speed Rail in Both I-25 and I-70 Upgrade Costs

Capital Costs by Route and Technology (Billions $2008)

Constrained I-70 7% Route/ Greenfield I-25	125 mph	150 mph	220 mph	300 mph
Infrastructure	$66.94	N/A	$35.59	$75.93
Vehicle	$1.92	N/A	$1.02	$2.44
Total	$68.86	N/A	$36.61	$78.37
Unconstrained I-70 4% Route/ Existing Rail I-25	**125 mph**	**150 mph**	**220 mph**	**300mph**
Infrastructure	$72.86	$28.56	$28.56	$82.42
Vehicle	$1.73	$0.66	$0.66	$2.32
Total	$74.59	$29.21	$29.21	$84.73

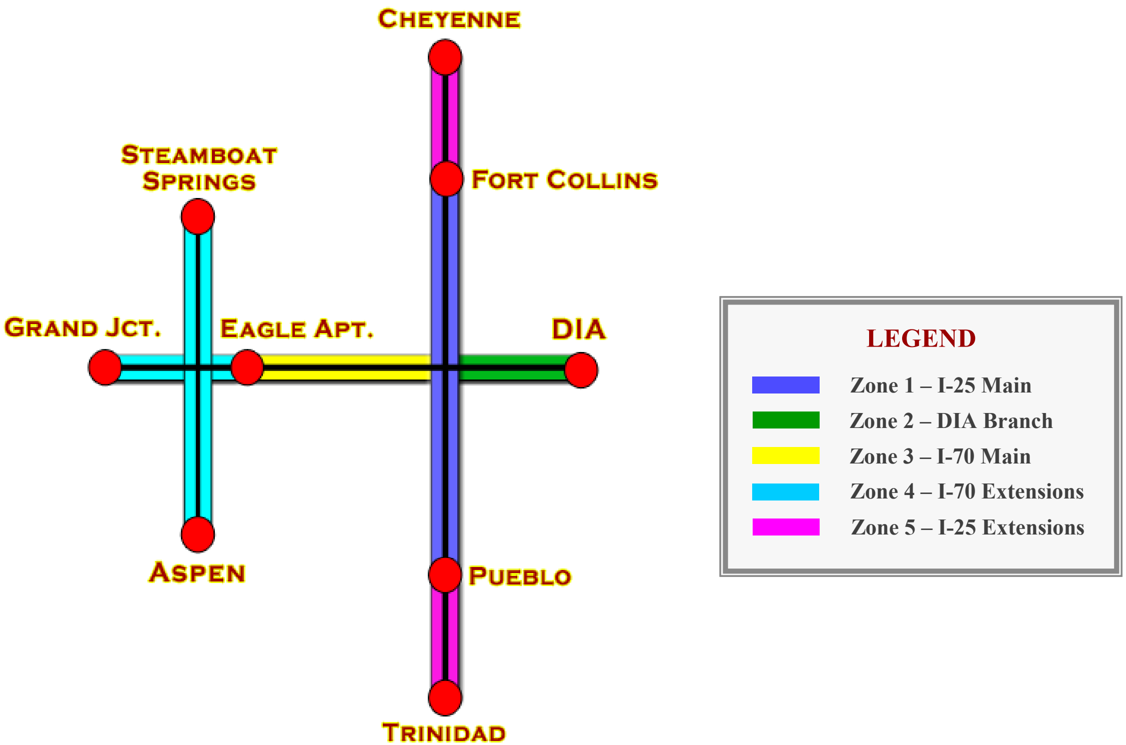
Capital Cost per Mile (Millions $2008)

Constrained I-70 7% Route/ Greenfield I-25	125 mph	150 mph	220 mph	300 mph
Miles	747.44	N/A	747.44	747.44
Capital Cost per Mile	$92.13	N/A	$48.98	$104.85
Unconstrained I-70 4% Route/ Existing Rail I-25	**125 mph**	**150 mph**	**220 mph**	**300 mph**
Miles	795.54	795.54	795.54	795.54
Capital Cost per Mile	$93.76	$36.72	$36.72	$106.51

* N/A means the train technology cannot operate over this alignment.

It should be noted that the capital costs in Exhibit 8-13 are very high, which led to difficulties with Cost Benefit ratios in the initial screening of options. See Chapter 9. Accordingly, a strategy for "truncating" or shortening the network as shown in Exhibit 8-14 was developed, for reducing the capital cost. (This schematic shows only the mainline that makes up the major costing segments, without branch lines.)

Exhibit 8-14: Major Capital Cost Segments



Costs estimates for the two network options, based on either an I-70 Right-of-Way or I-70 Unconstrained alignment, coupled with a new Greenfield alignment or Existing Rail in I-25, respectively, were developed based on the segmentation shown in Exhibit 8-14. These results are shown in Exhibits 8-15 and 8-16.

Comparing these two figures it can be seen that the I-70 Right-of-Way (or Constrained) / I-25 greenfield option in Exhibit 8-16 generates substantially more revenue, primarily because of the strength of the greenfield alignments both on I-25 and on the Western extensions. Also, the same exhibit shows that I-70 costs from Denver to Eagle Airport comprise a lower percentage of total cost, because of the very high costs of these greenfields on I-25 and in the west.

The most important thing to note is the relatively high share of revenue (93 percent and 95 percent, respectively) that is associated with a "Core" system that extends from Fort Collins to Pueblo, and from Denver International Airport (DIA) to Eagle Airport. By eliminating the high-cost extensions to Trinidad, Cheyenne and the three western destinations, the cost of the system could be dramatically reduced without losing much revenue. (Please note that these extensions were all costed as double-track electrified rail or maglev options. The possibility of providing a lower cost diesel service for these Western extensions was not evaluated by this study.)

Exhibit 8-15: Capital Cost Distribution for Unconstrained I-70/Existing Rail on I-25: 150-mph Electric

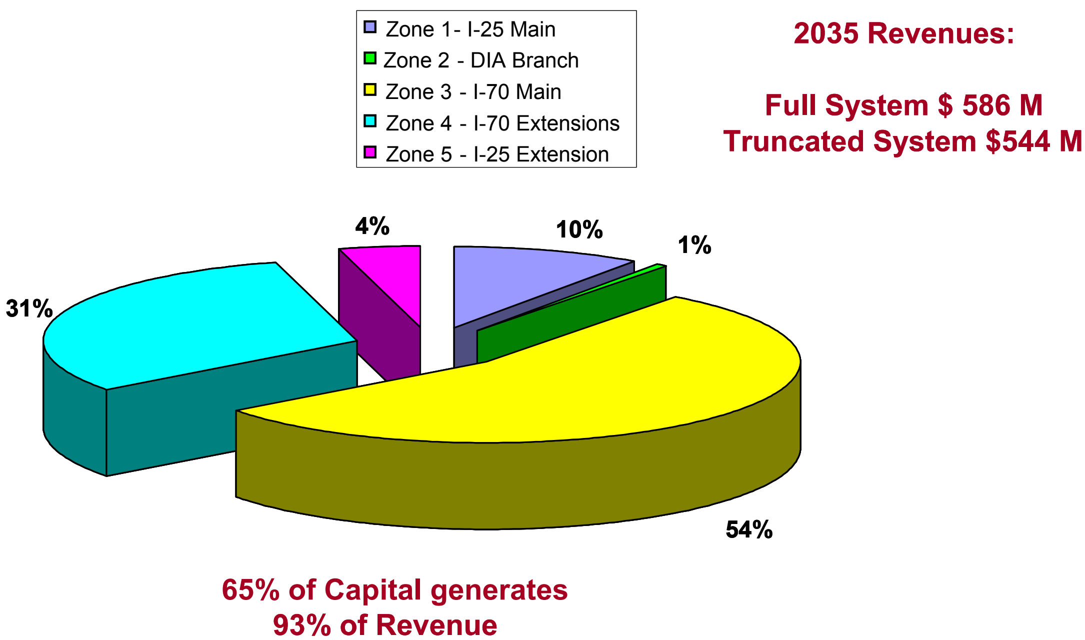
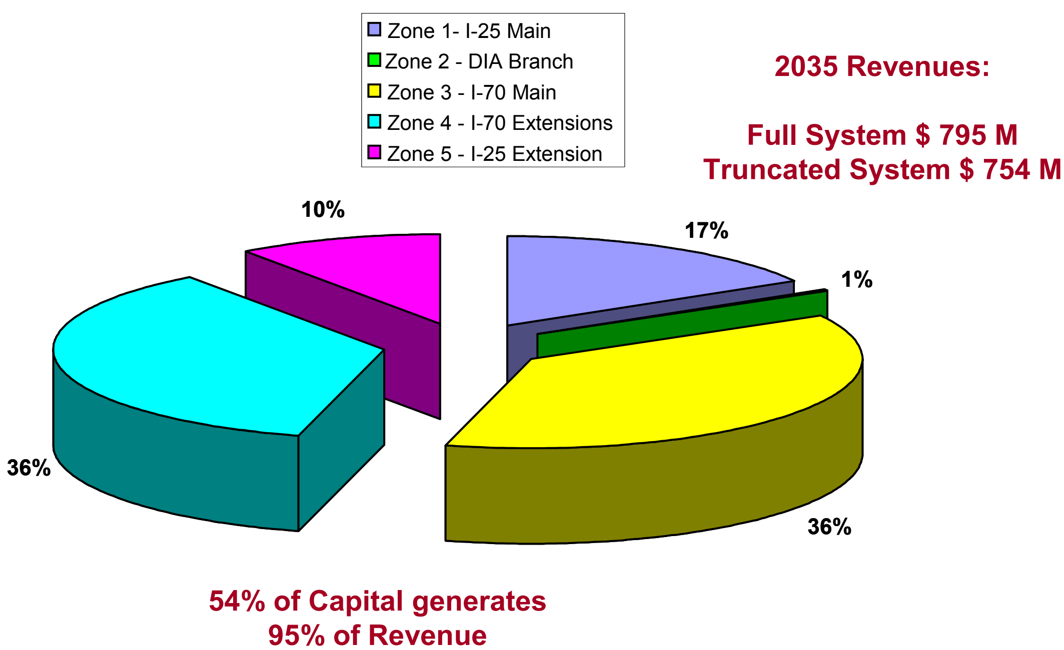


Exhibit 8-16: Capital Cost Distribution for I-70 Right-of-Way/Greenfield on I-25: 220-mph Electric Rail



8.6 Summary

This chapter has described the unit costing basis for the development of capital costs for this study.

Costs were developed initially for two main network options, a constrained route following I-70 with 7 percent grades, and an unconstrained route having only 4 percent grades. These were paired with greenfield and existing rail alignments on I-25.

These two network options have been evaluated for the full RMRA system, but it was found that a truncated system between Fort Collins and Pueblo and DIA and Eagle County Airport could still capture a very high percentage of the projected revenue and ridership, at substantial capital cost savings. Accordingly additional options will be developed for this core system.

Chapter 9 will define an "FRA Developed" option by combining segments of the original constrained and unconstrained alignments using a mix-and-match approach. After this, a four-phase implementation plan will be developed in Chapter 10.

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9 Evaluation of Alternatives

9.1 Introduction

In Chapters 3 and 4, alternative routes and technologies were developed to support a feasibility level economic analysis to help Colorado understand the overall implications for a statewide intercity rail system. In order to evaluate these alternatives, it is important to identify the FRA feasibility criteria for public-private partnership. The FRA has defined the financial and economic criteria for public-private partnership[1] as follows:

1. **Financial Analysis:** Positive Operating Ratio, defined as Operating Revenue / Operating Cost. This measures the project's ability to be a self-sustaining and franchisable system in terms of its day-to-day finances.
2. **Economic Analysis:** Positive Cost Benefit Ratio, defined as Total Benefit/Total Cost. This measures whether the project makes a positive contribution to the economy from an economic perspective.

Operating ratios are usually expressed on a year-by-year basis, but they can also be expressed as a Present Value of Revenue / Present Value Operating cost over the lifetime of a project.

Cost Benefit ratios are usually expressed as a Present Value of Total Benefit / Present Value of Total Cost over the lifetime of a project, but if year-by-year financial cash flows are not fully available, these ratios can be approximated on the basis of a single year snapshot. Such approximations necessarily embed a typical rate of demographic growth and capital cash flows in accordance with a multi-year, phased system implementation plan. Once specific information on the rate of ridership and revenue growth, and a system implementation plan detailing the capital cash flows becomes available, then that information can be included to further refine the initial estimates of the Cost Benefit ratio. This highly detailed analysis has been completed for an alternative example and those results are presented in Chapter 10.

This chapter describes the process by which alternatives were initially developed and then evaluated, leading to the development of a number of feasible options based on the FRA economic and financial criteria. Section 9.2 further defines the measure of economic efficiency that is used to assess the FRA criteria. The remainder of the chapter describes the process and rationale used in the initial optimization of network alternatives.

[1] "High-Speed Ground Transportation for America", USDOT FRA, 1997 and "Maglev Deployment Program", USDOT FRA, 1999.

9.2 Measures of Efficiency

For each alternative being evaluated, the FRA measures of financial and economic efficiency were calculated. These assessments integrate the forecasted capital, operating, and maintenance costs with the revenue projections over the lifetime of the project. The analysis is based on the following components:

- Operating and implementation plans for the alternative passenger rail service options
- Cost estimates for operations, infrastructure and acquisition of rolling stock
- Ridership and revenue estimates based on projected travel demand and assumptions regarding fare levels and other services (on board catering, and express mail)
- Cash flow analysis that includes statements of revenues and expenses as well as sources and uses of funds, including the impact of the financing alternatives

Two measures, net present value (NPV) and Cost Benefit ratio were used to evaluate the economic returns of the system. Similar measures, net present value (NPV) and Operating ratio were used to evaluate the financial returns.

Both measures require the development of a project's year-by-year financial and economic returns, which are then discounted to a base year, to estimate present values over the lifetime of the project. The discount rate used is set by the GAO and reflects the long-term cost of money. The long-term cost of money is reflected in bond rates, and influenced by the level of risk associated with a project.

The operating ratios reported here follow FRA's criteria definition, but are different from the commercial operating ratio calculations that are typically presented by freight railroads and intercity bus companies. The FRA's criteria are also different from the fully-allocated cost reports typically produced by Amtrak. Following the FRA feasibility criteria:

1. The Operating Ratio as calculated here includes *direct operating costs only*. Unlike Amtrak's fully allocated costs, the operating ratio calculations presented here do not include capital costs, depreciation or interest.
2. The Operating Ratio presented here is defined as Revenues/Costs. It should be noted that freight railroads and intercity bus companies typically define it as the reciprocal Costs/Revenues.

As defined by the FRA, a positive operating ratio does not imply that a passenger service can attain full financial profitability by covering its capital costs, but it does allow the operation to be franchised and operated by the private sector. The FRA's definition puts passenger rail on the same basis as other passenger transportation modes, such as intercity bus and air, where the private sector operates the system but does not build or own the infrastructure it uses.

All calculations are performed using standard financial formula, as follows:

Financial Measure:

$$\text{Operating Ratio} = \frac{\text{Present Value of Revenues}}{\text{Present Value of Costs}}$$

Economic Measure:

Net Present Value = Present Value of Benefit – Present Values of Costs

$$\text{Cost Benefit Ratio} = \frac{\text{Present Value of Benefits}}{\text{Present Value of Costs}}$$

Present Value is defined as:

$$PV = \Sigma \; C_t / (I + r)^t$$

Where:

PV = Present value of all future cash flows
C_t = Cash flow for period t
r = Discount rate reflecting the opportunity cost of money
t = Time

9.2.1 Key Assumptions

The analysis projects travel demand, operating revenues and operating and maintenance costs for all years from 2010 through 2050. Following GAO guidelines, the financial analysis has been conducted in real terms using constant 2008 dollars. Accordingly, no inflation factor has been included and a real discounting rate of 3.9 percent was used. Revenues and operating costs have also been projected in constant dollars over the time frame of the financial analysis. A summary of the key efficiency measure inputs are presented below.

Ridership and Revenue Forecasts

Ridership and revenue forecasts were prepared in ten year intervals from 2010 through 2050. Revenues in intervening years are projected based on interpolations, reflecting projected annual growth in ridership. Revenues include not only passenger fares, but also onboard service and express parcel revenues. Because of this, the revenues are slightly higher than those that were forecasted in Chapter 6.

Capital Costs

Capital costs include rolling stock, track, freight railroad right-of-way purchase or easement fees, bridges, fencing, signaling, grade crossings, maintenance facilities and station improvements. The capital cost projections are based on year-by-year projections of each cost element and include all of the capital costs, plus some selected elements of additional costs as needed to support year-by-year capacity expansion of the system. At the time of the initial screening of options a detailed system implementation plan had not yet been developed, so it was necessary to approximate the Cost Benefit ratios based on forecasted 2035 results. For the FRA Developed Option (as defined in Chapter 8, a hybrid network subjected to more detailed economic evaluation) a year-by-year implementation plan was developed which detailed the Capital cash flows and funding requirements. Using this added information the Cost Benefit calculations could be further refined. This was done in Chapter 10.

Operating Expenses

Major operating and maintenance expenses include equipment maintenance, track and right-of-way maintenance, administration, fuel and energy, train crew and other relevant expenses. Operating expenses were estimated in 2008 constant dollars so that they would remain comparable to revenues. However, these costs do reflect the year-by-year increase in expense that is needed to handle the forecasted ridership growth, in terms of not only directly variable expenses such as credit card commissions, but also the need to add train capacity and operate either larger trains, or more train-miles every year in order to accommodate anticipated ridership growth.

Operating costs are included as a cost, whereas system revenues are included as a benefit in the discounting calculation over the life of the system. In this way they directly offset one another in the Net Present Value calculation and also reflect in the Cost Benefit calculation. It can be seen that a system that requires an operating subsidy, e.g. where costs exceed revenues, will tend also to reflect this in the Cost Benefit ratio. This is why 79-mph rail systems typically fail on both the Operating Ratio and Cost Benefit ratio criteria.

Implementation Period

According to the implementation plan that is stated in Chapter 10, the planning and construction period for the FRA Developed Option will take up to thirteen years with start-up of full system operations not occurring until 2024. However, this information was not yet known at the time of the initial alternatives screening, which assumed a somewhat faster build-out of the system. Because the revenues and benefits were also expected to start sooner, this timing assumption has had negligible impact on the Cost Benefit calculation result.

9.2.2 Cost Benefit Requirements

A key FRA requirement is the need for public capital investment to be supported by the economic benefit that will be generated by the rail system. For this calculation of economic benefit we include consumer surplus, revenues generated by the system environmental and external mode benefits; costs include both capital and operating cost. Similarly to the way most highway projects are justified, the primary justification for intercity rail projects relies on time savings multiplied by the user's value of time. The consumer surplus term equates to this user's value of time savings as being the benefit an individual receives over and above the fare charged for using the system.

Calculation of cost benefit ratios requires a detailed, year-by-year forecast to support the calculation of Net Present Values for all the costs and benefits associated with the project. Specifically, a year-by-year estimate of system revenues, consumer surplus, operating costs, capital costs, and external benefits is needed to develop the FRA cost benefit analysis.

However, the rate of population growth in Colorado is very fast compared to other states, which results in significant growth in traffic over the life of the system. Our assumptions regarding the rate of traffic growth are consistent with the state demographics, MPO's, and BEA documented in Chapter 6. This has several consequences for the correct calculation of Cost Benefit ratios for this project:

- It would be inappropriate to increase the ridership and revenue of the system in future years, without also reflecting the added operating and capital costs that will be needed to accommodate this growth in traffic.
- The result is a steady improvement in the system financial performance that reflects improved economies of scale over the 30-year life of the system. While the Cost Benefit ratios calculated do take this forecast growth into account, they also add the additional capital cost for providing the capacity needed to handle it.

A ridership ramp-up factor of 50 percent was assumed for the first year and 75 percent for the second year. This leads to a need for operating support to cover the first two years' start-up losses. In the third year of operations the system starts to produce operating surpluses.

9.2.3 Estimate of Economic Benefits

The economic benefits to be used in the analysis include:

- User Benefits (Consumer Surplus)
- Other Mode and Resource Benefits

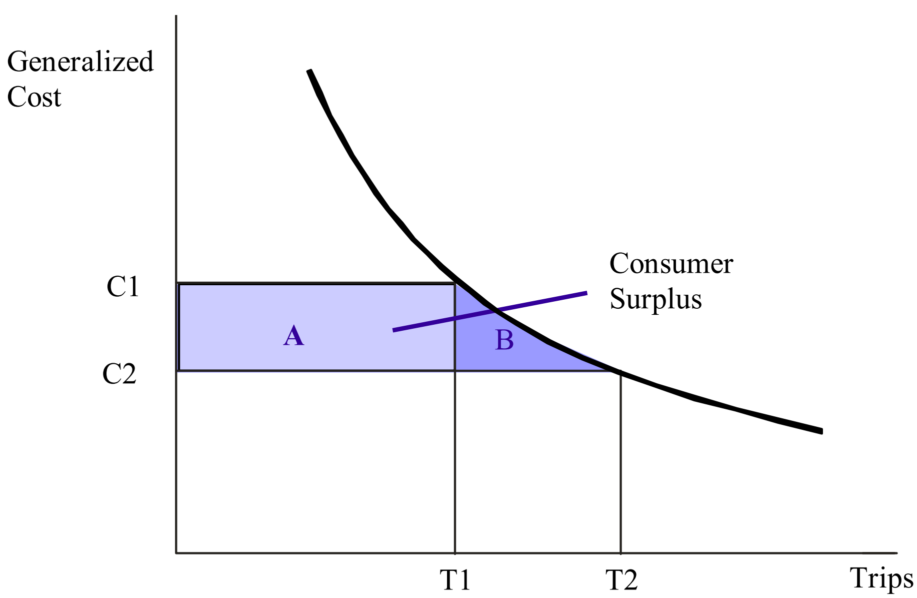
User Benefits

The analysis of user benefits for this study is based on the measurement of generalized cost of travel, which includes both time and money. Time is converted into money by the use of Values of Time. The Values of Time (VOT) used in this study were derived from stated preference surveys conducted in this and previous study phases and used in the *COMPASS*™ multimodal demand model for the ridership and revenue forecasts. These VOTs are consistent with previous academic and empirical research and other transportation studies conducted by TEMS.

Benefits to users of the rail system are measured by the sum of system revenues and consumer surplus. Consumer surplus is used to measure the demand side impact of a transportation improvement on users of the service. It is defined as the additional benefit consumers (users of the service) receive from the purchase of a commodity or service (travel), above the price actually paid for that commodity or service. Consumer surpluses exist because there are always consumers who are willing to pay a higher price than that actually charged for the commodity or service, i.e., these consumers receive more benefit than is reflected by the system revenues alone. Revenues are included in the measure of consumer surplus as a proxy measure for the consumer surplus forgone because the price of rail service is not zero. This is an equity decision made by the FRA to compensate for the fact that highway users pay zero for use of the road system (the only exception being the use of toll roads). The benefits apply to existing rail travelers as well as new travelers who are induced (those who previously did not make a trip) or diverted (those who previously used a different mode) to the new passenger rail system.

The *COMPASS™* demand model estimates consumer surplus by calculating the increase in regional mobility, traffic diverted to rail, and the reduction in travel cost measured in terms of generalized cost for existing rail users. The term generalized cost refers to the combination of time and fares paid by users to make a trip. A reduction in generalized cost generates an increase in the passenger rail user benefits. A transportation improvement that leads to improved mobility reduces the generalized cost of travel, which in turn leads to an increase in consumer surplus. Exhibit 9-1 presents a typical demand curve in which Area A represents the increase in consumer surplus resulting from cost savings for existing rail users, and Area B represents the consumer surplus resulting from induced traffic and trips diverted to rail.

Exhibit 9-1: Consumer Surplus Concept



The formula for consumer surplus is as follows:

$$\text{Consumer Surplus} = (C_1 - C_2)*T_1 + ((C_1 - C_2)*(T_2 - T_1))/2$$

Where:

C_1 = Generalized Cost users incur before the implementation of the system

C_2 = Generalized Cost users incur after the implementation of the system

T_1 = Number of trips before operation of the system

T_2 = Number of trips during operation of the system

The passenger rail fares used in this analysis are the average optimal fares derived from the revenue- maximization analysis that was performed for each corridor. User benefits incorporate the measured consumer surplus, as well as the system revenues, since these are benefits transferred from the rail user to the rail operator.

Other Mode and Resource Benefits

In addition to rail-user benefits, travelers using auto or air will also benefit from the rail investment, since the system will contribute to highway congestion relief and reduce travel times for users of these other modes. For purposes of this analysis, these benefits were measured by identifying the estimated number of air and auto passenger trips diverted to rail and multiplying each by the updated monetary values used in the FRA/USDOT study, *High-Speed Ground Transportation in America*.

Air Benefits: The air benefits that are allowed by the FRA methodology could not be applied to the Colorado system, since the trip length distribution of Colorado trips is too short, and the markets served are really not air-competitive. In Colorado, rail would serve more as a feeder to air than as a competitor. Although the Colorado system still projects significant highway benefits, because the air benefits are missing, the overall level of Other Mode benefit benchmarks at a somewhat lower level than those estimated for other high-speed rail projects across the nation, such as in the Midwest.

Highway Congestion: There will be reduced congestion and delays on highways due to auto travelers diverting to the RMRA rail system. The benefit was measured by estimating the time saved and multiplying it by the auto travelers' value of time. In addition, in the I-70 corridor the impact of reduced reliability due to weather conditions was assessed both in terms of its impact on travel demand and diversion.

Resources Benefits: The implementation of any transportation project has an impact on the resources used by travelers. The consequent reduction in highway congestion will result in resource savings to vehicle operators and reduced emissions of air pollutants for all non-rail modes.

Vehicle operating cost savings for non-business travelers could be included as an additional resource benefit. This reflects the fact that social/leisure travelers do not accurately value the full cost of driving when making trips. As a result, the consumer surplus calculation for commuters, social, leisure and tourist travelers has not fully reflected the real cost of operations of an automobile, but only the cost of gas. The difference between the cost of gas and the full cost of driving reflects a real savings that could be included in a Cost Benefit analysis. It has not been included here, however, because the FRA did not include it in their 1997 study. If it were included, the addition of this benefit would increase the overall Other Mode and Resource Benefits estimate by approximately 20 percent.

Emissions: The diversion of travelers to rail from the auto and air modes generates emissions savings. The FRA calculated emissions savings based on changes in energy use with and without the proposed rail service. Their methodology takes into account the region of the country, air quality regulation compliance of the counties served by the proposed rail service, the projection year, and the modes of travel used for access/egress as well as the line-haul portion of the trip. For this study, it was assumed that emissions savings would be proportional to the number of diverted auto vehicle-miles. Consistent with the approach used by the FRA, the number of vehicle-miles saved was calculated by multiplying the number of diverted auto trips, times average trip length, divided by an average vehicle occupancy factor.

9.3 Results of Preliminary Analysis

The alternatives developed for evaluation were assessed to develop a preliminary estimation of the FRA Efficiency measures, i.e., operating ratio and cost benefit ratio based on year 2035 forecast results. In developing the representative routes for the I-25 and I-70 corridor, the following types of alignment are considered:

- **Existing rail** – a route using either the tracks or right-of-way of an existing rail corridor
- **Constrained/Highway Right-of-Way** – a route that is solely within or contiguous to the rights-of-way of the I-70 or I -25 highway
- **Unconstrained/Greenfield –** a route that is outside the I-70 and I-25 highway Rights-of-Way

Exhibits 9-2 and 9-3 show the results for the six base alternatives. In Exhibit 9-2 it can be seen that the two I-25 diesel alternatives fail the operating ratio test, but that the electric alternatives pass. It can be seen that the operating ratios increase as speed increases. In Exhibit 9-3 it can be seen that all the alternatives fail the cost benefit test with the best results being 0.83 for 110-mph diesel I-25 corridor only, and the 220-mph I-70 and 0.7 for the I-25 greenfield route. As a result, none of the preliminary alternatives pass the FRA requirement and clearly the alternatives need to be modified.

Exhibit 9-2: Operating Ratio Results: Full-Network – 2035 – Central Case (Millions $2008)

	79 mph I-25 Existing Rail only	110 mph I-25 Existing Rail only	125 mph I-70 Constrained (7%) I-25 Greenfield	150 mph I-70 Unconstrained (4%) I-25 Existing Rail	220 mph I-70 Constrained (7%) I-25 Greenfield	300 mph I-70 Constrained (7%) I-25 Greenfield
Revenue	36.46	117.00	600.66	586.33	795.79	893.10
Operating Costs	68.94	132.36	373.10	416.09	484.43	448.38
2035 Operating Ratio	0.53	0.88	1.61	1.41	1.64	1.99

Exhibit 9-3: Economic Evaluation of Full Network – 2035 – Central Case (Millions $2008)

	79 mph I-25 Existing Rail Only	110 mph I-25 Existing Rail Only	125 mph I-70 Constrained (7%) I-25 Greenfield	150 mph I-70 Unconstrained (4%) I-25 Existing Rail	220 mph I-70 Constrained (7%) I-25 Greenfield	300 mph I-70 Constrained (7%) I-25 Greenfield
BENEFITS	Option 1a/b	Option 2a/b	Option 3a	Option 4	Option 5b	Option 6a
Revenue	36.46	117.00	600.66	586.33	795.79	893.10
Consumer Surplus	7.74	117.45	513.80	543.87	720.81	682.55
Resource Savings	3.39	72.66	312.18	312.18	390.22	444.05
Total Benefits	47.59	307.11	1426.64	1442.38	1906.82	2019.70
COSTS						
Operating Costs	68.94	132.36	373.10	416.09	484.43	448.38
Capital Costs	230.74	237.22	4241.84	1799.59	2255.20	4827.45
Total Costs	299.68	369.58	4614.94	2215.68	2739.63	5275.83
Cost Benefit Ratio	0.16	0.83	0.31	0.65	0.70	0.38

9.4 Refinement of Base Alternatives

A number of strategies were used to modify the base alternatives:

- **Truncation**: Elimination of the weakest elements of the networks
- **Mix and Match**: Combine different technologies to reduce capital cost and maintain service
- **Western Strategies**: To evaluate the impact of a diesel option for the western extensions beyond Eagle Airport
- **Selection of FRA Developed Option:** Using FRA efficiency criteria, Steering Committee and public information input.

9.4.1 Truncation Analysis

An evaluation of the volume of riders of the networks showed that the traffic demand beyond Fort Collins in the north I-25 corridor, south of Pueblo in the south I-25 corridor, and west of Eagle airport in the I-70 corridor was very weak. As described in Chapter 8, the capital cost for the more remote parts of the system is 40-50 percent of the total cost, but generates only 3 to 6 percent of the revenue. As such, it was decided to truncate the networks. The financial results of this truncation are shown in Exhibit 9-4.

The results of the truncation analysis show a considerable improvement over the base alternatives. For the truncated network, 110-mph I-25 diesel alternative, the 150-mph electric alternative, and the 220-mph electric alternative all achieve the FRA efficiency targets. Even the maglev options do better particularly the 300-mph maglev, although none of the maglev options are able to quite achieve the positive cost benefit ratio.

Exhibit 9-4: Operating Ratio Results: Truncated – 2035 – Central Case (Millions $2008)

	79 mph I-25 Existing Rail	110 mph I-25 Existing Rail	125 mph I-70 Constrained (7%) I-25 Greenfield	150 mph I-70 Unconstrained (4%) I-25 Existing Rail	220 mph 7% I-70 Constrained (7%) I-25 Greenfield	300 mph I-70 Constrained (7%) I-25 Greenfield
Revenue	33.29	107.64	600.29	544.25	754.58	874.03
Operating Costs	51.74	94.68	319.60	344.25	409.60	357.90
2035 Operating Ratio	0.64	1.14	1.88	1.58	1.84	2.44

Exhibit 9-5: Economic Evaluation: Truncated – 2035 – Central Case (Millions $2008)

	79 mph I-25 Existing Rail	110 mph I-25 Existing Rail	125 mph I-70 Constrained (7%) I-25 Greenfield	150 mph I-70 Unconstrained (4%) I-25 Existing Rail	220 mph 7% I-70 Constrained (7%) I-25 Greenfield	300 mph I-70 Constrained (7%) I-25 Greenfield
BENEFITS	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Revenue	**33.29**	**107.64**	**600.29**	**544.25**	**754.58**	**874.03**
Consumer Surplus	**7.07**	**112.23**	**792.95**	**700.02**	**960.66**	**955.30**
Resource Savings	**3.10**	**64.59**	**296.57**	**296.57**	**370.71**	**421.85**
Total Benefits	**43.45**	**284.46**	**1689.81**	**1540.84**	**2085.95**	**2251.18**
COSTS						
Operating Costs	**51.74**	**94.68**	**319.60**	**344.25**	**409.60**	**357.90**
Capital Costs	**173.75**	**178.64**	**1946.56**	**1164.24**	**1225.84**	**2254.56**
Total Costs	**225.49**	**273.32**	**2266.16**	**1508.49**	**1635.44**	**2612.46**
Cost Benefit Ratio	**0.19**	**1.04**	**0.75**	**1.02**	**1.28**	**0.86**

9.4.2 Mix and Match Analysis

In order to evaluate if a combination of technologies that might work better, a Mix and Match analysis was carried out that defined three new alternatives. These combinations were all applied to the truncated networks:

> **Option 7** – 110-mph diesel on I-25, Fort Collins to Pueblo with 220 mph on I-70, DIA to Eagle Airport.
>
> **Option 8** – 150-mph electric on I-25, Fort Collins to Pueblo with 220 mph on I-70, DIA to Eagle Airport.
>
> **Option 9** – 110-mph diesel on I-25, Fort Collins to Pueblo with 300-mph maglev on I-70, DIA to Eagle Airport.

The results for the Mix and Match options all produced positive operating ratio and cost benefit results, a 1.02 Cost Benefit for Option 7, a 1.20 for Option 8, and 1.04 for Option 9. However, all these results are lower than the truncated 220-mph electric option, which has a 1.28 Cost Benefit result. See Exhibits 9-6 through 9-8.

Exhibit 9-6: Mix-and-Match Applied to Truncated Networks

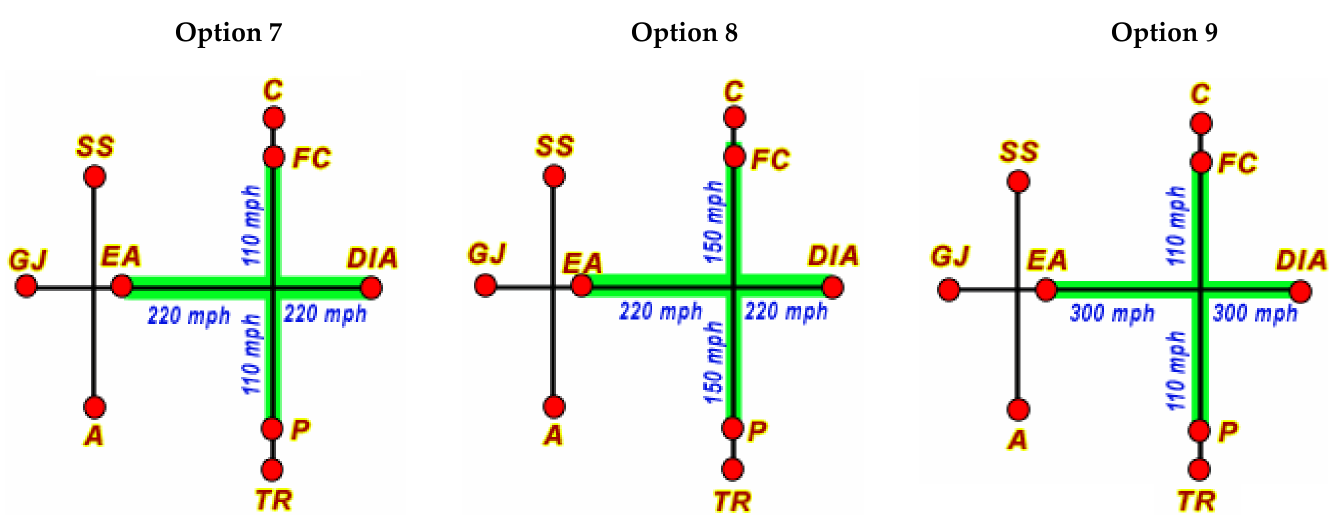


Exhibit 9-7: Operating Ratio Results: Mix and Match – 2035 – Central Case (Millions $2008)

		New Mix and Match Alternatives		
	220 mph I-70 Constrained (7%) I-25 Greenfield Truncated	110 mph I-25 Existing Rail Truncated on I-25 w/ 220 mph 7% I-70 Constrained Truncated on I-70	150 mph I-25 Existing Rail Truncated on I-25 w/ 220 mph 7% I-70 Constrained Truncated on I-70	110 mph I-25 Existing Rail Truncated on I-25 w/ 300 mph 7% I-70 Constrained Truncated on I-70
	Option 5	Option 7	Option 8	Option 9
Revenue	754.58	492.56	633.74	511.83
Operating Costs	409.60	341.21	377.16	270.13
2035 Operating Ratio	1.84	1.44	1.68	1.89

Exhibit 9-8: Economic Evaluation of Mix and Match – 2035 – Central Case (Millions $2008)

		New Mix and Match Alternatives		
	220 mph I-70 Constrained (7%) I-25 Greenfield Truncated	110 mph I-25 Existing Rail Truncated on I-25 w/ 220 mph 7% I-70 Constrained Truncated on I-70	150 mph I-25 Existing Rail Truncated on I-25 w/ 220 mph 7% I-70 Constrained Truncated on I-70	110 mph I-25 Existing Rail Truncated on I-25 w/ 300 mph 7% I-70 Constrained Truncated on I-70
BENEFITS	**Option 5**	**Option 7**	**Option 8**	**Option 9**
Revenue	**754.58**	**492.56**	**633.74**	**511.83**
Consumer Surplus	**960.66**	**646.2**	**717.76**	**609.29**
Resource Savings	**370.71**	**241.50**	**340.98**	**407.00**
Total Benefits	**2085.95**	**1380.26**	**1692.48**	**1528.12**
COSTS				
Operating Costs	**409.60**	**341.21**	**377.16**	**270.13**
Capital Costs	**1225.84**	**1010.24**	**1034.88**	**1201.20**
Total Costs	**1635.44**	**1351.45**	**1412.04**	**1471.33**
Cost Benefit Ratio	**1.28**	**1.02**	**1.20**	**1.04**

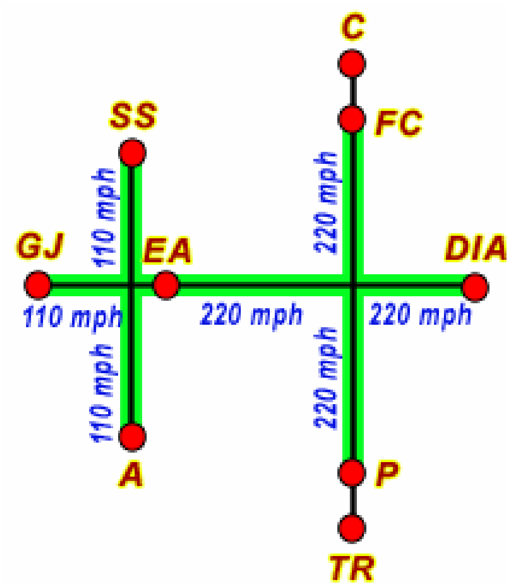
9.4.3 Western Strategies

A hypothetical 79/110-mph diesel service was considered beyond Eagle Airport to Steamboat Springs, Aspen, and Glenwood Junction. The aim was to use $1-2 billion to provide a baseline service of about 4 trains per day, which would be comparable with demand. Since these trains could also run as far east as Silverthorne and Keystone, they could provide service "under the wire" of the 220-mph electric service. This would enhance the economics of these trains. To test this possibility, two options were developed, Options 5W and 9W. These are simply options 5 and 9 with the western lines added. See Exhibits 9-9 through 9-11.

Option 5W - 220 mph on Core System, 110 mph west of Eagle Airport
Option 9W - 300 mph on I-70, 110 mph west of Eagle Airport, and 110 mph on I-25

Exhibit 9-9: Western Expansion Phase Alternatives

Option 5W



Option 9W

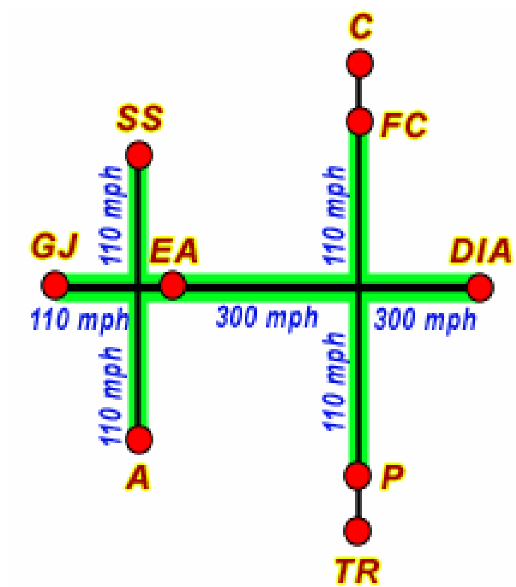


Exhibit 9-10: Operating Ratio Results: Western Expansion – 2035 – Central Case (Millions $2008)

	220 mph I-70 Constrained (7%) I-25 Greenfield Truncated w/ 110 W of Eagle	300 mph I-70 Constrained (7%) on I-70 w/ 110 on I-25 and W of Eagle
BENEFITS	Option 5W	Option 9W
Revenue	781.27	569.18
Operating Costs	469.60	320.13
2035 Operating Ratio	1.66	1.78

Exhibit 9-11: Economic Evaluation of Western Expansion – 2035 – Central Case (Millions $2008)

	220 mph I-70 Constrained (7%) Greenfield Truncated w/ 110 W of Eagle	300 mph I-70 Constrained (7%) on I-70 w/ 110 on I-25 and W of Eagle
BENEFITS	Option 5W	Option 9W
Revenue	781.27	569.18
Consumer Surplus	980.08	637.37
Resource Savings	380.67	430.78
Total Benefits	2142.02	1637.33
COSTS		
Operating Costs	469.60	320.13
Capital Costs	1299.76	1275.12
Total Costs	1769.36	1595.25
Cost Benefit Ratio	1.21	1.03

The results of the analysis show that both options 5W and 9W could support western extensions if the capital cost were limited to $1 billion. However, the 300-mph maglev option has its Cost Benefit reduced to 1.03, which is very small given the error range in the estimates. The 220-mph Electric still shows a good return, and could probably sustain $2 billion in added costs if the 110-mph diesel were to run under the wire as far as Keystone and Silverthorne.

9.5 The FRA "Developed" Option

Following discussions with the Steering Committee on the potential for serving the I-25 and I-70 corridors with an intercity passenger rail system, a decision was made to select the 220-mph Electric Rail option for further development which included truncation west of Eagle County Airport, truncation north of Fort Collins, and truncation south of Pueblo. This option has the advantage of producing the best operating and cost benefit results with minimal capital cost compared to the other alternatives.

Given this direction the study team fine-tuned the 220-mph Electric Rail option by considering how it might be best fitted to the I-70 and I-25 corridors. The result of this fine-tuning was called the FRA "Developed" option since it was developed by the study team for presentation to FRA as a network combination that could meet FRA's economic and financial feasibility criteria. For the development of a final set of financial projections for this feasibility study, a composite network selecting the best features of the earlier Constrained and Unconstrained networks, shown in Exhibit 9-12, was developed. In the longer term, development of an expanded network with Western Extensions as shown in Exhibit 9-13 could be considered. With the involvement and support of Wyoming and New Mexico, even the north and south extensions on I-25 could be added in the future. Exhibit 9-14 shows a more detailed map of the proposed FRA Developed rail system.

For developing a network for more detailed evaluation, called the FRA Developed Option, the results of the preliminary screening suggested the following:

- For the I-25 corridor the Greenfield alignments performed best, primarily because of the strength of the added Lone Tree and North Suburban stations, which improve system access in the Denver suburban market. The Freight Rail risk analysis described in section 10.6 determined that it was advantageous to extend the I-25 Greenfield all the way around Colorado Springs with stops at Woodmen Road and Colorado Springs airport, rather than using the existing freight rail alignment through town, as described in Appendix I.
- For the I-70 corridor from Denver to Eagle Airport, the unconstrained alignment offered the best train operations and served the resorts more directly. However, some portions of the proposed route raised environmental concerns, and construction would also require a great deal of costly tunneling.

In the I-70 corridor, a combination of segments from the original I-70 Right-of-Way and unconstrained alignments were retained in the FRA Developed Option. This reflects the input received from the RMRA Steering Committee, Public Input meetings and from members of the I-70 Coalition. The objectives for definition of the FRA Developed Option were to:

- Minimize the environmental intrusiveness of the rail system
- Minimize construction impacts on the I-70 highway
- Reduce the amount of costly tunneling that was recommended in the original plan
- Minimize or eliminate the use of 7 percent gradients if possible
- Improve rail access to local communities while preserving direct service to the ski resorts

Exhibit 9-12: FRA Developed Rail Network for Detailed Evaluation

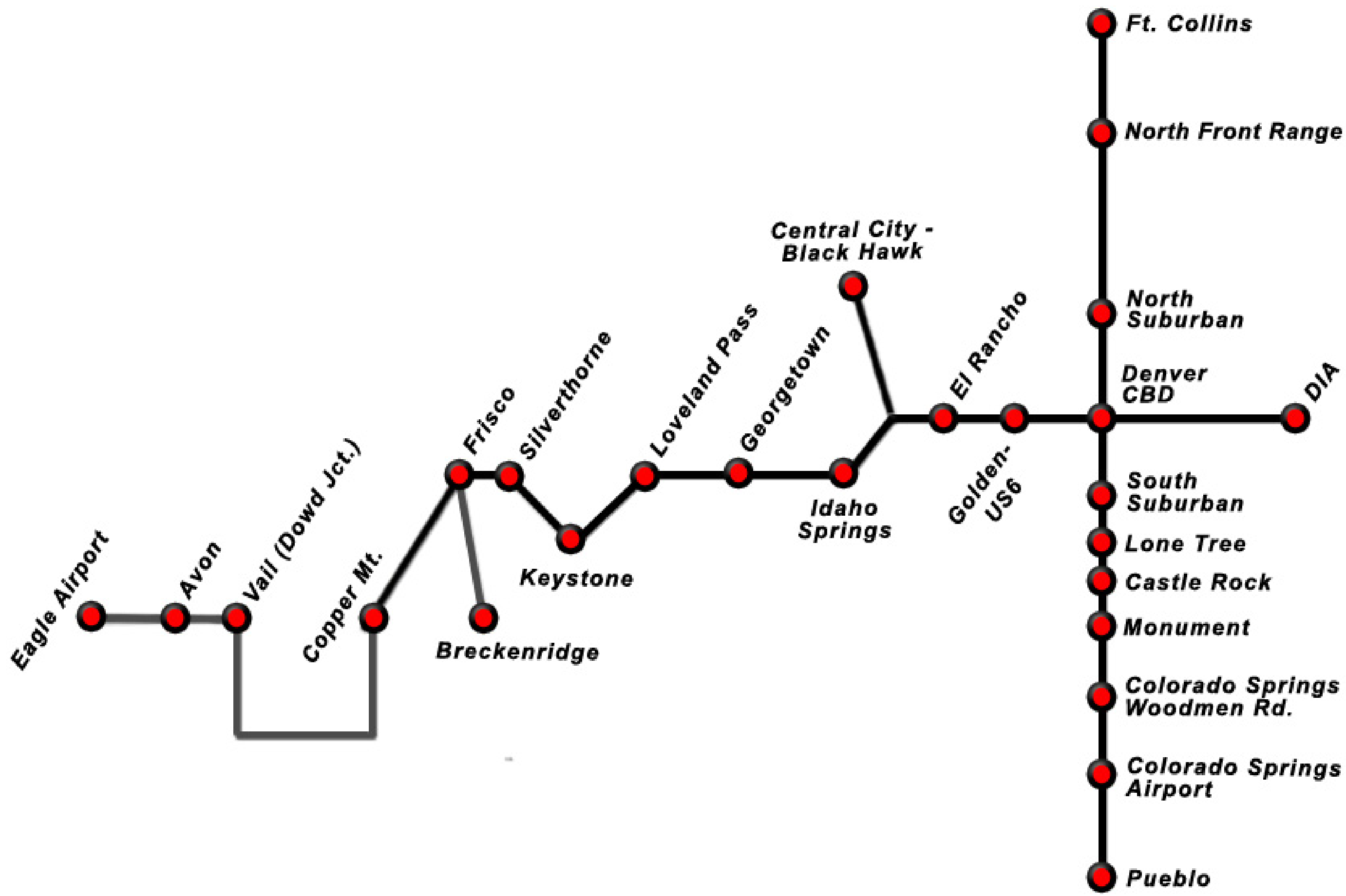


Exhibit 9-13: FRA Developed Network with Western Extensions

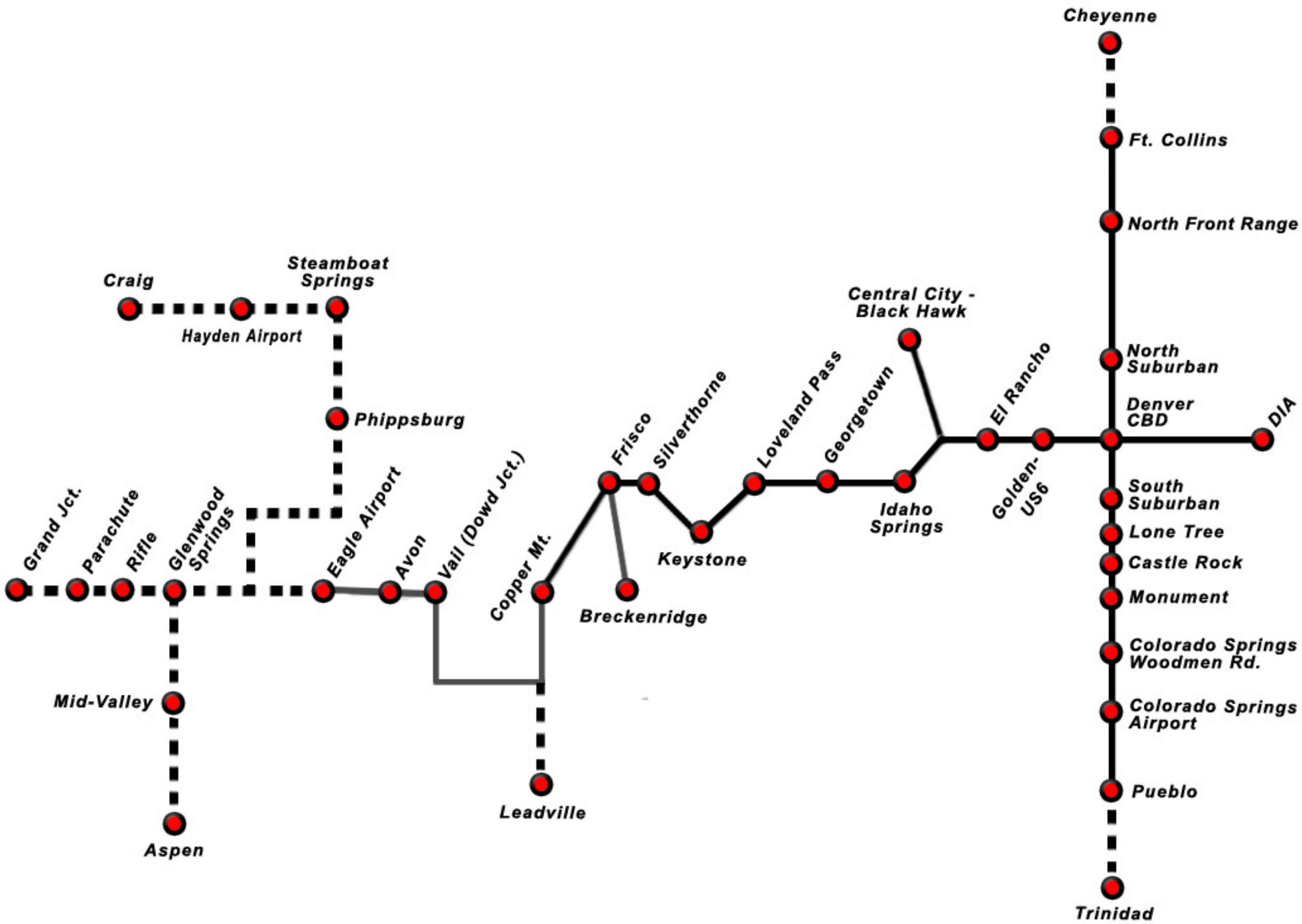
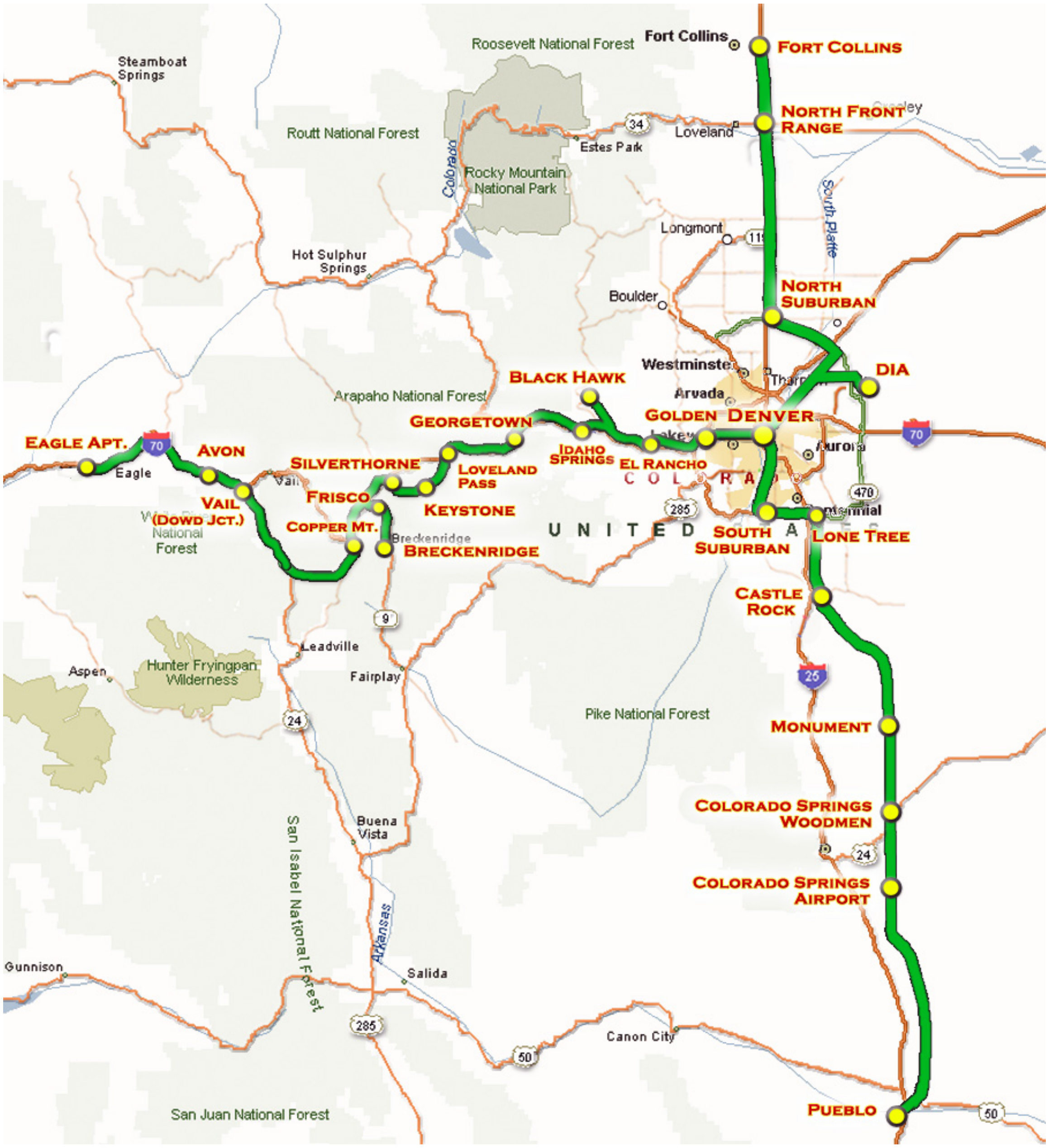


Exhibit 9-14: FRA Developed Rail Network Alignments Map



The selection of segments comprising the FRA Developed Option has tried to balance these sometimes-conflicting objectives in a reasonable way, and as such it may not represent the final solution. However, it is moving the development of the feasible options towards a consensus solution that reflects community goals. One alternative will be used for the purpose of financial evaluation in the current Feasibility study, but should not be considered the only possibility. In any following Program Development work, the proposed route needs to be subject to a detailed preliminary engineering and environmental analysis. Appendix H further discusses the definition of the FRA Developed Option highlighting the value of retaining 4 percent rather than 7 percent gradients where possible. Appendix I refines the Colorado Springs options.

In the I-25 corridor, the FRA Developed Option consists of the Greenfield alternative that was used for the 220-mph Truncated network evaluation. No modifications have been made to the routes presented in the original alternative. It is possible that a hybrid solution for I-25 could be developed based on a greater use of existing rail lines. Without an I-70 corridor connection, a passenger system based on existing rail lines in the corridor may be all that Colorado could afford. However, with the added boost from I-70 connecting traffic, the I-25 market improves to the point where it could support the development of Greenfield routes. Therefore Greenfield routes are used in I-25 for the purpose of the current evaluation, without prejudice to the NEPA process or other route possibilities, including the existing rail option. The routes included in the FRA Developed Option, both with and without possible Western Extensions, are shown in Exhibits 9-12 and 9-13.

As shown in Exhibit 9-12, in the I-70 corridor, a composite of I-70 Right-of-Way and unconstrained alignment segments have been assembled:

- From downtown Denver, the proposed corridor follows US-6 to the junction of I-70 and US-6 near Golden.
- Although the Clear Creek Canyon would provide better rail operations, because of community concerns the I-70 alignment via El Rancho was assumed to Floyd Hill. This segment involves some sections of 7 percent gradient, which should be eliminated or reduced as much as possible in the development of a final rail alignment. At Floyd Hill a branch line to Black Hawk would diverge into a new rail tunnel constructed in the vicinity of the proposed highway gaming tunnel, to reach the State Route 119 corridor on the backside of the mountain.
- From Floyd Hill up to Loveland Pass, the route within or contiguous to I-70 between Floyd Hill and Loveland Pass was used, with the exception of the Georgetown tunnel. The unconstrained segments offer better geometry and higher speed potential, are less costly to construct, and minimize maintenance of traffic concerns on the parallel I-70 highway corridor. If it proves feasible to use the Clear Creek Canyon or as an alternative, develop a 4 percent gradient option via El Rancho (which would probably involve a tunnel option) then the Georgetown tunnel should be added back into this segment to limit the maximum grade to just 4 percent all the way from Denver to Eagle Airport.
- From Loveland Pass to Silverthorne, the proposed North Fork tunnel using 4 percent grades to Keystone was used along with a connecting line that follows US-6 from Keystone back to Silverthorne. This avoids rail tunnel construction parallel to the EJMT and bypasses a steep

and difficult segment where the highway is constructed on the side of a mountain with 7 percent grades. It puts Keystone on the main line, making it easy to stop as many trains as desired there, and limits to one the number of branch lines that are needed to serve Summit County, simplifying and allowing for more efficient rail operations.

- Because of extensive tunneling that would be needed to implement a rail alignment along the south side of Lake Dillon, to reduce the tunneling expense and improve access to local communities, the proposed rail corridor has been routed back north to rejoin the I-70 highway corridor at Silverthorne. It would then follow the I-70 highway through Frisco and on to Copper Mountain using the PEIS alignment. This alignment currently has some short segments of 7 percent grade. It is assumed that by making minor route diversions off the highway right-of-way it may be possible to ease the worst grades down to 4 percent on a corridor north of Lake Dillon, although a detailed engineering assessment of unconstrained alignments has not been conducted here. West of Frisco, a branch line would tunnel back through Royal Mountain to avoid the built up part of Frisco, and to head south to Breckenridge.
- West of Copper Mountain the Pando option was assumed, for avoiding difficult 7 percent gradients on Vail Pass, and to minimize construction impacts on I-70.
- West of Pando to Avon and Eagle Airport the existing rail alignment has been assumed.

The FRA Developed Option, based on 220-mph Electric Rail technology has a capital cost of $21.13 billion, up from $19.84 Billion that was estimated for the original truncated 220-mph system. It is higher than the cost of the 220-mph system because the Developed Option includes additional tunnel segments for reducing gradients, improving market access, improving operations and reducing project implementation risks.

Chapter 10 presents an analysis of the FRA Developed Option, based on a detailed plan that allows identification of the specific cash flows and benefit streams associated with implementation of the system. This Business Plan approach allows for calculation of precise Net Present Values, Cost Benefit criteria and Operating Ratios associated with the prospective implementation and operation of the rail system. Exhibit 9-15 previews the key results of this analysis.

Exhibit 9-15: FRA Developed Option, Summary of Key Results

COST BENEFIT RATIO **(Total Benefits ÷ Total Cost)**	**1.49**
OPERATING RATIO **(Revenue ÷ Operating Costs)**	**1.90**

As a result, the refinements incorporated into the FRA Developed Option have improved the Cost Benefit ratio from 1.28 to 1.49, as a result of the optimized implementation plan and the full detailed Business Plan assessment. The economic assumptions that led to this improvement will be more fully described in the next chapter.

10 Implementation Plan and Rail Right-of-Way Risk Analysis

This chapter describes an implementation plan for the FRA Developed Option, which includes key milestones and phasing for the development of the system. Funding options/strategies will be discussed in Chapter 11.

For the FRA Developed Option, both a sensitivity and risk analysis were performed. The sensitivity analysis will consider socioeconomic, rail service, operating and capital costs, and revenue ranges. The risk analysis will primarily consider downside factors, and will include a quantitative analysis comparison of a totally non-freight railroad corridor compared to use of existing rail corridors. The study currently assumes shared use of rail corridors for access to downtown Denver, through Colorado Springs and from Pando to Eagle Airport. However, the RMRA Steering Committee asked for development of an alternative that would not need to share right-of-way with freight railroads, and which could facilitate the use of FRA non-compliant equipment. This work was performed as a supplement to the original study and the key results are presented at the end of this chapter.

10.1 Implementation Phase Definition

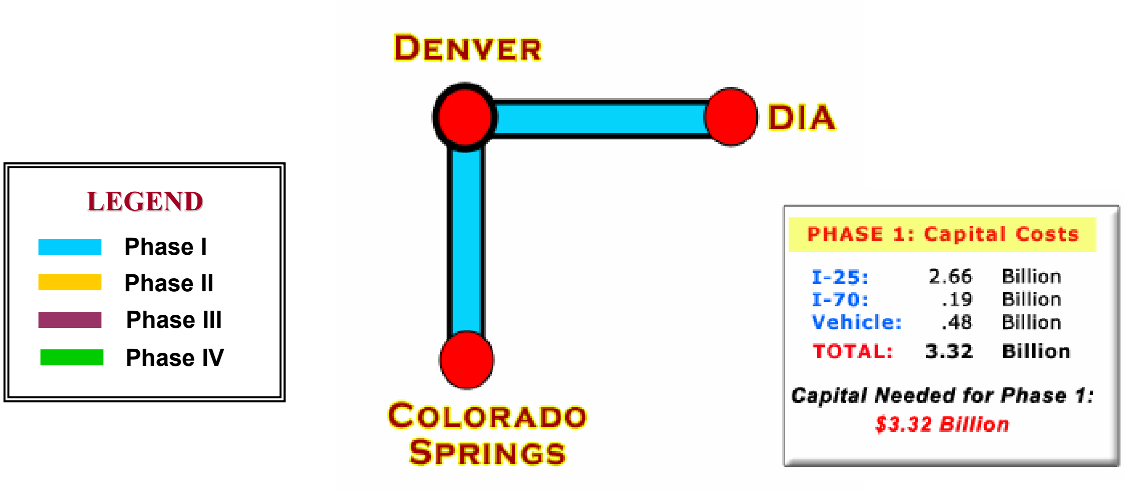
For evaluation in this Feasibility Study, a preliminary set of implementation phases has been developed. Since final alignments and phasing will be developed during the NEPA process, this discussion is intended only to jump start consideration of implementation options for the next planning phase. For the current study, four phases have been proposed as shown in Exhibits 10-1 through 10-4:

- **Phase I** would build the initial segments from Denver International Airport (DIA) to downtown Denver to Colorado Springs. Ridership projections have consistently shown that these will be the peak load segments for the entire system, so they are a logical first phase.
- **Phase II** would extend service in I-70 from downtown Denver to Summit County resorts including to Keystone, Breckenridge and Copper Mountain. This will likely be the most difficult and expensive segment to construct because of extensive tunneling needed for I-70 crossing the Continental Divide. Rather than avoiding this segment, since its construction is likely to take the longest, it is essential to gain the environmental clearance and funding commitments needed to get the earliest start possible on the I-70 tunnels. Construction on Phase II should proceed concurrently with development of other segments even if those segments can be completed first.
- **Phase III** would extend I-25 service north to Fort Collins and south to Pueblo. Depending on the level of funding and issues identified during the NEPA process, Phase III may be able

to be completed before Phase II. However, this analysis assumes that Phases II and III will open concurrently.

- **Phase IV** would extend I-70 service west to Eagle Airport and also complete the branch line to Black Hawk. Construction of a line from Copper Mountain west to Eagle Airport via Pando does not entail any major tunneling and uses an existing rail right-of-way, so it also may be able to complete earlier than Phase II. This might make sense as a way to jump-start earlier development of the proposed diesel-powered Intermountain Connection.[1] However, this analysis assumes this phase will open concurrently with Phases II and III.

Exhibit 10-1: Phase I – DIA to Colorado Springs



[1] See: http://www.eaglecounty.us/ecotransit/TransitVision2030/pdf/IMCview.pdf

Exhibit 10-2: Phase II – Denver to Summit County Resorts

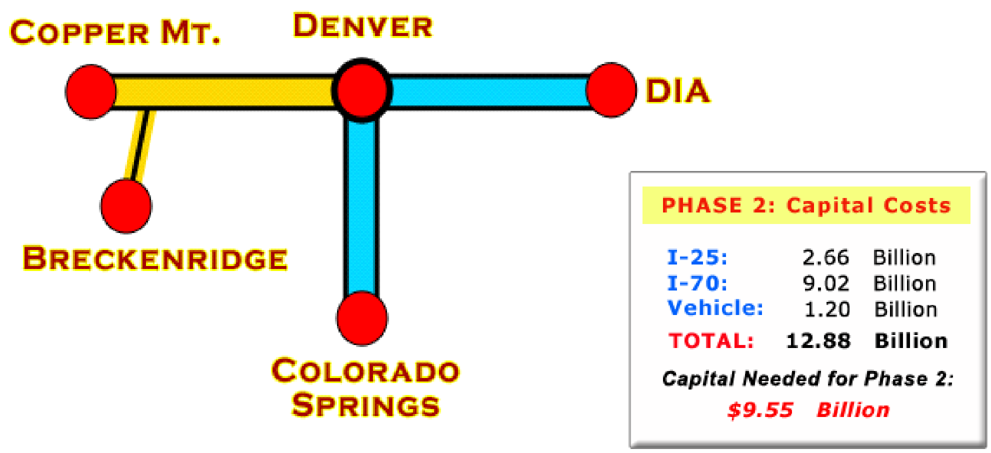


Exhibit 10-3: Phase III –I-25 Extensions to Pueblo and Fort Collins

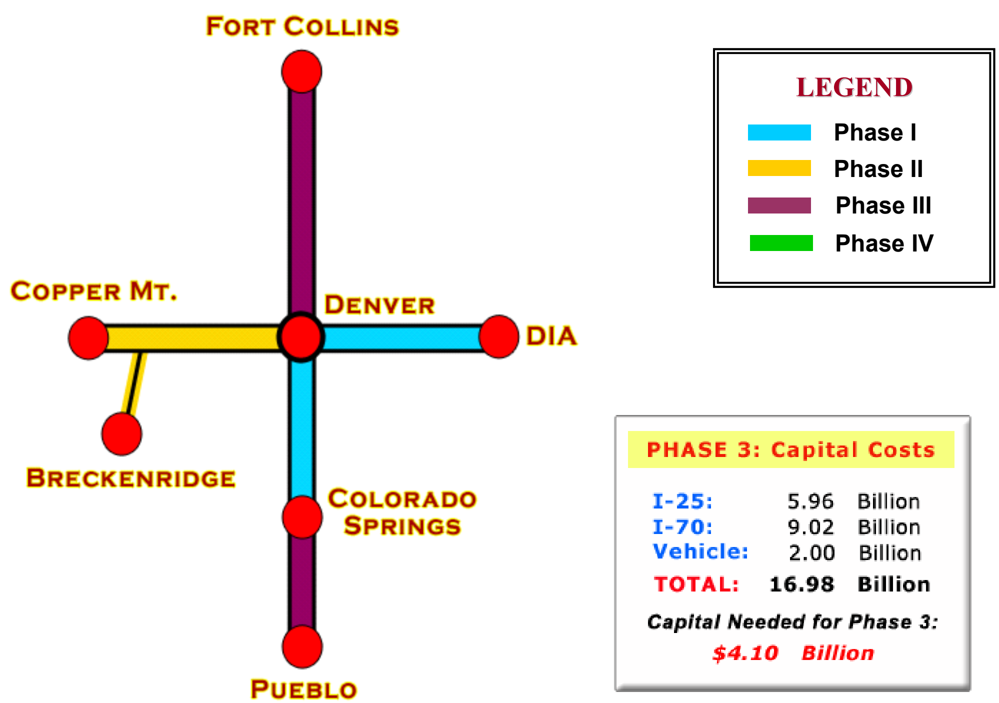
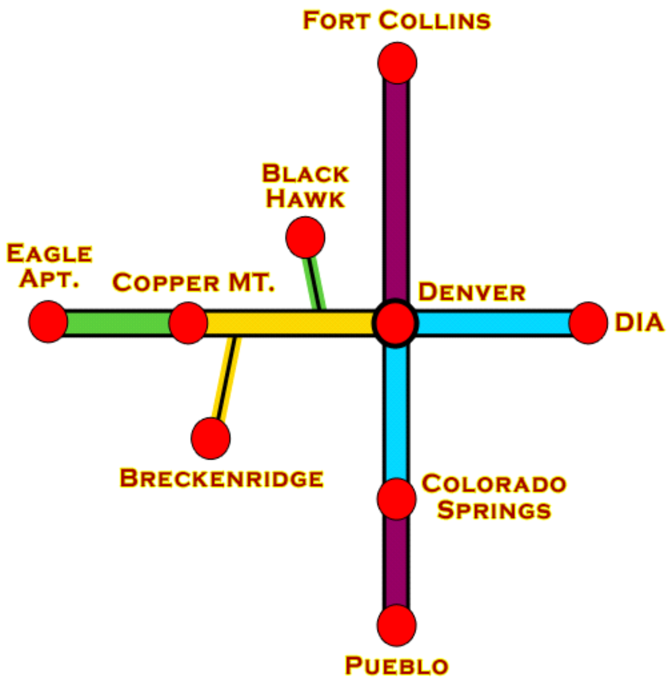


Exhibit 10-4: Phase IV –I-70 Extensions to Eagle Airport and Black Hawk



PHASE 4: Capital Costs		
I-25:	5.96	Billion
I-70:	12.97	Billion
Vehicle:	2.20	Billion
TOTAL:	**21.13**	**Billion**
Capital Needed for Phase 4:	***$4.15***	***Billion***

10.2 Implementation Phase Timings

For development of an implementation plan, a key consideration is the length of time it takes to progress through the environmental planning and project development process, followed by detailed design, construction, testing and certification of the system.

- Planning issues on the I-70 corridor are complex, but the I-70 effort has a head start because of the substantial amount of work that has already been completed by the I-70 PEIS. However it is still essential to remain focused on moving expeditiously if relief to current I-70 traffic congestion is to be forthcoming in any reasonable time frame.
- Planning on I-25 is also complex. It involves several urban segments and a need to coordinate with freight railroads and the R2C2 project, as well as the need to deal with environmental and community issues on proposed Greenfield segments.

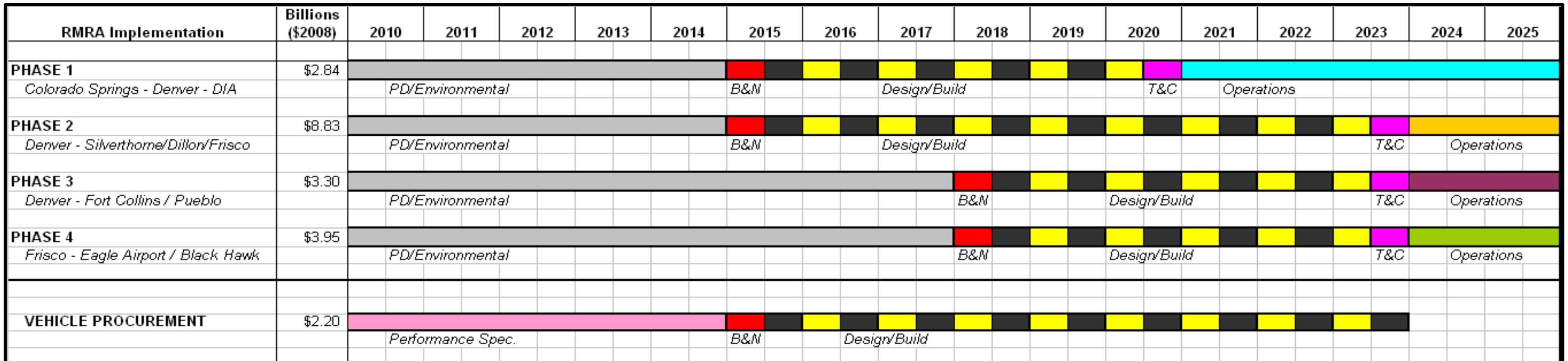
As a result, because of the complexities involved in planning both the I-25 and I-70 corridors, the project development (PD) including the preliminary engineering (30 to 45 percent) and environmental document phase (PEIS/EIS) has been estimated as five years for both corridors. Project development for Phases III and IV could be started concurrently if desired, although the main focus must be on completing the work that is needed to support the start of construction on Phases I and II at the earliest possible date. A Design-Build approach has been assumed for compressing the implementation time scale of the project. This approach allows some construction to start occurring prior to the full completion of the final engineering design phase by the design-build contractor.

Exhibit 10-5 shows a proposed implementation plan for the system.

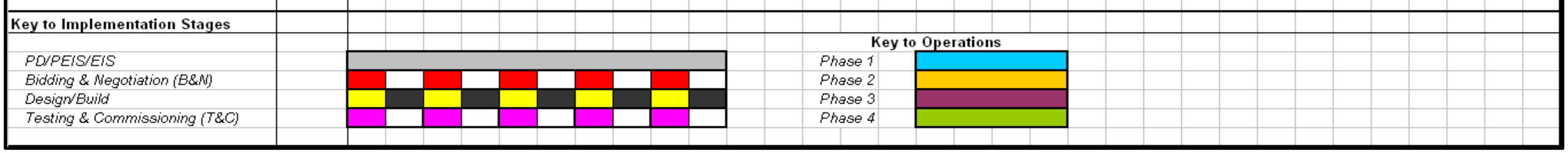
- **Phase I** needs six years for the design-build phase from the date of completion of 30 percent preliminary engineering and environmental documents that would result in a 2021 opening date for the system. Included in the six year design build phase is 6 months in the front for bidding and negotiating design build segments and 6 months at the end for testing and commissioning.
- **Phase II** takes longer because of the design-build time needed for tunnels. The design-build segments start with a 6 month bidding and negotiation phase, followed by 8 years of design-build, and ending with 6 months of testing and commission. The I-70 corridor from Denver to Copper Mountain could be in service by 2024.
- **Phases III and IV** need six years for implementation. Assuming no funding or construction resource bottlenecks, both are assumed to open concurrently with Phase II in 2024.

Even though Phases II, III and IV are all assumed to implement concurrently, for more flexibility in future NEPA planning, they have still been identified as independent phases in this feasibility study.

Exhibit 10-5: Proposed RMRA Implementation Plan



Total Investment	Billions ($2008)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
PD/PEIS/EIS	$ 2.46	$ 0.06	$ 0.06	$ 0.06	$ 0.09	$ 0.44	$ 0.47	$ 0.47	$ 0.25	$ 0.27	$ 0.27						
Design/Build	$ 16.46								$ 1.92	$ 1.92	$ 1.92	$ 2.67	$ 2.67	$ 2.67	$ 2.67		
Total Infrastructure	$ 18.92	$ 0.06	$ 0.06	$ 0.06	$ 0.09	$ 0.44	$ 0.47	$ 0.47	$ 2.17	$ 2.19	$ 2.19	$ 2.67	$ 2.67	$ 2.67	$ 2.67		
Total Rolling Stock	$ 2.20								$ 0.26	$ 0.26	$ 0.26	$ 0.35	$ 0.35	$ 0.35	$ 0.35		
Total Investment	$ 21.12	$ 0.06	$ 0.06	$ 0.06	$ 0.09	$ 0.44	$ 0.47	$ 0.47	$ 2.44	$ 2.46	$ 2.46	$ 3.03	$ 3.03	$ 3.03	$ 3.03		



10.3 Capital Requirements

Capital investment requirements have been estimated for each construction phase, based on the total cost estimate that has been developed for the FRA Developed Option. The routes and costs included in each implementation phase are described below.

10.3.1 Phase I - Denver International Airport to Denver to Colorado Springs

The FRA Developed Option leaves the future intermodal center at DIA and proceeds westward on the south side of 96th Street through the Rocky Mountain Arsenal. The route crosses SH 2 at the intersection of 96th Street and the BNSF Brush subdivision on an elevated structure lands on or contiguous to the BNSF existing rail. The route follows the BNSF right-of-way to the Sand Creek Junction to Denver Union Station. The FRA Developed Option proceeds to the south on the BNSF/UPRR Joint Line to Littleton. The route crosses C-470 on an elevated structure and lands on the south of C-470. The route proceeds in an area contiguous to C-470 to the west. The route crosses over I-25 and lands on the east side. The route continues south contiguous to the I-25 right-of-way to a location approximately 1.2 miles north of the center of Castle Rock where it transitions to a greenfield alignment on the Front Range and proceeds towards Colorado Springs. East of Colorado Springs, the route leaves the greenfield and uses a route consisting of existing rail rights-of-way onto the Joint Line at the UPRR MP 72.8 and into downtown Colorado Springs to the site of the former Denver, Rio, Grande and Western Station on the Joint Line UPRR MP 74.9. The estimated infrastructure costs for this FRA Developed Option between DIA and Colorado Springs is detailed in Exhibit 10-6.

Exhibit 10-6: Estimated Capital Cost by Project Element (Phase I)

Phase I: DIA to Denver to Colorado Springs	Total Costs in Millions $2008
Track work	$663.098
Structures	$564.925
Systems	$308.002
Crossings	$11.501
Stations/Maintenance Facilities	$201.91
Total of Construction Elements	$1,748.716
Contingency	$494.857
Other Costs	$600.427
SUBTOTAL Infrastructure	$2,844.000
Vehicles	$480.000
TOTAL PHASE I	$3,324.000

10.3.2 Phase II - Denver to Keystone/Breckenridge and Copper Mountain

The FRA Developed Option leaves the I-25 corridor from the BNSF/UPRR Joint Line immediately north of the intersection of US-6 and I-25. It crosses the I-25/US-6 interchange on a high level structure and lands within or contiguous to the US-6 right-of-way and proceeds west to the crossing of US -6 with I-70. The route follows the PEIS alignment within the right-of-way of limits of I-70 from US-6 to Floyd Hill via El Rancho. From Floyd Hill to Idaho Springs, the route proceeds within or contiguous to the south side of I-70 to Idaho Springs. The route continues within or contiguous to the south side of I -70 from Idaho Springs to Georgetown. From the east boundary of Georgetown, the route proceeds to a point on the PEIS alignment near the west boundary of Silver Plume within or contiguous to the I-70 right-of-way. The route proceeds within or contiguous to the I-70 right-of-way on the south side from Silver Plume to a point near the Loveland Pass interchange with I-70 (MP 216). At this point, the route enters the North Fork Tunnel and exits the tunnel and proceeds on the north side of US-6 into Keystone. The route proceeds within or contiguous to US-6 from Keystone to Dillon and Silverthorne. The route proceeds into the right-of-way limits of I-70 and follows the PEIS alignment toward Frisco. At a point near the west boundary of Frisco, the Breckenridge branch line proceeds south through a tunnel. It exits the tunnel and proceeds within or contiguous to SH-9 to Breckenridge. From Frisco, the main line follows the PEIS alignment to Copper Mountain. The estimated infrastructure cost between Denver and Copper Mountain is detailed in Exhibit 10-7.

Exhibit 10-7: Estimate Capital Cost by Project Element (Phase II)

Phase II: Denver to Copper Mountain	Total Costs in Millions $2008
Track work	$527.054
Structures	$4,313.489
Systems	$421.480
Crossings	$2.279
Stations/Maintenance Facilities	$85.000
Total of Construction Elements	$5,349.302
Contingency	$1,574.791
Other Costs	$1,910.746
SUBTOTAL Infrastructure	**$8,834.839**
Vehicles	$720.000
TOTAL PHASE II	**$9,554.839**

10.3.3 Phase III - Colorado Springs to Pueblo and Denver to Fort Collins

Colorado Springs to Pueblo

From downtown Colorado Springs, the FRA Developed Option proceeds on the existing rail BNSF/UPRR Joint Line to Fountain. Between Colorado Springs and Fountain, a connection to Fort Carson can be made in the vicinity of BNSF MP 78.8. At Fountain, the route leaves the existing rail right-of-way near BNSF MP 88.7 onto the Front Range and proceeds on a greenfield route south to Pueblo. North of Pueblo, the greenfield route meets with the BNSF/UPRR Joint Line and proceeds into downtown Pueblo.

Denver to Fort Collins

From downtown Denver, the FRA Developed Option proceeds on the BNSF Brush subdivision existing rail route to a point where the existing rail route intersects with E-470. The route proceeds onto the north side of E-470 and crosses I-25 on an elevated structure and lands on the west side of I-25. The route proceeds north to the vicinity of County Road 6 where it crosses on an elevated structure and lands in the median. The route proceeds north in the median of the I-25 highway to the North Front Range Station and north to a Fort Collins station.

The estimated infrastructure cost for these extensions is detailed in Exhibit 10-8.

Exhibit 10-8: Estimate Capital Cost by Project Element (Phase III)

Phase III: Colorado Springs to Pueblo and Denver to Fort Collins	Total Costs in Millions $2008
Track work	$897.839
Structures	$499.342
Systems	$526.607
Crossings	$6.318
Stations/Maintenance Facilities	$56.000
Total of Construction Elements	$1,986.106
Contingency	$595.832
Other Costs	$722.943
SUBTOTAL Infrastructure	**$3,304.880**
Vehicles	$800.000
TOTAL PHASE III	**$4,104.880**

10.3.4 Phase IV - I-70 Copper Mountain to Eagle County Airport and Black Hawk Branch

Copper Mountain to Eagle County Airport

From Copper Mountain, the optimized core route (greenfield) proceeds south on the east side of SH 91 and crosses SH 91 on an elevated structure and continues on elevated structure through the National Forest and connects with the UPRR Tennessee Subdivision at Pando Junction. Costs for this segment assume a Vail station at Dowd Junction but no branch line into Vail. There are some very restricted sections of the Eagle River gorge between Pando and Minturn, but the capital cost estimate takes these into account. The FRA Developed Option continues within or contiguous to the UPPR right-of-way existing rail route to the Eagle County Airport.

Black Hawk Branch

From the base of Floyd Hill near I-70 at MP 244, the FRA Developed Option enters Black Hawk Tunnel (approximate length of 5300 LF) and proceeds to SH 119. The route proceeds within or contiguous to SH-119 to Black Hawk.

The estimated infrastructure cost for these extensions is detailed in Exhibit 10-9.

Exhibit 10-9: Estimate Capital Cost by Project Element (Phase IV)

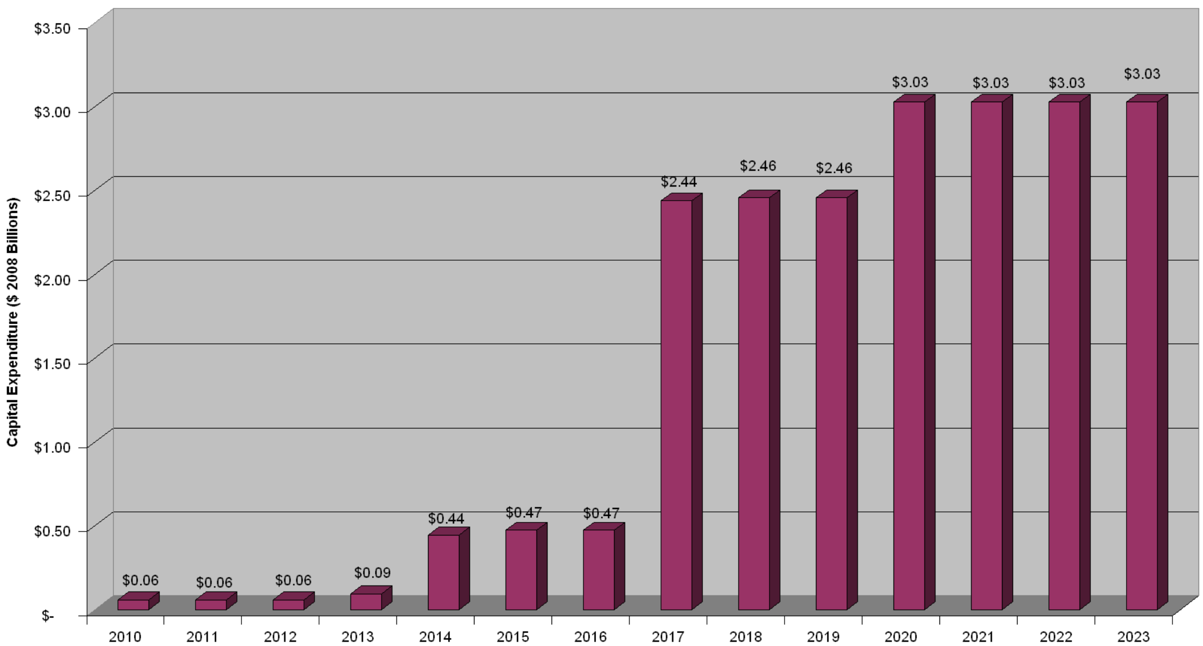
Phase IV: Copper Mountain to Eagle County Airport and Black Hawk Branch	Total Costs in Millions $2008
Track work	$617.297
Structures	$1,390.563
Systems	$339.709
Crossings	$0
Stations/Maintenance Facilities	$25.000
Total of Construction Elements	$2,372.569
Contingency	$711.771
Other Costs	$863.615
SUBTOTAL Infrastructure	**$3,947.955**
Vehicles	$200.000
TOTAL PHASE IV	**$4,147.955**

10.3.5 Implementation Phase Timings

For development of an implementation plan, a key consideration is the length of time it takes to progress through the environmental planning and project development process, followed by detailed design, construction, testing and certification of the system.

Exhibit 10-10 shows the cash flows resulting from the overall implementation plan. For seven years of project development from 2010 through 2016 expenditures remain at a level of $60 million per year, ramping up to $470 million per year in 2016. Once construction starts in 2017, implementation takes seven years at an average level of expenditure of $2.8 billion per year, but likely ranging between $2.5 and $3.0 billion depending on the activities of the specific year.

Exhibit 10-10: Projected Allocation of Construction and Equipment Costs



The capital plan includes $2.20 billion for 50 trains by 2020, an average cost of $44 million each for a 300-seat train. At current exchange rates the trains may cost more than that if they were all imported from Europe, but this estimate is reasonable for domestic production of a volume order of trains under "Buy American" provisions. Equipment cost could be reduced if grades were limited to 4 percent on the whole system. To keep pace with ridership growth, the capital plan provides for purchases of 15 additional trains in 2030, 15 trains in 2040 and 10 trains in 2050.

The capital requirement also includes an allowance for track and infrastructure renewal, which is gradually ramped according to the factors given in Exhibit 7-6. A fully ramped level of capital replacement was estimated to add an additional 77 percent in cost or $43 million per year over and above the level of operating maintenance expenditures, but this full normalized level of cost is not reached until 2041. It has, therefore, a relatively minor impact since it does not start occurring until rather late in the planning period.

Infrastructure renewal does not need to be included in the Operating Ratio because it is a capital cost, not an operating cost. It has been included in the Cost Benefit calculation. However, the projected operating surpluses are more than sufficient to cover this cost.

A discounted cash flow basis was used for calculating the cost benefit ratio associated with implementation of the Colorado Rail System. A 3.9 percent interest real interest rate was used consistent with GAO guidelines. This calculation assumed project development and construction from 2010 through 2020, with Phase I operations starting in 2021. Construction on the remainder of the system continues through 2023 as shown in Exhibits 10-4 and 10-5. However there is a three-year overlap where some operating benefits help offset the development costs associated with other parts of the system.

Train-miles were ramped up on a year-to-year basis to maintain a constant 75 percent load factor. This assumes that train operations will be tightly matched to demand each year through incremental adjustments and additions to the operating plan, so that the growth in capacity matches the growth in ridership and revenue. Because fixed costs remain constant as ridership grows, this results in steadily declining average costs and improving operating ratios throughout the life of the system.

10.4 Financial Results

Exhibit 10-11 presents a pro-forma Financial Statement showing projected operating cash flows associated with implementation of the system. This statement assumes a two-step Implementation with Phase I becoming operational in 2021, and Phases II through IV coming on-line in 2024, in accordance with the implementation plan of Exhibit 10-15.

Revenue ramp up factors of 50 percent and 75 percent were assumed for the first two years of operation. This results in small operating losses in the first implementation year of each phase. These start-up losses are normal and expected, and need to be anticipated and built into the Financial Plan. A small loss of $8.9 million occurs in 2021 associated with the Phase I startup, and again in 2024 a loss of $36.5 million is associated with the Phase IV startup.

The level of these startup operating losses is not of a great concern (assuming financing can be arranged) since the Year 2 operating surplus is $16.4 million, more than enough to repay the first year losses; and again the Year 3 operating surplus is $43.3 million, more than enough to cover the anticipated loss in 2024. Because these are transient losses associated with start-up, the losses can be financed using a funding mechanism such as a TIFIA loan (Transportation Infrastructure Finance and Innovation Act of 1998) so that these short-term losses can be capitalized and paid back at a later time, without requiring an operating subsidy.

The cash flow analysis shows that the system, once through the initial start-up period, will be financially self-sustaining and in fact capable of generating substantial operating surpluses on an annual basis. For example, the operating surplus in 2035 is estimated as $454.6 million. Over the projected 30-year life of the system, these surpluses (undiscounted) come to a total of $12.96 billion. This compares to an initial cost of $21.13 billion for the whole system. As a result, the available cash from operations is not sufficient, by itself, to justify the cost of building the system (i.e. the project cannot finance itself.)

Once built the free cash flow generated from operations will be substantial, so in the context of a public-private partnership there could be a possibility for the system to self-fund a good share, but not all, of its capital cost. For example, there appears to be the possibility that a private operator could afford to buy their own trains to operate over the line, as well as fund the periodical infrastructure maintenance (capital) costs that were assumed by this business plan. Or, if the operating surpluses were paid to RMRA and revenue bonds issued against these prospective future cash flows, there would likely be enough money to pay the assumed 20 percent local match for building the system without needing any local taxpayer funds.

Capital Costs are treated as a grant to the project, on the basis of an agreed split between Federal, state, and private sources. These agreements will be worked out in detail in subsequent financial discussions between the parties. Potential contributions are identified in the funding chapter, and specific capital cash flows will then be identified, and the specific costs and borrowing requirements can be estimated. On a project of this scale a number of creative financing techniques are likely to be used to even out flows and minimize financing costs. Typically, these costs would work out in the vicinity of 1-2 percent of total project cost, given the availability of such financing instruments as Delayed Match, Grant Anticipation Notes, Transportation Infrastructure and Finance Innovation Act (TIFIA), Matching In-kind Contributions, and Direct Capital Grants to the project.

10.5 Cost Benefit Results for the FRA Developed Option

Development of the Cost Benefit ratio for the FRA Developed Option reflects fine-tuning of the capital plan, route structure and implementation plan, as well as the development of refined ridership and revenue forecasts using the COMPASS™ model. Improvements to demand modeling include development of separate Long and Short Distance trip models, as well as refined networks reflecting the route structure of the FRA Developed Option.

The ridership and revenue result is not changed very much from the earlier forecast. Exhibit 10-16 shows the comparison between the earlier "220-mph 7% Truncated" result and the current estimate for the FRA Developed Option. It can be seen that revenue has gone up, but consumer surplus has gone down in a balanced way, this reflects the result of further fare optimization, as well as the refinement of the long distance/short distance modal split models. The net result has very little impact on the Cost Benefit calculation.

Exhibit 10-11: Pro-Forma Financials, Colorado FRA Developed Option, 2021-2050

Thousands of 2008 $	Total to 2050	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Revenues																
Ticket Revenue	**$23,515,988**	$49,540	$76,668	$105,368	$243,385	$376,109	$630,669	$648,203	$665,738	$683,272	$700,807	$723,773	$746,740	$769,706	$792,672	$815,639
On Board Services	**$1,881,279**	$3,963	$6,133	$8,429	$19,471	$30,089	$50,454	$51,856	$53,259	$54,662	$56,065	$57,902	$59,739	$61,576	$63,414	$65,251
Express Parcel Service (Net Rev)	**$1,175,799**	$2,477	$3,833	$5,268	$12,169	$18,805	$31,533	$32,410	$33,287	$34,164	$35,040	$36,189	$37,337	$38,485	$39,634	$40,782
Total Revenues	**$26,573,066**	$55,980	$86,635	$119,066	$275,025	$425,003	$712,656	$732,470	$752,284	$772,098	$791,912	$817,864	$843,816	$869,768	$895,720	$921,672
Train Operating Expenses																
Energy and Fuel	**$779,903**	$2,922	$3,015	$3,108	$19,201	$19,779	$20,345	$20,912	$21,478	$22,045	$22,612	$23,355	$24,098	$24,842	$25,585	$26,328
Train Equipment Maintenance	**$4,306,918**	$16,728	$17,259	$17,790	$105,989	$109,179	$112,307	$115,434	$118,561	$121,688	$124,816	$128,919	$133,023	$137,126	$141,230	$145,333
Train Crew	**$1,406,072**	$5,461	$5,635	$5,808	$34,602	$35,644	$36,665	$37,686	$38,706	$39,727	$40,748	$42,088	$43,428	$44,767	$46,107	$47,447
On Board Services	**$1,485,985**	$4,100	$5,252	$6,467	$23,156	$28,869	$39,447	$40,544	$41,642	$42,739	$43,837	$45,275	$46,713	$48,151	$49,590	$51,028
Total Train Operating Expenses	**$7,978,878**	$29,210	$31,160	$33,173	$182,947	$193,471	$208,764	$214,576	$220,388	$226,200	$232,012	$239,637	$247,262	$254,886	$262,511	$270,136
Other Operating Expenses																
Track	**$1,537,110**	$8,820	$8,820	$8,820	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950
Station	**$331,425**	$3,150	$3,150	$3,150	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925
Call Ctr Variable + T-Agent and CC C	**$1,312,586**	$3,518	$5,446	$7,487	$12,843	$19,833	$35,354	$36,326	$37,297	$38,269	$39,241	$40,487	$41,732	$42,978	$44,224	$45,469
Insurance	**$934,985**	$1,866	$2,888	$3,969	$9,780	$15,115	$25,057	$25,755	$26,452	$27,150	$27,848	$28,763	$29,679	$30,595	$31,510	$32,426
Admin and Mgt	**$892,619**	$14,978	$15,040	$15,102	$25,377	$25,748	$26,113	$26,477	$26,841	$27,206	$27,570	$28,048	$28,526	$29,004	$29,482	$29,960
Operator Profit	**$620,859**	$3,413	$3,754	$4,112	$12,710	$14,180	$16,985	$17,387	$17,789	$18,191	$18,593	$19,118	$19,642	$20,167	$20,691	$21,216
Total Other Operating Expenses	**$5,629,584**	$35,745	$39,098	$42,641	$128,585	$142,751	$171,383	$173,819	$176,255	$178,691	$181,127	$184,291	$187,454	$190,618	$193,782	$196,946
Total Operating Expenses	**$13,608,462**	$64,956	$70,259	$75,814	$311,532	$336,222	$380,147	$388,395	$396,643	$404,891	$413,139	$423,928	$434,716	$445,505	$456,293	$467,082
Cash Flow From Operations	**$12,964,604**	($8,976)	$16,376	$43,252	($36,507)	$88,781	$332,509	$344,075	$355,641	$367,207	$378,773	$393,936	$409,100	$424,263	$439,427	$454,590
Operating Ratio		0.86	1.23	1.57	0.88	1.26	1.87	1.89	1.90	1.91	1.92	1.93	1.94	1.95	1.96	1.97

Exhibit 10-11: Pro-Forma Financials, Colorado FRA Developed Option, 2021-2050 (ctd)

Thousands of 2008 $	Total to 2050	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Revenues																
Ticket Revenue	**$23,515,988**	$840,010	$864,381	$888,753	$913,124	$937,496	$966,859	$996,223	$1,025,586	$1,054,950	$1,084,313	$1,117,276	$1,150,238	$1,183,201	$1,216,163	$1,249,126
On Board Services	**$1,881,279**	$67,201	$69,151	$71,100	$73,050	$75,000	$77,349	$79,698	$82,047	$84,396	$86,745	$89,382	$92,019	$94,656	$97,293	$99,930
Express Parcel Service (Net Rev)	**$1,175,799**	$42,001	$43,219	$44,438	$45,656	$46,875	$48,343	$49,811	$51,279	$52,747	$54,216	$55,864	$57,512	$59,160	$60,808	$62,456
Total Revenues	**$26,573,066**	$949,211	$976,751	$1,004,291	$1,031,830	$1,059,370	$1,092,551	$1,125,732	$1,158,912	$1,192,093	$1,225,274	$1,262,521	$1,299,769	$1,337,017	$1,374,265	$1,411,512
Train Operating Expenses																
Energy and Fuel	**$779,903**	$27,117	$27,907	$28,696	$29,485	$30,274	$31,225	$32,176	$33,127	$34,078	$35,029	$36,097	$37,165	$38,233	$39,301	$40,369
Train Equipment Maintenance	**$4,306,918**	$149,689	$154,044	$158,399	$162,755	$167,110	$172,361	$177,611	$182,861	$188,111	$193,362	$199,257	$205,152	$211,047	$216,942	$222,837
Train Crew	**$1,406,072**	$48,869	$50,290	$51,712	$53,134	$54,556	$56,270	$57,984	$59,698	$61,412	$63,126	$65,051	$66,976	$68,900	$70,825	$72,749
On Board Services	**$1,485,985**	$52,554	$54,080	$55,607	$57,133	$58,659	$60,499	$62,338	$64,177	$66,017	$67,856	$69,921	$71,986	$74,051	$76,116	$78,181
Total Train Operating Expenses	**$7,978,878**	$278,229	$286,321	$294,414	$302,507	$310,600	$320,354	$330,109	$339,864	$349,619	$359,373	$370,326	$381,278	$392,231	$403,183	$414,136
Other Operating Expenses																
Track	**$1,537,110**	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950	$55,950
Station	**$331,425**	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925	$11,925
Call Ctr Variable + T-Agent and CC C	**$1,312,586**	$46,829	$48,188	$49,547	$50,907	$52,266	$53,877	$55,488	$57,099	$58,710	$60,321	$62,137	$63,953	$65,770	$67,586	$69,403
Insurance	**$934,985**	$33,397	$34,369	$35,341	$36,313	$37,284	$38,456	$39,627	$40,799	$41,970	$43,141	$44,457	$45,772	$47,087	$48,402	$49,718
Admin and Mgt	**$892,619**	$30,467	$30,975	$31,482	$31,990	$32,497	$33,109	$33,720	$34,332	$34,943	$35,555	$36,242	$36,929	$37,615	$38,302	$38,989
Operator Profit	**$620,859**	$21,776	$22,337	$22,897	$23,457	$24,018	$24,690	$25,363	$26,036	$26,709	$27,381	$28,137	$28,893	$29,649	$30,405	$31,162
Total Other Operating Expenses	**$5,629,584**	$200,345	$203,743	$207,142	$210,541	$213,940	$218,007	$222,074	$226,140	$230,207	$234,273	$238,848	$243,422	$247,997	$252,571	$257,146
Total Operating Expenses	**$13,608,462**	$478,573	$490,065	$501,557	$513,048	$524,540	$538,361	$552,183	$566,004	$579,825	$593,647	$609,174	$624,701	$640,228	$655,755	$671,282
Cash Flow From Operations	**$12,964,604**	$470,638	$486,686	$502,734	$518,782	$534,830	$554,190	$573,549	$592,908	$612,268	$631,627	$653,348	$675,069	$696,789	$718,510	$740,231
Operating Ratio		1.98	1.99	2.00	2.01	2.02	2.03	2.04	2.05	2.06	2.06	2.07	2.08	2.09	2.10	2.10

Exhibit 10-12: Comparison of Revenue and Consumer Surplus

(Millions $2008)	220-mph 7% RW/GF Truncated	FRA Developed Option
Revenue	$754.6	$921.7
Consumer Surplus	$960.7	$811.6
Total	$1,715.3	$1,733.3

While consumer surplus reflects a benefit to users of the rail system (over and above what they have to pay for), external mode benefits reflect additional benefits accruing to non-users of the system -- such as those people who continue to drive their automobiles.

External Mode benefits consist of auto congestion savings and emissions reduction. The detailed calculation for these supports a higher level of benefit than was estimated in the preliminary screening.

- Highway congestion savings is accounted by the diversion of auto users to rail, in turn reducing the congestion on the highway and improving the level of service to remaining users. The monetary value of these savings was conservatively estimated based on the number of diverted auto trips. The result of the calculation benchmarked in the same approximate range as many Midwest corridors.
- Diverted autos also reduce emissions along the length of the trip, which is accounted for as emission savings. Vehicle emissions are higher when the speed of the vehicle is lower. The emission factors for carbon monoxide, hydrocarbons, NOx, Sox, PM_{10} (Particulate) and carbon dioxide were obtained from the Environmental Protection Agency database[2]. The emission factors in tons per mile were converted to cost per emission by multiplying the valuation of emissions in $ per ton. This valuation was obtained from High-Speed Ground Transportation (HSGT) for America Report (1997)[3] and by applying the consumer price index (CPI) value, converted to $2008.

The other major factor affecting the Cost Benefit ratio is the timing and implementation of capital cost. Since the Cost Benefit ratio is based on a Present Value calculation, the timing of capital cash flows can affect the result. Although capital costs are slightly higher than before, given the current implementation plan the start of the major expenditures is postponed until 2017 and then compressed into a tight seven-year construction period. Some Phase I benefits start occurring as early as 2021 even before construction on the system is fully completed. In the discounting calculation, both costs and benefits that occur earlier are given greater weight. The result is that capital costs, even though slightly higher than before, have been spread out in such a way as to reduce their overall impact on the Cost Benefit ratio.

[2] See: http://www.epa.gov/ and http://www.epa.gov/oms/climate/420f05001.htm - calculating
[3] See: http://www.fra.dot.gov/downloads/RRDev/cfs0997ch6.pdf

These results reflect the Present Value of the benefit and cost streams in constant $2008, discounted at a 3.9 percent real interest rate. Application of this discounting factor over the 14-year implementation time frame for the system reduces the Present Value of the Capital Cost from $21.13 billion down to the $15.03 billion that is shown in Exhibit 10-13.

The results of the Cost Benefit calculation show a projected 1.49 result for the 220-mph FRA Developed Option. An average Operating Ratio of 1.90 over the life of the project can be estimated based on the Present Values of System Revenues and Operating Costs. If automobile operating cost savings were added as described in Chapter 9, the Cost Benefit ratio would improve to 1.58.

Exhibit 10-13: Operating Ratio and Cost Benefit Calculation – 2010-2050 (NPV in Billions $2008)

System Revenues	$13.44
Operating Cost	$7.08
Operating Surplus	$6.36
OPERATING RATIO (Revenue ÷ Operating Costs)	**1.90**

System Revenues	$13.44
Consumer Surplus	$11.81
External Mode	$8.04
TOTAL BENEFITS	**$33.31**
Capital Cost	$15.03
Operating Cost	$7.08
Infrastructure Renewal	$0.23
TOTAL COST	**$22.35**
COST BENEFIT RATIO (Total Benefits ÷ Total Cost)	**1.49**

10.6 Freight Railroad Right-of-Way Risk Analysis

The reason for conducting the risk analysis includes the possible challenges with negotiating with the freight railroads at a reasonable cost. This is due to the technical requirements for separating passenger and freight trains and ensuring appropriate capacity for both systems. This includes the uncertainty of the R2C2 freight relocation project, which would be an essential prerequisite to the freight railroads being able to share rights-of-way. As a result, it is prudent for the study to develop alternatives to the use of freight rail right-of-way.

The proposed Colorado 220-mph Electric Rail system includes several segments of freight railroad right-of-way. On the I-25 corridor, shared freight rail right-of-way would be used for access to downtown Denver and Colorado Springs. On the I-70 corridor, freight rail right-of-way would be used from Pando west to Eagle Airport. It should be noted that all Risk analysis options continue to serve both downtown Denver and DIA, although not as many trains would go to downtown Denver in the Risk analysis options that use E-470 instead of the Joint Line for access from I-25 south.

Since the passenger rail system would use freight rights-of-way in only these few places, the RMRA Steering Committee asked for development of an option that would be *completely* independent of freight rail rights-of-way. This mitigates risks associated with freight right-of-way sharing, including the need for modifying European or Japanese high-speed trains for FRA compliance. This task was identified as a “Risk Analysis” for identifying the additional costs and benefits associated with either the elevated or bypass alignments that would be needed to completely separate passenger from freight rail rights-of-way. In order to do this, capital costs, operating costs, ridership and revenue need to be adjusted. Several route modifications, identified as either original or revised “bypass” options, are shown in Exhibits 10-14 through 10-17. In these exhibits, the red line reflects the portion of the network that was unchanged; the blue line reflects sections of the original network that were removed and the green line shows new “Bypass” segments to be added.

- In the Denver area, two route options were developed as in Exhibits 10-14 and 10-15:
    - **Option 1**: An Elevated option over existing rail right-of-way, using the Joint Line, Consolidated Main Line and Brush Line rights-of-way.
    - **Option 2**: A Bypass alternative via E-470. This bypass option misses the Suburban South station at Littleton, but adds stops at Parker and Aurora. It eliminates use of all but a short stretch of Consolidated Main Line right-of-way that is still required to link downtown Denver to US-6 and the I-70 corridor, but adds a new easterly alignment to E-470 and DIA.

- To avoid the need for sharing freight rail right-of-way through Colorado Springs, a bypass option was also developed there. As Exhibit 10-16 shows, the proposed downtown CBD and South stations were relocated to suburban sites at Woodmen Road and the airport.

- Finally Exhibit 10-17 shows a greenfield alternative that was developed to avoid the need for sharing Union Pacific right-of-way west of Pando.

Costs were estimated only on a parametric basis and as sensitivities on the following ranges:

- Capital Costs Range: *Low to High*
- Bypass Speed Range: *Slow to Fast*
- Equipment Capital and Operating Cost: *Compliant vs. Non-Compliant*

From Fort Collins to Denver, the route alternatives in Exhibit 10-15 are:

- **220-mph Electric Rail:** From the I-25 / E-470 interchange, the alignment follows E-470 east to the I-76 interchange. Crossing the UP tracks it turns southwest onto the BNSF Brush line right-of-way to downtown Denver, sharing the segment south of 96th Avenue with the DIA spur.
- **Bypass Option:** This alternative continues on E-470 past DIA to the I-70 / E-470 interchange, where the line to downtown Denver and the I-70 corridor turns west to the proposed RTD Peoria Street/ Smith Road station. East of Peoria Street, the Bypass would have to either share or parallel the RTD right-of-way into downtown Denver.

From Denver to Pueblo, the route alternatives in Exhibit 10-16 are:

- **220-mph Electric Rail:** The existing Consolidated Main Line and Joint Line rail rights-of-way are used from downtown Denver to Littleton. From Littleton the alignment follows C-470 east to Lone Tree, then I-25 south to Castle Rock. South of Castle Rock, the alignment moves east for easier topography. In Colorado Springs the abandoned Rock Island right-of-way is followed back to the existing rail through downtown. The existing rail corridor is followed to Fountain where the greenfield alignment to Pueblo resumes.
- **Bypass Option:** This alternative uses the E-470 from the I-70 / E-470 interchange to I-25 at Lone Tree, with an intermediate station stop at Parker Road. At Lone Tree, the Bypass option rejoins the FRA Developed Option south. However, to avoid the existing rail corridor through downtown Colorado Springs, the Bypass option includes a greenfield alignment along the east side of Colorado Springs with a suburban station.

From Pando to Eagle Airport, Exhibit 10-17 shows an existing rail (UP Tennessee Pass line) option, along with a new greenfield alternative that would either elevate over the UP rail line, or else use new right-of-way in the corridor.

The Elevated Option 1 for the Denver Metro area developed an estimate for an elevated structure from Littleton (in the south, at Joint Line MP 14) to Sand Creek Junction (in the North, at Brush Line MP 537.4) as shown in Exhibit 10-18. This follows the same rail corridor originally assumed for the 220-mph Electric Rail option, but elevates the passenger line to achieve separation from freight rail.

Exhibit 10-14: Denver Metro Area: Risk Analysis Routes

<u>OPTION 1:</u> Elevate over Existing Rail through Denver (same alignment as 220-Electric Rail)

<u>OPTION 2:</u> Bypass Option uses E-470 around Denver and I-70 corridor to the east

Exhibit 10-15: I-25 North Risk Analysis Routes

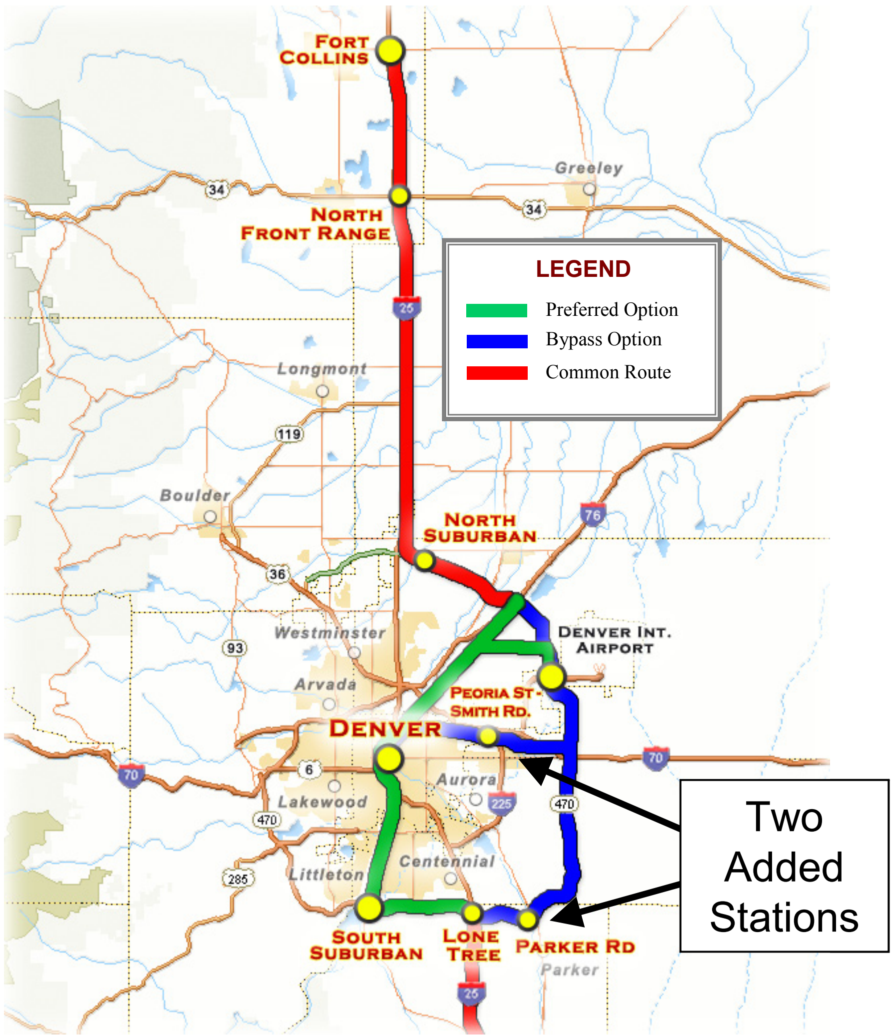


Exhibit 10-16: I-25 South Risk Analysis Routes

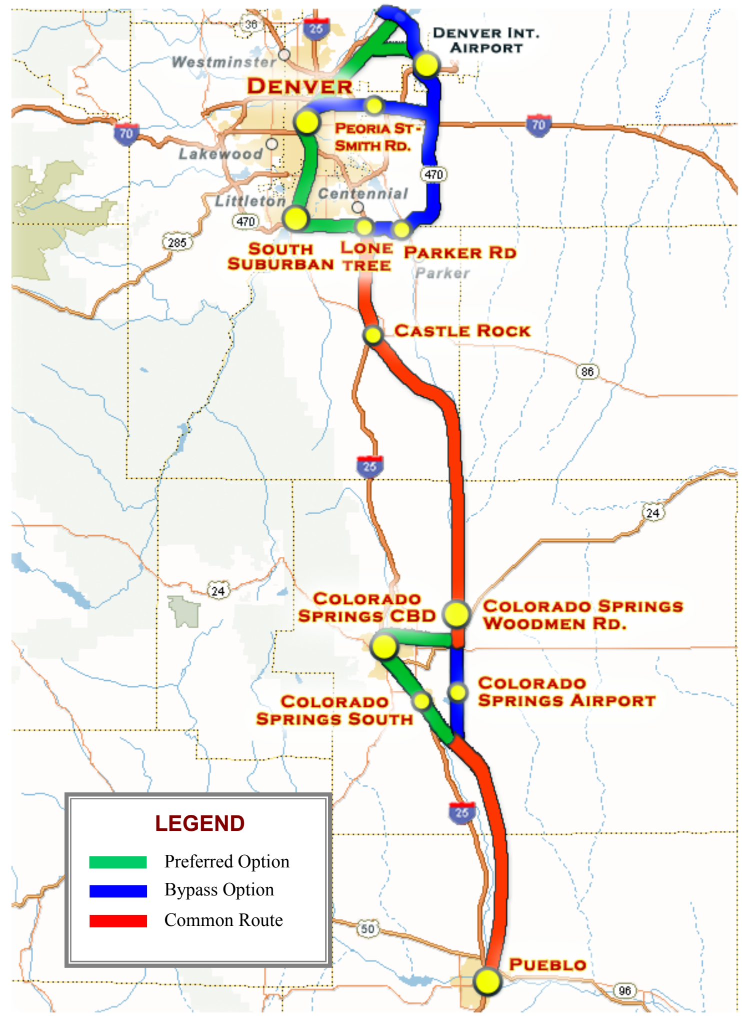


Exhibit 10-17: I-70 West Risk Analysis Routes

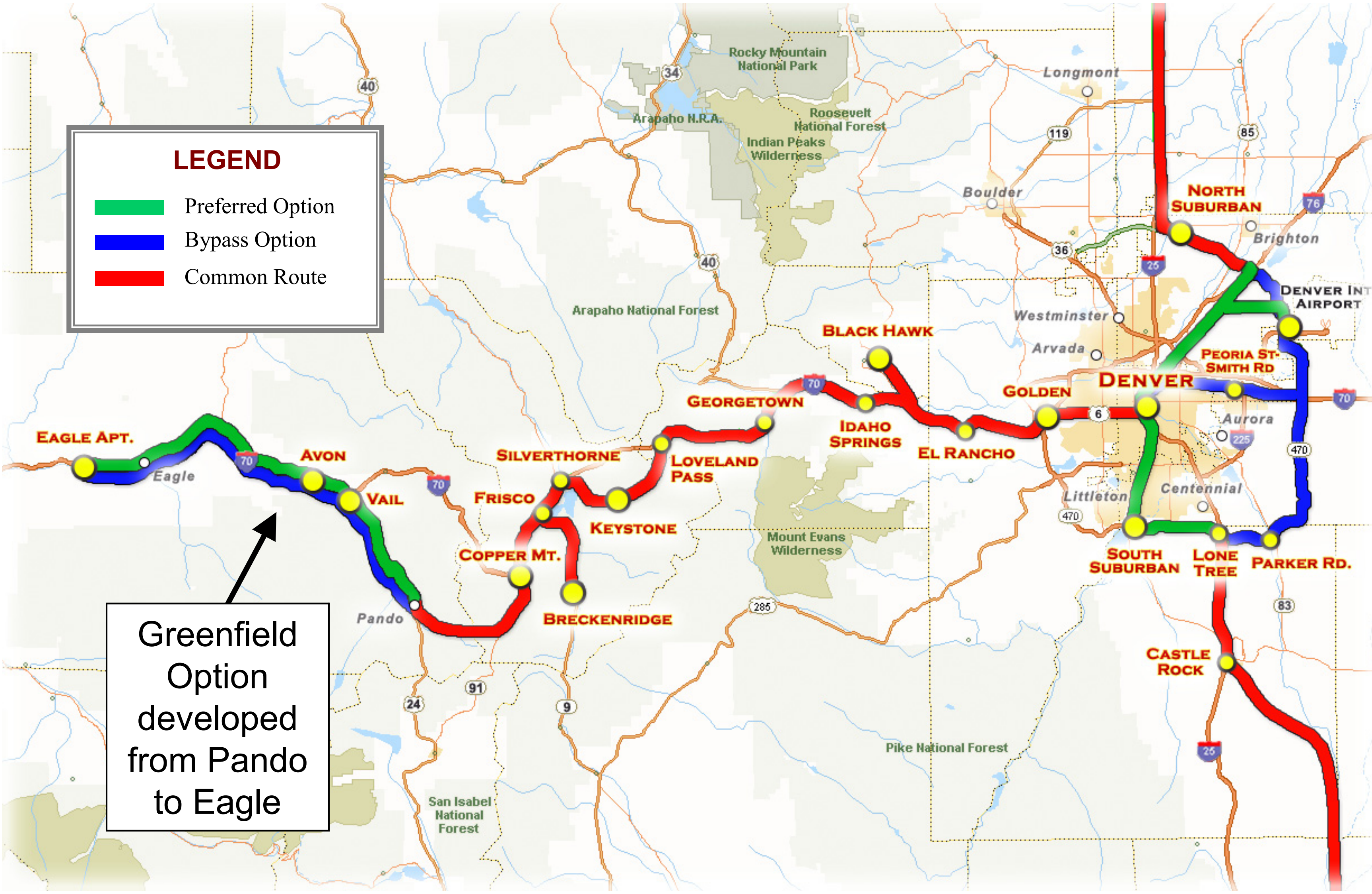
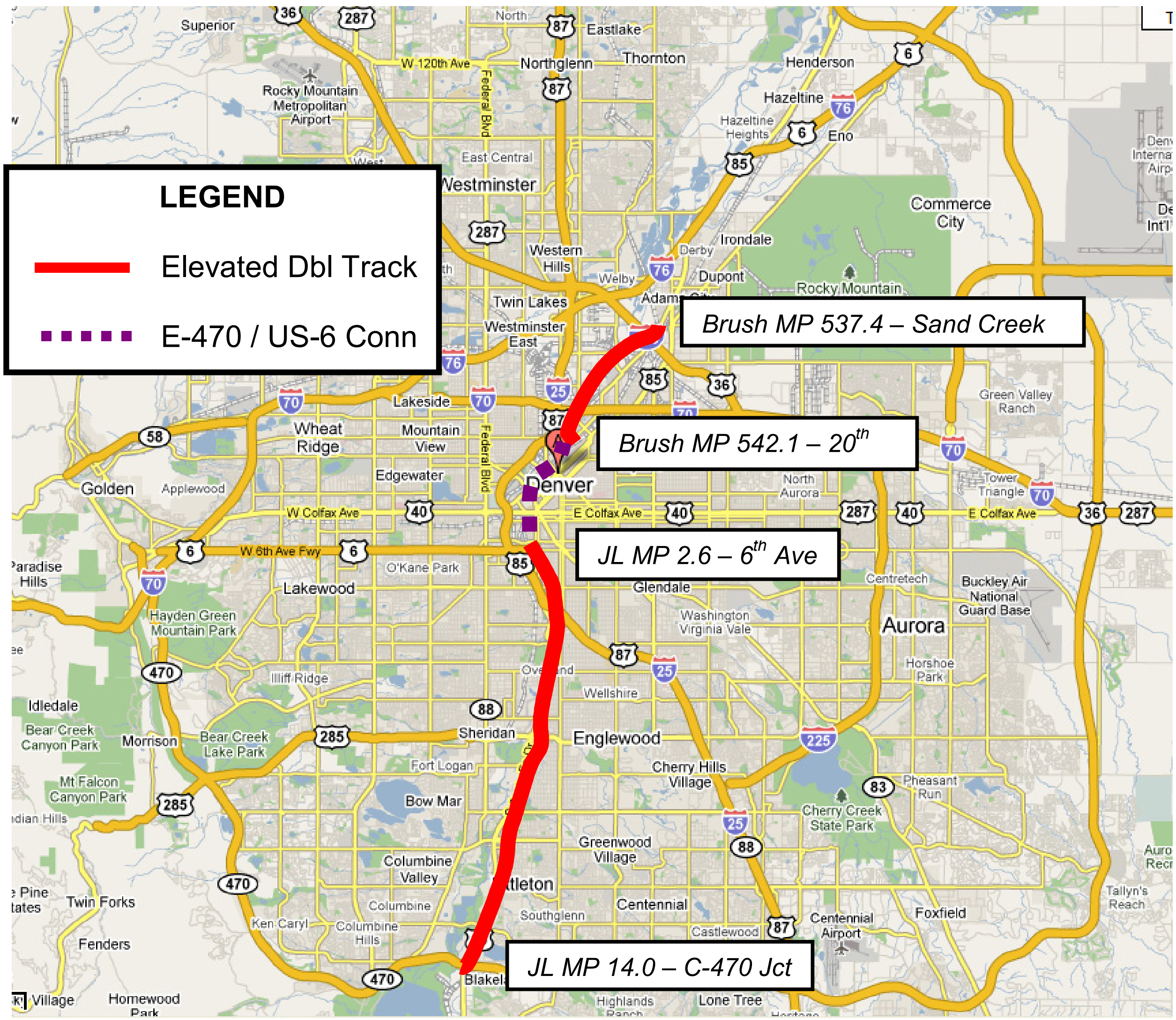


Exhibit 10-18: Option 1 Elevated Option for Denver



However, it may be that this elevation is not necessary. BNSF Railway reviewed the Joint Line sharing plan that was presented to the RMRA Steering Committee on Feb 27, 2009 and agreed to the conceptual feasibility of adding at-grade tracks in the Joint and Brush Line corridors. They felt the plan was a reasonable starting point, and saw value in the additional separation this plan would provide between freight and LRT operations. Since sharing the Joint Line corridor at-grade still remains a distinct possibility, access to the rail corridor may be negotiated at a cost much less than the cost of the elevated structure.

10.6.1 Infrastructure Mileage Comparison

- **220-mph Electric Rail:** From Lone Tree to the E-470 / I-25 interchange the distance is 9 miles of greenfield plus 30 miles of existing rail alignment. The DIA spur adds 12 miles, but 4 miles from downtown Denver to the US-6 interchange are shared with the Bypass alignment, so the total mileage of track that could be eliminated by the bypass alignment is 9 + 30 + 12 – 4 = 47 miles.
- **Bypass Option:** From Lone Tree to the E-470 / I-25 interchange the distance is 29 miles. From the E-470 / I-70 interchange to downtown Denver via Peoria Street is 15 miles, so the total mileage of additional track required by the Bypass is 44 miles. A branch line to the DIA terminal would add 4 more miles, so it can be seen that the length of the two Denver metro options are practically equivalent. However, the Colorado Springs Bypass is 6 miles shorter than the existing rail line through downtown.
- **I-70 West:** A greenfield alignment from Pando to Eagle Airport may offer an opportunity to improve the route geometry, but the total length of this segment has been assumed to remain the same.

10.6.2 Station Comparisons

In developing the Denver Bypass, downtown Denver (DUS) continues to be served in all options. However, several new station locations have been developed to serve local markets:

- An Aurora station was added at Peoria Street and Smith Road, near the I-225 / I-70 highway interchange. This station would serve a highly populated area, and would also provide Light Rail connectivity to the Denver Tech Center via the I-225 corridor. Adding this stop fills a "gap" in the area coverage of the high-speed rail system, significantly improving network accessibility in east Denver.
- A new station was also added at Parker Road along the E-470 to replace the South Suburban station at Littleton. This gain and loss roughly balance one another.

The Colorado Springs stations were moved to suburban locations at Woodmen Road and the airport. Access to some zones that were formerly associated with the downtown station are now more convenient to the airport station. The greenfield alignment around Colorado Springs (with two station stops) saves 6 miles and 8 minutes compared to the route via downtown, resulting in faster service to all points north. As a result, traffic at the airport increased in the Bypass option compared to the former South Colorado Springs station; while Woodmen Road stop had slightly less traffic than the former downtown station. The total ridership and revenue generated by the two Colorado Springs stations remained about the same in either alternative.

For the DIA station, the 220-mph Electric Rail Alternative assumed a 12-mile long stub-end branch line to the airport. The DIA station would be co-located with the RTD East Line station adjoining the main airport terminal building. This would provide the most seamless transfer for passengers arriving DIA.

In the Bypass option however, the E-470 highway passes about four miles to the west of the DIA terminal, so a station could be located either in the vicinity of the E-470 / Pena Blvd interchange, or else a 4-mile branch line connecting to the airport terminal could be built. Because the length of the branch line is reduced from 12 miles to just 4 miles in the Bypass option, direct airport access is actually easier to provide than before.

Since the option of providing direct rail service to the airport terminal still exists, for consistency with the earlier estimates Bypass Option ridership projections are based on direct service to the airport terminal and train-running times include an allowance for airport access. If the DIA station were located at E-470 / Pena Boulevard the Bypass would be shortened by 8 miles and 10-15 minutes, but the forecast would have to be adjusted because of the need for a transfer and connection time from the airport terminal to the train station. A more detailed evaluation should be conducted in a later study phase when more information on the possible DIA station options becomes available.

10.6.3 Running Time and Mileage Comparison – Preferred vs. Bypass Options

Because this work was performed only as a risk assessment and not a full route evaluation, detailed geometry for the E-470 Bypass alignments was not developed. Two options were developed as sensitivities on average commercial speed (with stops) of 60 mph and 90 mph. Exhibit 10-19 gives a time and distance comparison for the I-25 North corridor, while Exhibit 10-20 develops a similar comparison for I-25 South.

Exhibit 10-19: Time and Mileage Comparison – I-25 North Corridor

	Developed + OPT 1 Elevated			OPT 2 Bypass (90 mph) *			OPT 2 Bypass (60 mph) *		
Segment	Travel Time (min)	Distance (miles)	Avg Speed (mph)	Travel Time (min)	Distance (miles)	Avg Speed (mph)	Travel Time (min)	Distance (miles)	Avg Speed (mph)
North Suburban - Denver	14	24	103	30	46	92	44	46	63
DIA-Denver	13	23	106	17	26	92	24	26	65
North Suburban - DIA	27	47	104	13	20	92	20	20	60

Exhibit 10-20: Time and Mileage Comparison – I-25 South Corridor

	Developed + OPT 1 Elevated			OPT 2 Bypass (90 mph) *			OPT 2 Bypass (60mph) *		
Segment	Travel Time (min)	Distance (miles)	Avg Speed (mph)	Travel Time (min)	Distance (miles)	Avg Speed (mph)	Travel Time (min)	Distance (miles)	Avg Speed (mph)
Lone Tree - Denver	13	23	106	26	40	92	33	40	73
Lone Tree - DIA	26	46	106	19	28	88	26	28	65
Lone Tree - North Suburban	27	47	104	32	48	90	46	48	63
Pueblo-Lone Tree	59	98	100	51	92	108	51	92	108

KEY

Better (green)

Worse (red)

In general, the impact of using Bypass routes is to improve access to DIA at the expense of access to downtown Denver and the I-70 corridor. However, the adverse impact of added travel time to Denver and I-70 is at least partially mitigated by the additional ridership generated by the Aurora station at Peoria Street and Smith Road. Specifically:

- From I-25 North to Denver and the I-70 corridor (as shown by the North Suburban to Denver result in Exhibit 10-19) the bypass adds 22 miles and 15-30 minutes. (These times are sufficient to allow the trains to access the DIA terminal on a 4-mile branch line.)
- The Bypass significantly shortens the time and distance from I-25 North stations to DIA, since it puts DIA directly on the through route to Fort Collins. The FRA Developed Option does not provide direct rail service from Suburban North to DIA, and assumes DIA riders must either take a shuttle bus from Suburban North or change trains in downtown Denver. The savings is 27 miles and 27-34 minutes.
- From DIA to downtown Denver, the Bypass via Peoria Street and Smith Road is only 3 miles longer than the original route that loops around the north end of the Rocky Mountain Wildlife Refuge. From DIA to downtown Denver, the Bypass takes 4-13 minutes longer than the 220-mph Electric Rail option, depending on the speed of the Bypass.
- From I-25 South to downtown Denver and I-70 (as shown by the Lone Tree to Denver result) the Bypass adds 17 miles and 13-20 minutes to the trip. This is partially offset by the 6 mile and 8 minute savings from the Colorado Springs shortcut. Even so, it still takes longer to use the Bypass to get from I-25 South to downtown Denver and the I-70 corridor.
- From Lone Tree to DIA, the Bypass via E-470 saves 18 miles but only 7 minutes, due to the 90-mph average commercial speed that was assumed for the E-470 routing and the good geometry of the rail lines via downtown Denver.
- For north-to-south travel from Lone Tree to North Suburban, the Bypass is shorter than going through downtown. If however a diversion via the airport were included in the train schedule, the bypass would actually be a mile longer than going through downtown, and the schedule would take 5-19 minutes longer.

In summary:

- Bypass options improve access to DIA, particularly from the north, and they add an important Aurora station at Peoria Street and Smith Road.
- Bypass options lengthen travel times from I-25 North to downtown Denver and the I-70 corridor by 15-30 minutes.
- Bypass options lengthen travel times from I-25 South to downtown Denver and the I-70 corridor by 5-12 minutes. From the south, the time and mileage impact associated with the bypass are partially offset by the Colorado Springs shortcut.
- The travel time impact on north-south (e.g. Pueblo to Fort Collins) or east-west (e.g. Vail to DIA) travel time via either option is negligible. If, however, a diversion via the DIA terminal were included, a Pueblo to Fort Collins trip via the Bypass would take longer than the more direct routing via downtown Denver.

10.6.4 Bypass Options: Revenue and Ridership Performance

Exhibit 10-21 summarizes the forecast Revenue and Ridership of the two Bypass variants relative to the original 220-mph Electric Rail Alternative, which is treated as the base case for comparison. Exhibit 10-18 shows the ridership impact of each Bypass variant by corridor[4].

Exhibit 10-21: 2035 Revenue and Ridership Performance of Bypass Options (Millions of $2008)

Option	Ridership	Ridership % of FRA Developed Option	Consumer Surplus	Revenue	Passenger Miles (Millions)
Developed + Opt 1	34,186,288	100%	$811.57	$807.56	2,494
OPT 2 Bypass (60 mph)	32,368,990	95%	$758.68	$804.78	2,453
OPT 2 Bypass (90 mph	35,504,284	104%	$866.46	$918.85	2,684

Exhibit 10-22: 2035 Corridor Impact of Bypass Options

Option	I-70 West	I-25 North	I-25 South
OPT 2 Bypass (60 mph)	90%	110%	98%
OPT 2 Bypass (90 mph	96%	124%	106%

Regardless of speed, the Bypass worsens I-70 and downtown Denver connectivity to I-25 both North and South. However, it puts DIA directly on the I-25 North corridor, and adds a strong Aurora station at the I-70 / I-225 Junction.

Exhibits 10-21 and 10-22 show that the result is highly sensitive to the quality of the Bypass:

- A 60-mph Bypass would result in an overall 5 percent *decrease* in ridership and revenue, with a 10 percent reduction on the I-70 corridor, due to the added time.
- A 90-mph Bypass would *improve* ridership and revenue by about 4 percent even though I-70 ridership would be reduced by about 4 percent. This is due to increased ridership from the new Peoria Street/Smith Road station and better DIA connectivity outweighing the negative impact of the more circuitous Bypass option.

[4] Ridership is measured at key segments north, south and west of Denver. For I-70 West, Loveland Pass to Keystone ridership is used; for I-25 North the metric is the North Front Range to North Suburban segment, and for I-25 South, Lone Tree to Castle Rock ridership is taken as the measure of corridor impact.

At the individual corridor level as shown in Exhibit 10-22:

- **I-25 North:** The effect of adding DIA connectivity and the new station at Peoria Street and Smith Road is *very positive* for the I-25 North corridor. The Peoria Street and Smith Road station provides access not only to Aurora but also to the entire I-225 corridor, including the Denver Tech Center, via the Light Rail connection. Adding these stations is beneficial to the I-25 North ridership, even for the low-speed 60-mph Bypass option.
- **I-25 South:** The I-25 South corridor has *mixed results*. A 60-mph Bypass degrades ridership in spite of new stations. However, a 90-mph Bypass would improve I-25 South ridership, since the benefit of the added Peoria Street and Smith Road station now outweighs the added travel time cost.
- **I-70 West:** The result for the I-70 corridor and downtown Denver is *always negative*. While the Peoria Street station does attract more I-70 trips, the suppression of travel demand from all I-25 corridor stations results in a net loss to I-70. Express trains that skip stops and ensuring the Bypass alignment is built to the highest geometric standard could help at least partially mitigate this adverse impact on I-70.

While the Bypass option clearly adds value to the I-25 North corridor, the case for the Bypass from I-25 South is weaker:

- The I-25 South corridor already has good access to Denver Tech Center and the I-225 corridor from its Light Rail connection at Lone Tree. The Peoria Street and Smith Road station does not add as much value to I-25 South as it does to I-25 North.
- The Bypass network requires dividing I-25 South train frequencies between DIA and downtown Denver. Accordingly it is not possible to provide as many trains from the south to DIA as would be possible if downtown Denver and DIA were combined onto a single line.
- The Bypass network adds significant time and mileage to the I-70 West connection, suppressing connecting ridership and revenue.

Consideration of a "Hybrid" option that uses the Joint Line from the South with the Bypass alignment to the north may produce an even better outcome. Doing this would improve I-70 connectivity to I-25 south and put DIA on the same line with downtown Denver, avoiding the need to split the I-25 South train frequencies. At the same time, it would still retain the benefits of the added Peoria Street station and DIA connectivity for the I-25 north corridor.

10.6.5 Risk Analysis Capital Costs

Exhibit 10-23 shows the ranges of Capital Costs that were developed on a segment basis for development of the Risk Analysis. The costs associated with the Dashed line segments are those that were developed for the original 220-mph Electric Rail Alternative. In contrast, costs developed for the Bypass and other risk segments have been expressed as a range, with the Central Value highlighted.

Adding up the individual segment totals, Capital Costs (for the central case projection, from Lone Tree to the Brush Line and E-470) have been estimated as follows:

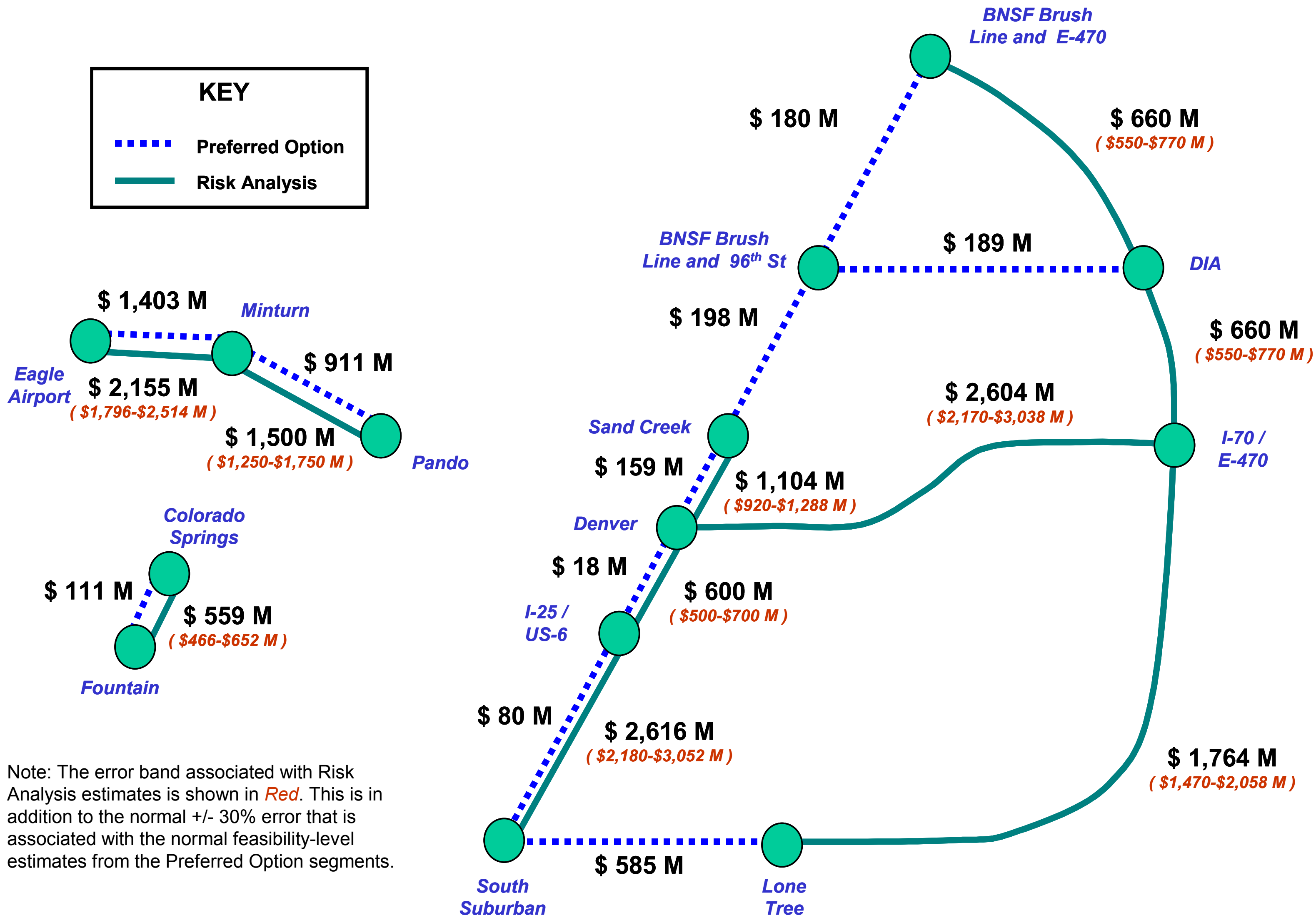
- Denver infrastructure for the 220-mph Electric Rail Alternative (at grade) is *$1.409 Billion*
- Denver infrastructure for the 220-mph Electric Rail Alternative (elevated over shared rail segments) is *$5.482 Billion*
- Denver infrastructure for the Bypass Option is *$6.288 Billion*

According to these calculations, the Bypass option is more expensive than elevating over the existing rail through downtown Denver; however, this conclusion is largely driven by the high cost for the entirely elevated I-70 / E-470 to downtown Denver segment, which at $2.604 Billion would cost nearly as much as elevating over the Joint Line at $2.616 Billion.

If any portion of this East corridor alignment could in fact be brought down to grade level, it is possible that this cost may be reduced. At the same time, as has already been discussed there may also be an opportunity for substantially reducing costs for Joint Line access by coordinating with BNSF Railway. It is recommended to continue working with both BNSF and UP Railroads in an effort to develop the most cost effective access possible to downtown Denver, whether by the Joint Line, East corridor, or even possibly both.

Exhibit 10-23 shows that the capital cost of the Pando to Minturn segment would increase from $911 million for improving the existing rail line, up to $1,500 million for a new alignment. While a new alignment would offer an opportunity for improving the geometry, if the existing rail line cannot be used on this segment then Tennessee Pass may actually be more expensive than a Vail Pass routing. If a lower gradient 4% alignment across Vail Pass could be identified, then Vail Pass could more effectively compete with the Tennessee Pass alignment that was assumed in the FRA Developed Option. The issues associated with development of either option require detailed engineering, and should be further explored in the context of a future environmental study.

Exhibit 10-23: Risk Analysis Capital Costs



Note: The error band associated with Risk Analysis estimates is shown in *Red*. This is in addition to the normal +/- 30% error that is associated with the normal feasibility-level estimates from the Preferred Option segments.

10.6.6 Non Compliant Equipment Savings

The current assumption for the 220-mph Electric Rail Alternative is that it would employ very powerful trains capable of climbing 7 percent mountain grades and that the trains could also be made FRA-compliant for sharing freight rights-of-way in urban areas. As compared to current European off-the-shelf train designs this would require some customization or modification of existing trains in order to meet a Colorado performance specification. However, there could be an opportunity for cost-savings if either the 7 percent grade-climbing or FRA compliance specification requirements could be relaxed.

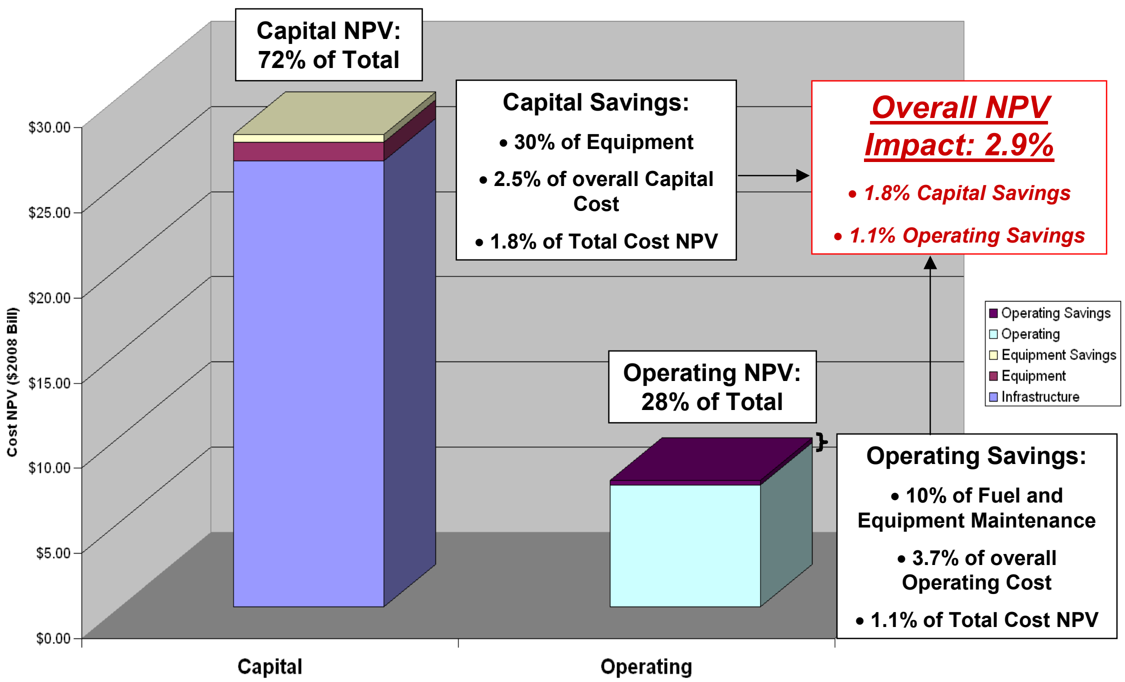
In our discussions with European train manufacturers, it seemed that the 7 percent grade-climbing capability could readily be achieved simply by adding more power to the train. The simplest approach for doing this would simply be to add power cars (such as TGV locomotives) onto the front and back of existing European high-speed trains. Although this solution would entail an added cost for the power cars, from a technical point of view it was not considered difficult, nor would adding power cars require significant changes to the train designs.

In contrast, European train manufacturers were much more reticent to discuss the issue of FRA buff strength compliance, because this could require significant changes to the structural designs of their trains. It is important to keep a balanced perspective on this issue, because the answer depends upon whom one talks to. For example, Bombardier, a domestic manufacturer already has an off-the-shelf FRA Tier II compliant train, so for them the need for FRA compliance is not an issue. But in the interests of facilitating competitive equipment procurement, it is important to respect the views of the European manufacturers by making an appropriate allowance for Engineering design changes in the equipment cost.

For the purpose of this analysis, it was assumed that a 30 percent reduction in Equipment capital cost could be obtained if off-the-shelf European train designs were employed without modification (except for possible addition of power cars.) An additional 10 percent savings in energy and equipment maintenance cost were assumed because of the 10 percent weight penalty that was assumed for FRA-compliant trains.

The results of this calculation are summarized in Exhibit 10-24 and show that most of the anticipated savings would come from the equipment Capital cost. This is because Capital cost comprises 72 percent of the Net Present Value (NPV) total costs in the Cost Benefit calculation; Operating Costs NPV comprise only the remaining 28 percent of total costs. It was estimated that the operation of Non Compliant equipment could reduce the cost NPV by an overall 2.9 percent resulting in a corresponding improvement in the Cost Benefit ratios. However, while they do provide some offset to the added costs, these savings in equipment Capital and Operating Cost are not sufficient to outweigh the additional infrastructure cost associated with extensive elevated structures.

Exhibit 10-24: Non Compliant Equipment Cost Savings

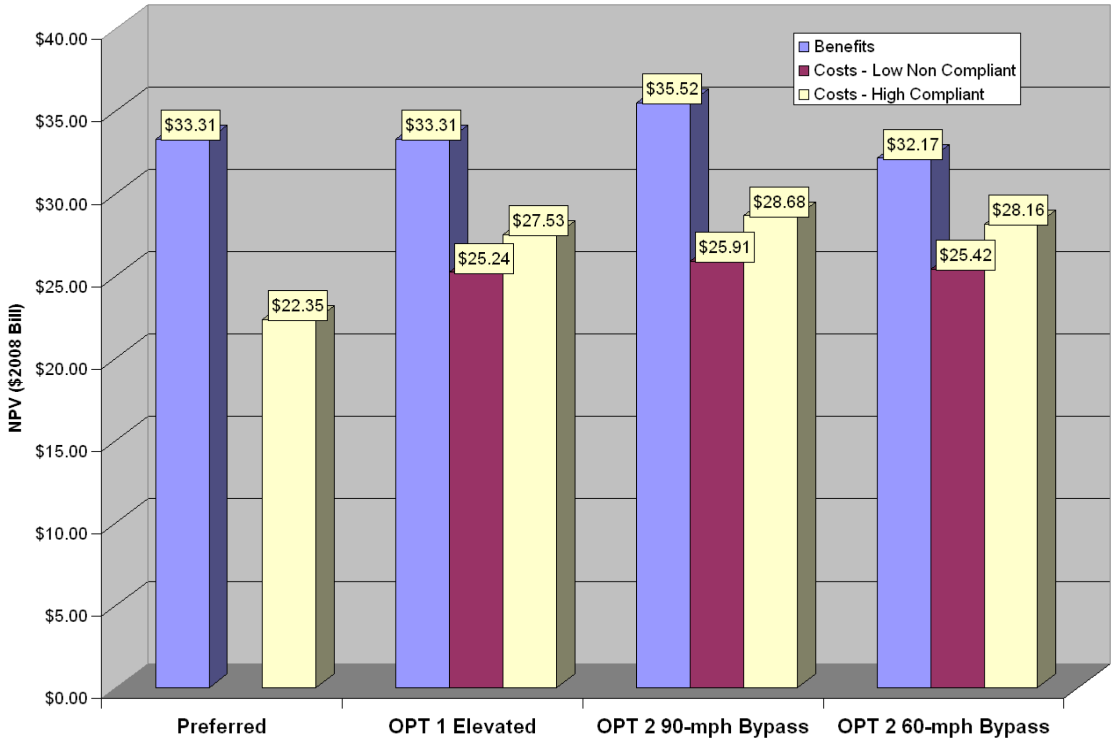


10.6.7 Economic Results

Exhibit 10-25 shows the Economic results for each alternative, in terms of a Best Case/Worst Case analysis. The results of the 220-mph Electric Rail Alternative are shown as a base for comparison. The Best Case assumes Low Capital Costs, with high-speed (90 mph average) on the bypass using non-compliant Equipment. The Worst Case assumes High Capital Costs, with low speed (60 mph average) on the bypass using Compliant Equipment.

It can be seen that the Benefits for the 90-mph Bypass are actually higher than for the 220-mph Electric Rail Alternative, implying that the addition of the Peoria Street and Smith Road station is worthwhile, even if that alignment proves to be more expensive than the alternative DIA routing along the north side of the wildlife refuge. It could in fact, be worth as much as $2.21 Billion (the increase in Benefits NPV from $33.31 Billion to $35.52 Billion.) But the elevated segment from I-70 / E-470 to downtown Denver costs $2.604 Billion, which is more than the benefits of adding the segment. Nonetheless, the Peoria Street and Smith Road station could be a valuable addition to the network if either the cost of the East corridor could be reduced, or if alternative access to the Joint Line were foreclosed.

Exhibit 10-25: Economic Results: Best/Worst Case NPVs



Converting the results from Exhibit 10-25 into ratios (for example, $33.31 / $22.35 = 1.49 Cost Benefit ratio for the 220-mph Electric Rail Alternative) the results of all scenarios are summarized in Exhibit 10-26. In addition, since the geometry for the E-470 bypass is not available and the speed capabilities are still uncertain, the ranges for the two Bypass Option speeds have been combined to develop an overall Best Case/Worst Case analysis. This shows that the Cost Benefit ratio for the Bypass option could range from 1.14 up to 1.37, depending on the exact final cost and configuration of the Bypass.

Exhibit 10-26: Economic Results: Best/Worst Case Cost Benefit Ratios

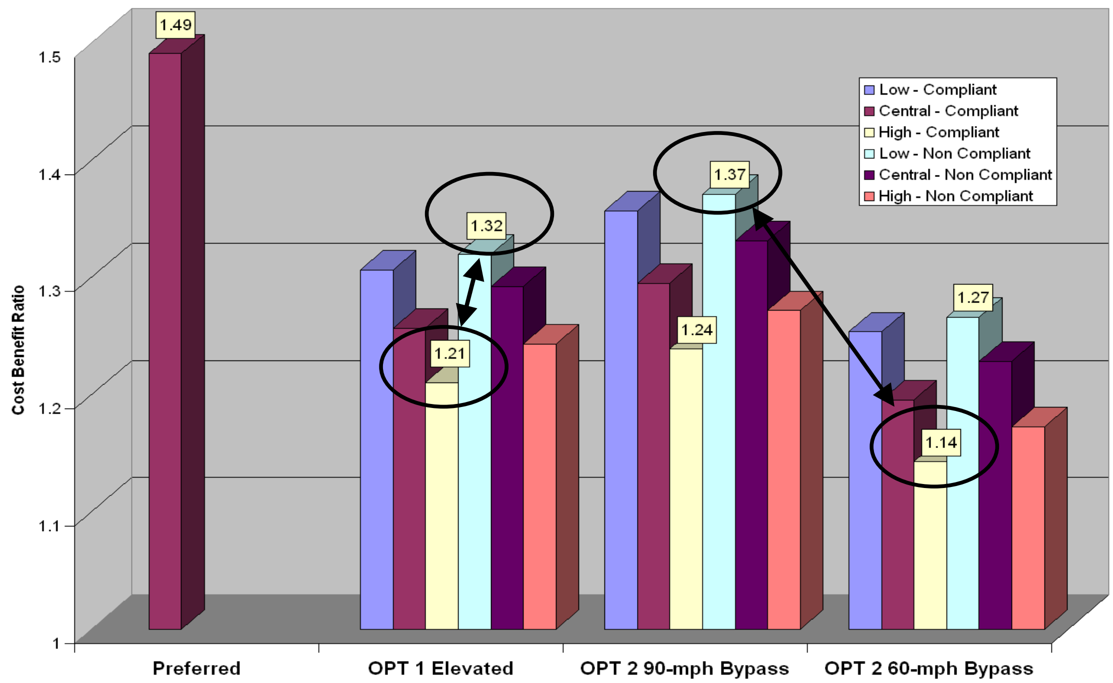
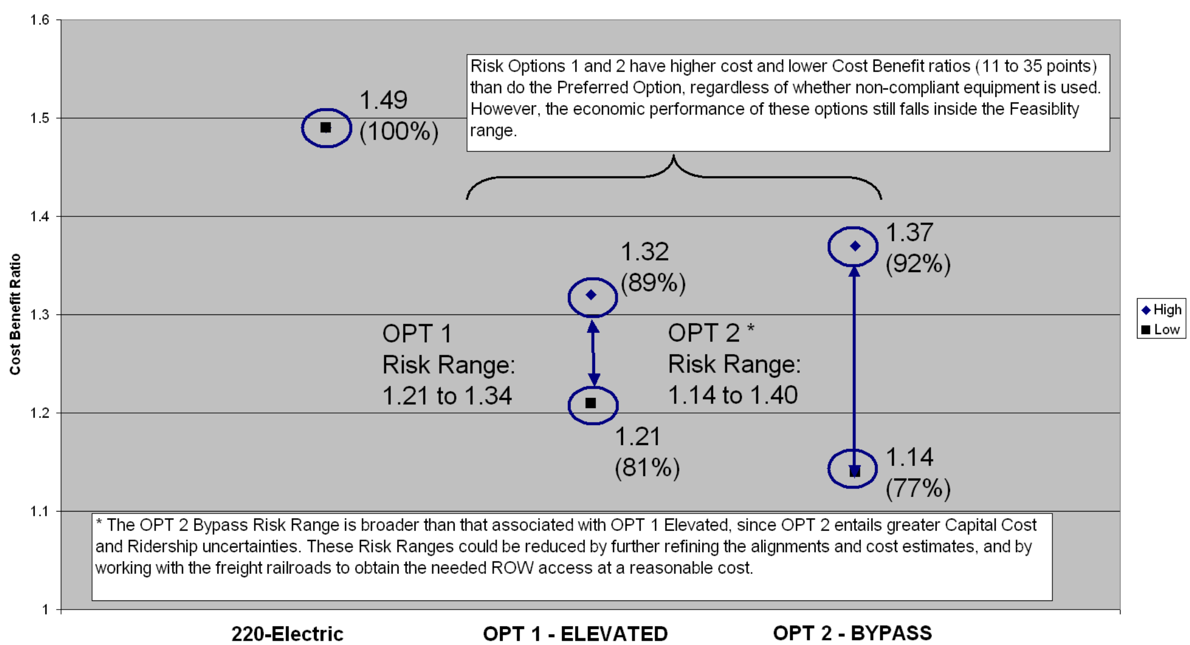


Exhibit 10-27 summarizes these results for each option, showing that the downside risk is 8-23 percent on the Cost Benefit ratio. All the Risk Options are still viable, but they produce lower Cost Benefit ratios than the original 220-mph Electric Rail Option.

Exhibit 10-27: Economic Cost Benefit Range Results



In Exhibit 10-27, it can be seen that the Bypass results have a greater error margin than does the Elevated option. This is because of the added uncertainty related to the operating speed of the Bypass. This uncertainty could be eliminated by developing a representative geometry for the E-470 Bypass, comparable to what has already been done for other segments of greenfield alignment that have been assessed by this study (such as I-70 West and I-25 North and South.) Additional work could also narrow the range of engineering costs, which would hopefully improve the worst case (1.14) result of this Risk analysis.

10.6.8 Risk Analysis Conclusions

All the Risk Options are still viable, but they produce lower Cost Benefit ratios than the original 220-mph Electric Rail Option. The downside risk is 8-23 percent on the Cost Benefit ratio.

Routing the DIA line via Peoria Street / Smith Road station would be a definite plus, but its economic and construction feasibility depends on resolving potential Right-of-Way conflicts with Union Pacific Railroad and the RTD East Corridor. Through routing service via DIA is beneficial to the I-25 North corridor, but if the airport terminal is not served directly, this gain must be traded off against any detrimental impact on DIA ridership and revenue. The tradeoffs on how to best route intercity service to or past DIA, as well as how to coordinate such services with the planned RTD East Corridor are very complicated. It is suggested that they be the subject of a detailed study in the future.

In conjunction with the greenfield option, an east suburban Colorado Springs station, such as the proposed location at Woodmen Road instead of downtown Colorado Springs, maintains ridership.

It should be noted that all Risk Analysis options have included a station in downtown Denver. However, the options using E-470 via Parker rather than the Joint Line from Littleton for access from the south, impose a circuitry penalty for access to downtown Denver. In addition, such options make rail operations more complex since the same train can no longer serve both downtown Denver and DIA without backtracking. Most likely separate trains would have to be operated to each destination. The efficiencies gained by being able to serve both stations from a single line, without a branch line that requires splitting the train frequencies, would be especially important in Phase I of the implementation plan (see Exhibit 10-1) that launches a startup service to Colorado Springs.

Nonetheless, the risk analysis has found that if a rail line along E-470 can be built with good geometry permitting high operating speeds and limited local stops, and if Right-of-Way access can be gained from E-470 / I-70 to downtown Denver at a reasonable cost, then the E-470 Bypass option could produce satisfactory economics and performance. This system would operate most effectively only if downtown Denver were served as part of the through route to I-70, which supports a sufficient level of train frequencies. If the I-70 corridor is not extended west of Denver it may be difficult to support an adequate level of service frequency if downtown Denver is basically relegated to the end of a branch line. For this reason, a Hybrid option utilizing the Joint Line for access from I-25 South along with direct service to DIA on the north might do even better than either of the options evaluated here. It is recommended that this be considered in a future study.

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11 Funding Alternatives

Implementation of the RMRA FRA Developed Option will require the state to develop a financing plan to fund the required capital costs. This plan will require a commitment from the state and the counties participating in the RMRA rail system with regard to institutional arrangements and funding process. Funding is available from a broad range of transportation programs, but will require a coordinated effort to identify all the relevant potential sources and pursue funding.

Many innovative financing concepts for transportation projects are available at state and local levels throughout the U.S. These projects include privatization or turnkey operations (i.e., design-build-operate projects), public-private partnerships, incorporating federal funds and federal credit enhancements in state and local projects, and establishing state infrastructure banks. In addition, bond issuance and leasing are options for increasing or leveraging funds to finance the required state contributions.

11.1 Federal Funding Programs

As of the time of preparing this report, there are a number of Federal programs that have been developed by the Federal Railroad Administration (FRA) over the last ten years to fund research, planning and corridor development. Many of these programs originated with the Intermodal Surface Transportation and Efficiency Act (ISTEA), and the Swift Rail Development Act. The ISTEA legislation was signed into law in June 1991, but has now been superseded by the "Passenger Rail Investment and Improvement Act of 2008". PRIAA provides grants of $1.9 billion for intercity rail and $1.5 billion for high-speed rail (i.e., trains that can reasonably be expected to reach speeds of 110 mph). Potential expenditures include "inquiring, constructing, improving or inspecting equipment, track and track structures."

11.1.1 Passenger Rail Investment and Improvement Act of 2008

High-Speed Rail Development ($1.5 Billion)[1] - From 2009 to 2013 $300 million will be made available each year for three years for the eleven existing authorized corridors, and will be available to Colorado if it achieves high-speed rail designation. Grants will cover 80 percent of project costs and need 20 percent local match. Funds are awarded competitively based on economic performance, ridership, and other social factors.

Intercity Passenger Rail Development ($1.9 Billion) - Each year (2009-2013) a state may apply for grants from the $380 million available. Grants can cover 80 percent of the capital costs of facilities and equipment necessary to provide new or improved passenger rail. Again, selection is

[1] This provision under Passenger Rail Investment and Improvement Act (PRIAA) is not to be confused with Intercity Passenger Rail Services grants under American Recovery and Reinvestment Act (ARRA), which have no similar speed restrictions.

competitive and based on economic performance, ridership and social factors. The grants are only available for speeds of 110 mph and up (i.e., not commuter rail), and recipients are subject to Buy America requirements.

11.1.2 American Recovery and Reinvestment Act: Capital Assistance for High Speed Rail Corridors and Intercity Passenger Rail Service (ARRA)

The Passenger Rail Investment and Improvement Act of 2008 has been supplemented by the American Recovery and Reinvestment Act (ARRA), which provides $8 billion in grants for passenger rail services capable of 110 mph for acquiring, constructing, improving or inspecting equipment, track, and track structures. The funds will be available through September 30, 2012. The funds will be distributed through three types of competitive grant programs:

1. High-Speed Rail (i.e., greater than 110 mph) grants for infrastructure and equipment to states, Amtrak, and public agencies
2. Intercity Passenger Rail Service - grants for rehabilitation of rolling stock and facilities to states, Amtrak, and public agencies
3. Congestion Relief - states and Amtrak can apply for grants to increase capacity and facilitate rail ridership.

Projects need to be included in state rail plans, and can achieve up to 100 percent grants (under track 2) for project costs (this includes EIS and preliminary engineering, but not train operating costs). Projects are subject to "Davis Bacon" wage rate and "Buy America" requirements.

11.2 Federal Credit Programs

The Transportation Equity Act for the 21st Century (TEA-21) created two credit programs to assist in funding passenger and high-speed rail projects. These programs include Rail Passenger Eligibility under the Transportation Infrastructure Finance and Innovation Act (TIFIA) and Railroad Rehabilitation and Improvement Financing (RRIF). The strategic goal under both programs is the use of credit rather than grants to help advance projects of national significance. As such, funding under the programs are loans and must be repaid.

11.2.1 Transportation Infrastructure Finance and Innovation Act

TIFIA provides federal assistance in the form of credit, rather than grants, to help fund major transportation investments of critical regional or national importance. The TIFIA credit program is designed to fill funding gaps and leverage substantial private co-investment by providing supplemental and subordinate capital in the form of long-term loans. A critical role for TIFIA loans is to pay for start-up costs, and ramp up losses for an otherwise "profitable" project.

The TIFIA credit program consists of three different types of financial assistance designed to address varying requirements throughout the project life cycle:

- *Secured loans* are direct federal loans to project sponsors offering flexible repayment terms. These provide combined construction and permanent financing of capital costs. The interest rate is "not less than" the yield on marketable Treasury securities of similar maturity on the execution date of the loan agreement.

- *Loan guarantees* ensure a federal government full-faith-and-credit guarantee to institutional investors making a loan to a project.
- *Standby lines of credit* represent secondary sources of funding in the form of contingent federal loans that may be drawn upon to supplement project resources (if needed) during the first ten years of project operations.

Projects eligible for federal financial assistance under surface transportation programs (Title 23 or Chapter 53 of Title 49) are eligible for the TIFIA program. In addition, projects of regional or national significance, such as inter-city passenger rail facilities and vehicles (including Amtrak and magnetic levitation systems), publicly-owned intermodal freight facilities on the National Highway system, border crossing infrastructure, and other large infrastructure projects, could also qualify under the TIFIA umbrella. The RMRA rail proposal is the type of project that would meet TIFIA eligibility requirements.

The U.S. Secretary of Transportation has developed criteria to guide the selection of TIFIA-candidate projects. These criteria include:

- The extent to which the project is nationally or regionally significant in terms of generating economic benefits, supporting international commerce, or otherwise enhancing the national transportation system.
- The creditworthiness of the project, including a determination by the Secretary that any project financing has appropriate security features (i.e., rate covenant) to ensure repayment.
- The extent to which the project will foster innovative public-private partnerships and attract private debt or equity investment.
- The likelihood that assistance would enable the project to proceed at an earlier date than the project would otherwise be able to proceed.
- The extent to which the project uses new technologies, including Intelligent Transportation Systems (ITS), that enhance the efficiency of the project.
- The amount of budget authority required to fund the federal credit instrument.
- The extent to which the project helps to maintain or protect the environment.
- The extent to which assistance would reduce the federal grant contribution to the project.

Investment funds may be provided by a corporation, joint venture, partnership, or governmental entity. The amount of federal credit assistance may not exceed 33 percent of total project costs. The Secretary must require each project applicant to provide a preliminary rating opinion letter from at least one rating agency indicating that the project's senior obligations have the potential to achieve an investment-grade rating.

The secured TIFIA loan must be payable, in whole or in part, from tolls, user fees, or other dedicated revenue sources; and include a rate covenant, coverage requirement, or similar security feature supporting the project obligations; and may have a lien on revenues. The Secretary establishes a repayment schedule for each secured loan based on the projected cash flow from project revenues and other repayment sources. Scheduled repayments of principal or interest shall begin not later than 5 years after the date of substantial completion of the project, and the final maturity date of the secured loan shall be no later than 35 years after the date of the substantial completion of the project.

11.2.2 Railroad Rehabilitation and Improvement Financing (RRIF)

The Railroad Rehabilitation and Improvement Financing Program (Section 7203 of TEA-21) is intended to make funding available through loans and loan guarantees for railroad capital improvements. The FRA is authorized to provide direct loans and loan guarantees up to $35 billion. Loans have been made in the range of $20 million to $250 million. The R2C2 project would qualify under RRIF.

The U.S. Secretary of Transportation is authorized to provide direct loans and loan guarantees to state and local governments, government sponsored authorities and corporations, railroads, and joint ventures that include at least one railroad. Funds are to be used to acquire, improve, develop or rehabilitate intermodal or rail equipment or facilities, including track, bridges, yards and shops. The Secretary is to prioritize those projects that enhance public safety and the environment, promote economic development, enable U.S. companies to be more competitive in international markets, are endorsed in state and local transportation plans, or preserve/enhance rail or intermodal service to small communities or rural areas.

The Secretary is allowed to accept a commitment from a non-federal source to fund, in whole or in part, the required credit risk premium. Credit risk premiums fund the costs associated with a potential default on the loan/loan guarantee. Private commitments can be used in lieu of or in combination with any appropriations of federal funds for this purpose. The Secretary (in consultation with the Congressional Budget Office) determines the amount required for credit risk premiums for each loan/loan guarantee on the basis of the circumstances of the applicant, including collateral offered, the proposed schedule for disbursing the funds, historical data on the repayment history of similar borrowers, and any other relevant factors.

The term of any loan may not exceed 25 years; the assistance must be justified by the present and probable future demand for rail services or intermodal facilities; the applicant must provide reasonable assurance that the facilities or equipment to be acquired, rehabilitated or established will be economically and efficiently utilized; and the obligation must be reasonably expected to be repaid, taking into account an appropriate combination of credit risk premiums and borrower collateral.

11.3 State and Local Financing

Federal funding under the grant programs described above usually requires a minimum local match of 20 percent at the state and local levels. In addition, several provisions are included in TEA-21 that provide greater flexibility to states and local governments in satisfying the non-federal matching requirements of a project.

11.3.1 Delayed or Tapered State/Local Match

TEA-21 permits grantees to defer payment of the state/local share of transit projects. The Secretary may allow the federal share to vary up to 100 percent on individual progress payments on a project, as long as the final contribution of federal funds does not exceed the maximum federal share authorized for the project. The states may wish to delay the application of their matching funding, particularly if they are trying to maximize the use of available state/local funds. This could occur because the funds are invested in a short-term security, for example, or otherwise encumbered. However, there may also be a situation where the grantee is seeking to arrange construction period financing or some other innovative financing mechanism, which could be facilitated through an uneven expenditure of Federal and matching funds.

The USDOT grant process is generally based on a level outflow for a specific project. For example, for every 20 percent expended by the state/locality, 80 percent in federal funds are expended. Little value can be added to such a cash stream through the assistance of private capital markets. However, if the federal dollars are expended first (e.g., for 100 percent of the design, engineering or environmental reviews), then the construction period can be financed with some private participation. In this instance, state/local funds can be "banked" or pledged as additional security for the construction period financing. This is all possible because there are no arbitrage concerns with state/local funds as there might be with the federal funds. The benefit of a delayed state/local match is that it may help assure the smooth progress of a major transit infrastructure project without any increase in federal outlays.

11.3.2 Credit for Acquired Land

TEA-21 expands the law relating to donated property to also allow the fair market value of land lawfully obtained by the state or local government to be applied to the non-federal share of project costs. If Colorado purchases right-of-way for the high-speed rail project, that purchase would count to the local match.

11.3.3 Using Federal Funds as Match

For transportation enhancement projects, the states may apply funds from other federal agencies to the non-federal share of the project. For example, Economic Development Funds, Highway or Transit funds, even grade crossing improvement grants from FRA could be used to match federal rail grant funds.

11.3.4 Local Funding

Financial support for the system may also come from a wide variety of local and regional sources, which at present typically contribute a share of certain costs of surface transportation projects (e.g., freeway interchanges). In the case of the Colorado corridors, endorsement of local funding for station construction or improvements (e.g., part of an urban renewal or downtown development program) can be justified given the economic benefits that will accrue to new development in station areas because of the high level of ridership in the I-70 and I-25 corridors.

Local communities frequently encourage businesses to enhance station facilities activities such as commercial offices, convenience stores, restaurants, cafes, and in the case of larger stations, even hotels. In addition, some communities have used their stations as transportation multimodal hubs with integrated bus and taxi operations. For these reasons, it is likely that funding for station facilities could be obtained from local communities. Given the character of high-speed rail stations, these developments by local government and the private sector could easily provide the total local match needed for Federal Funds.

11.4 Private Sector Contributions

Private sector contributions may also be used to partially fund public works projects and can be used as non-federal matching funds. Private developers may be willing to provide cash and in-kind contributions to support transportation improvements from which they expect to benefit. Businesses and individuals may have a strong interest in promoting certain types of development and may be willing to contribute money, property, or services to enhance the feasibility of the project. Special benefits may accrue to private contributors in the form of projects sited near property owned by the developer, the creation of access points between the developer's property and the project, zoning concessions, development rights, or public recognition.

11.4.1 Joint Development

Joint development involves adjoining facilities shared by the public and private developers, such as a station adjoining office or retail space. Developers may be granted development rights for stations in exchange for contributions toward funding a transportation project. Contributions could include one-time payments toward the rail project or annual payments that can be applied to project costs or operating costs. Project viability depends on real estate market conditions and the ability of the public agency to provide necessary inducements for development. Inducements may include land, favorable zoning changes, lower financing costs, or improved public access to the developer's property.

11.4.2 Freight Railroads

Freight railroads will be major recipients of benefits because of infrastructure investments in track, signaling and rights-of-way. As a result, they may experience substantial productivity gains within their operations and significantly lower track maintenance and renewal. Therefore, the freight railroads may contribute to the costs of implementing the Colorado High-Speed Rail project through such projects as R2C2, increasing the local match potential.

11.5 Debt Financing

The use of debt financing provides the ability to advance project implementation by borrowing against projected future revenues. Several forms of debt financing are discussed on the following page.

11.5.1 Bond Issuance

The issuance of bonds and availability of up-front bond proceeds enables projects like the Colorado High-Speed Rail corridor to proceed in an uninterrupted fashion since project funding is secure. Additionally, the use of bond financing allows major capital projects, which are long-lived assets, to be paid for over their useful lives rather than by current users. Tax-exempt debt represents bonds issued by a public agency or authority and backed by a specified source of revenue. Taxable debt represents bonds issued under structures in which the project costs are not eligible under the Internal Revenue Code for funding by tax-exempt bonds. Taxable debt would be issued at an interest rate approximately 1.5 to 3.0 percentage points higher than tax-exempt debt, because the interest income from these bonds would be subject to federal, state, and local income taxes, which in turn affect investor returns. The basic structure of bonds is the same, whether tax-exempt or taxable.

11.5.2 Tax-Exempt Bonds

There are two major categories of tax-exempt bonds -- general obligation and revenue. The full faith and credit of the issuer with taxing power secures general obligation bonds. Revenue bonds are payable from specific revenue sources and do not permit bondholders to force taxation or legislative appropriation of funds not pledged for payment of debt service. Revenue bonds are non-recourse to the taxing power of the state in which the issuing authority is located. The only sources of repayment and security for bondholders are the specific revenues that are pledged under the bond indenture.

Under certain conditions (as defined in the Internal Revenue Code), state agencies and authorities would be able to issue tax-exempt "governmental use bonds" for a project. Exemption of the interest income on the bonds from federal taxes will lower the interest costs of the bonds, because investors can achieve the same effective return on tax-exempt bonds issued with a lower interest rate as they would achieve on taxable bonds at higher rates. For the bonds to obtain tax-exempt status, certain criteria must be met. Funded assets must be publicly owned. The operating contract must be a short-term contract that satisfies certain conditions, including termination rights by the public authority, and compensation cannot be based on a percentage of gross or net revenues. If a long-term operating contract is employed and the operating contract conditions discussed above are not met, tax-exempt governmental use bonds cannot be issued.

For different reasons (defined in the Internal Revenue Code), a second type of state-issued, federal tax-exempt bond, the "private activity bond," cannot be used for the 110-mph options. Under current law, these bonds may generally be used in private concessions for high-speed rail projects, except for the acquisition of rolling stock, for a system with operating speeds that meet a 150-mph minimum speed threshold. Thus, the Colorado High-Speed Rail corridor may qualify for “private activity bonds” for the higher speed (e.g., 220 mph) option, where its operating speeds are expected to meet or exceed the 150-mph requirements.

11.5.3 American Reconstruction and Rehabilitation Act (ARRA) Bonds

Under the ARRA the potential for bonds has been greatly expanded. Specific options include –

- Private Activity Bond (PAB's) - All PAB's issued in 2009 and 2010 will be exempted from the Alternative Minimum Tax (AMT).
- High-Speed Rail (PAB's) - ARRA allows purchases to deduct costs for buying and carrying Tax Exempt Bonds.
- Build America Bonds – In 2009 and 2010 Government Purpose bonds receive a cast subsidy or tax credit from the federal government equal to 35 percent of interest costs.
- Recovery Zone Bond – ARRA authorizes $10 billion in special BAB's in economically distressed/high unemployment areas. BAB's will receive a 45 percent interest subsidy.
- Qualified Energy Conservation Bonds (QECR) – QECR are 70 percent tax credit bonds with broad application to capital costs, research grants, emissions reduction projects. ARRA makes $3.2 billion available to states on population basis, with no more than 30 percent being used for PAB's.

11.5.4 Use of Proceeds and Source of Repayment

The revenues that are pledged to repay debt frequently include portions of a state's motor fuel taxes, motor vehicle registration fees, motor vehicle license or permit fees, and sometimes a portion of the state's sales tax. While net revenues from the operation of the proposed system could be pledged to repay the bonds, the interest rate for an untested entity such as the Colorado High-Speed Rail Authority would probably be substantially higher than those available to the individual states.

11.5.5 Establishment of New or Expanded Debt

States have constitutional or legislative restrictions on the issuance of debt. In addition, the enactment of a transportation bond program may require legislative action to establish the size of the program, identify existing or new revenue sources that will be pledged over a multi-year period to repay debt, and develop guidelines for the types of projects to be financed. The development of each new or expanded financing program must be tailored to meet specific legal, political and financial constraints. In this study, it has been assumed that each state will have (or will secure) the necessary bonding capability.

11.5.6 Structuring Considerations

Tax-exempt bonds can be structured as long-term, fixed-rate debt where the interest rate is established at the time of sale. Potential investors and the rating agencies carefully evaluate the credit strength of a bond issue. The key credit factor is the expected strength and stability of the pledged revenues.

11.5.7 Grant Anticipation Notes

Grant Anticipation Notes (GANs), or similar instruments, offer states an additional mechanism to raise up-front capital on the basis of receiving future federal funds. The term GAN refers to a debt financing instrument that permits its issuer to pledge future USDOT FRA funds to repay investors.

GANs are generally short term, usually less than one year to maturity but sometimes as long as two to three years to maturity, and intended only to meet short-term financial needs.

When the GAN is issued, the main form of security backing this debt financing instrument is the state's obligation of future federal aid apportionments based on a Letter of Intent or a Full Funding Agreement from the USDOT FRA. Short-term GANs are defined as notes backed by future obligations of a currently authorized Full Funding Agreement. Therefore, assuming that a state issued the GAN in the second year of a five-year authorization period, the term of the notes (or at least that portion backed by federal funds) could not exceed four years.

Federal tax law presently prohibits tax-exempt bonds from being directly or indirectly guaranteed by the federal government (i.e., Full Funding Agreement). Therefore, to enhance the credit rating of the issuance, additional security for the GANs is often required. Because of the shorter maturity and the additional security pledged, GANs usually are issued at a rate that is approximately one percent less than that for general obligation bonds. Accordingly, they could be a potential source of funding during the construction period, when the amount of funds received from federal grants does not meet the capital requirements of the construction program.

11.5.8 Leasing

There are two potential funding mechanisms for financing rolling stock and possibly maintenance facilities. One option is off-shore or cross-border leasing and the other is the issuance of Certificates of Participation (COPs). There must be a separation of federal and state interest in the equipment or facility in order to use cross-border leases or COPs to leverage additional funds, or when using short-term lending or debt subordination where arbitrage issues could be involved. For example, the portion of a fleet or facility without federal interest could be financed and the proceeds used to earn interest or act as a credit enhancement on a bond issue supporting a major investment, thus generating savings for the state. Any legislative package proposed for the Colorado High-Speed Rail Authority should include the powers necessary to enter into such leases.

11.5.9 Off-Shore or Cross-Border Leasing

Off-shore or cross-border leasing is a mechanism by which the state purchases rolling stock, such as railcars, then simultaneously sells them to a non-U.S. investor who would be allowed to take investment tax credits or tax depreciation write-offs on the value of the equipment. The investor in turn leases them back to the state, and the tax benefits are shared with the state through reduced leased costs. The foreign investor pays the state an up-front consideration usually ranging from five to ten percent of the cost or value of the vehicles. The balance of the proceeds is deposited in a trust account to prepay the lease payments. Cross-border leasing is an ideal market for railcars because of their long life and "resalebility." The market has a proven advantage; however, it is volatile with uncertainties as to the availability and amount of savings. At a given point in time there may be more demand than supply.

11.5.10 Certificates of Participation

Certificates of Participation (COPs) are methods of issuing debt, similar to bonding, secured by the value of the vehicles and/or facilities of the project. The investors become the technical owners of the vehicles/facilities and "lease" them back to the state. The lease payments become the service on the debt and, at the end of the lease period, the debt is retired and ownership reverts back to the state or issuing agency. COPs represent an interest in the payments the issuer has promised to make, but which are subject to annual appropriation by the issuer's governing body. The issuer must actually appropriate the funds each year; therefore, there is an element of risk not present in bonds. Although COPs can be insured, the interest rate is usually higher because of the increased risk.

11.6 Funding Summary

Many states are exploring opportunities to involve the private sector more completely in the implementation of high-speed rail projects. At this time, it is assumed that the state will create a public-private partnership to fund its portion of the capital costs while using one or a combination of the project funding alternatives discussed above. It is expected that the most likely funding mechanisms will include:

- Federal Financial Assistance and grants
- Cash flow management (TIFIA, GANs)
- Cost reduction techniques (cross-border leases, COPs)
- Private sector and public-private partnerships for station development and train operation

The current objective of most High-Speed Rail initiatives and bills in Congress is 80 percent federal participation with a 20 percent local match. It is anticipated that during the proposed Program Development phase, a consensus on how to generate the local match by a public-private partnership can be achieved.

12 Conclusions and Next Steps

12.1 Introduction

The RMRA Feasibility and Business Plan study offers a prime opportunity to enhance Colorado's transportation network. Implementation of a high-speed rail system in the I-25 and I-70 corridors would enhance mobility and provide additional needed transportation capacity in the state at a time of rising gas prices and increasing congestion. It would be a strong economic engine, both supporting and generating economic growth and transit-oriented development in the towns and cities connected to the system.

The study has identified the market for high-speed passenger rail service in Colorado, and shown the potential for a linked and fully integrated I-70 and I-25 high-speed rail system. The representative routes evaluated in the I-25 and I-70 corridors make extensive use of existing rail and highway rights-of-way, but greenfield options have also been developed where they can be shown to improve the performance of the system. The analysis has shown that on its own the I-25 corridor can sustain a 110-mph diesel option, but if I-25 were linked to a I-70 DIA to Eagle Airport corridor, the combined corridors would be capable of supporting 220-mph electric rail technology that could provide a single-seat ride.

The analysis has focused on technologies that could be expected to be ready for operational implementation by 2020. For any Colorado high-speed rail system, a critical factor in the system's performance is the gradients associated with the I-70 corridor, and this study has identified ways of connecting the I-70 communities using 4 percent grade segments that are easily climbed by modern high-speed trains.

In future analysis further consideration must be given to the I-70 corridor route, which has three locations with 7 percent grades. While modern high powered passenger and maglev trains can climb these grades, albeit at reduced speeds, consideration should be given to using more tunnels (at higher cost) to reduce the required climbing requirement of the trains and provide better performance in terms of speed and time. The most critical gradients to be considered are those 7 percent sections on the eastern face of the Rockies between Golden and Silver Plume. In the FRA Developed Option route, 4 percent grade segments have already been developed for crossing Loveland and Vail passes which make them less critical than the mountain areas between Golden and Silver Plume.

For evaluating the alternatives, FRA efficiency criteria were used and the FRA Developed Option, as well as both the 220-mph and 150-mph truncated network alternatives satisfied both the financial and economic criteria. This showed that potential exists for a public-private partnership similar to those proposed in California and in Florida for implementing the system. While Federal funding programs are still being developed, it is clear that a combination of state, federal and public-private funding can be used to develop the system. Federal grants of 50-80 percent for infrastructure are anticipated, particularly if tax credit funding is used to expand federal financing capability.

12.2 Statewide Mobility

The RMRA statewide passenger rail system would significantly improve regional mobility in Colorado by linking many of the state's largest communities and attractions. While the initial system would connect well over 85 percent of the state's population, its eventual build out would connect over 95 percent.

An extensive public outreach program has been initiated in support of this study, and the analysis has been sensitive to the key concerns identified as a result of the study. Potential station locations for the proposed system were identified in conjunction with local communities and corridor representatives.

12.3 Environmental Benefits

While the proposed Colorado passenger rail system has not been subject to a full environmental analysis, it is clear that the system would provide many economic and environmental benefits. These include reduced automobile use, and specifically resource savings in terms of emissions, noise, safety, gas reductions, highway infrastructure, and travel time savings both for individuals diverting from the automobile, as well as those continuing to drive. High-speed rail would also have a positive impact on the region's land use encouraging higher density and proximity of development to the high-speed rail stations. In an environmentally sensitive corridor these benefits are critically important.

12.4 Challenges

The development of a Colorado high-speed passenger rail system faces significant challenges. These include:

- **Public Funding:** To overcome the physical constraints of the I-70 corridor, the cost of construction in the I-70 corridor would be very significant. The I-70 corridor would cost three times that of the I-25 corridor. However, the I-70 corridor is a very powerful economic engine for the Colorado economy. Given its highly sensitive environment, investment in high-speed rail makes sense in both financial and economic terms. Critical elements in developing a funding plan would be:
  - The role of the Federal Government in providing Infrastructure Grants
  - The role of the State in developing match money and public-private partnerships to help finance, construct, and operate the system.
- **Freight Railroads:** A critical component of the Colorado Passenger Rail System is the potential use of freight railroad rights of way in the I-25 corridor, as well as for supporting future western extensions. This is clearly viewed as a major risk factor, as both the state and

freight railroads need to agree on what can be done and its costs. CDOT has carried out studies with the freight railroads on the potential for a rail bypass around Denver, and there are indications that the railroads would be willing to negotiate with CDOT. There are significant costs for both using and not using the freight railroad right-of-way, and these need to be evaluated carefully in a Cost Benefit Analysis considering both public and private benefits. There is both significant public and political opposition to and support for a rerouting of the freight lines.

- **Technology:** The operation of a high-speed rail system in the mountain corridor would be unique in the world, so no existing or off-the-shelf train in use today can reasonably be expected to meet all of Colorado's requirements. However, while the 220-mph Electric Rail technology evaluated in this study with its combination of components for speed, tilting, and 7 percent grade-climbing ability at 60-mph is not in operation anywhere in the world today in this configuration, all of the features or components needed to create such a train have been proven and are operational in revenue service in numerous applications. The 300-mph maglev technology is also not in use on 7 percent grades today, although its manufacturer provides performance specifications for vehicle operation on grades of up to 10 percent.

  Since the system will require a minimum of 5 to 7 years for additional study, environmental clearance and engineering design, it is likely that vehicle technologies will continue to evolve and improve. Off-the-shelf Electric Multiple Unit trains are capable of operating on 7 percent grades at 40-mph and on 4 percent grades at more than 80-mph. To mitigate risks associated with the potential need for equipment modifications, the FRA Developed Option sought to limit grades to 4 percent so only a few 7 percent segments remain. (See Appendix H) This allows the use of off-the-shelf trains since exposure to schedule impacts would be limited to only a few short sections. There is also an equipment risk associated with the potential need for FRA compliance modification. Current very high-speed trains from Europe and Japan are not FRA compliant and while this issue is likely to be addressed within the 5 to 7 year time frame cited above, it is currently a risk factor. However, this risk was addressed in Section 10.6 by development of additional route and infrastructure options that completely separate passenger operations from freight trains.

12.5 FRA Criteria for Corridor Designation

In answer to the six FRA corridor feasibility factors that were identified at the outset of this study:

- **Speed:** Both the I-70 and I-25 corridors would include many segments where more than 90-mph speeds would be attainable. The top speed achieved by the FRA Developed option would be 220-mph in several sections of the proposed I-25 South greenfield alignment. The I-25 North corridor is not quite capable of 220-mph due to curves in the highway alignment and frequent stops, but it is capable of speeds consistently exceeding 110-mph and could reach 200-mph in some places. Because of the development of the unconstrained alignment option for I-70, several segments of the proposed I-70 corridor are straight enough to support 90-mph or higher speed running. The segment from DIA to Denver to Golden supports speeds in excess of 150-mph and a top speed of 220-mph. Much of the I-70 mountain corridor despite its poor geometrics and steep grades could operate faster than 90-mph, leading to an average speed of 75-mph from DIA to Eagle Airport. Speeds exceeding 150-mph could be reached west of Copper Mountain on the new alignment to Pando.

- **Ridership:** Both the I-70 and I-25 corridors have strong ridership potential which would be capable of supporting at least 16-20 daily round trips on each corridor, and even more service as traffic grows in the future. Ridership demand is strong enough to support a double tracked railroad solution on all corridors.
- **Maximum Speed Percentage:** Because of the high power requirement for operating on 4-7 percent gradients, the proposed Colorado trains would have a very high theoretical maximum cruise speed of 220-mph on level track. On I-25 about 20 percent of the route can operate at 220-mph but only 5 percent on I-70. On both corridors however, much of the route is operable at more than 90-mph, despite severe curvature and/or gradients.
- **Non-Rider Benefits:** As shown in Exhibit 10-9, the projected external mode benefits to non-riders are substantial and equate to a quarter of the total benefit from this project. This shows that the proposed rail system will be able to divert enough auto traffic to noticeably reduce highway congestion, so that even non-users will benefit from the system.
- **Financial Support:** This study, like many other high-speed rail projects, has assumed a 70-80 percent federal match with a 20-30 percent local contribution. It can be seen in Exhibit 10-9 that the present value of the operating surplus is $13.449 billion revenue minus $7.083 billion operating cost or $6.366 billion. This is 42 percent of the capital cost of the system. Private operators would demand a higher rate of return on their investment than would a public source; nonetheless in a public-private partnership, it is likely that any of the 220-mph electric rail options could raise more than 20 percent of their needs from private sector funding sources. The operating surpluses of the system could likely be used to service revenue bonds that could be used to pay the local matching share of capital.
- **Freight Railroad Cooperation:** Even though the FRA Developed option relies heavily on greenfield alignments, it still uses freight railroad right-of-way from Littleton through downtown Denver past DIA airport to the E-470 on the north[1], and from Dowd Junction to Eagle Airport. As a result, one of the largest potential risk factors for the study is the role that the freight railroads are likely to play. However, at least one of the railroads has shown a great interest in the Colorado DOT "R2C2" initiative. By reducing freight traffic on some existing rail lines the "R2C2" initiative could help clear the way for the implementation of passenger rail. Alternatively, the use of elevated structures or alternative alignments assessed in Section 10.6 could alleviate this requirement and mitigate the risk associated with sharing freight rail rights of way.

[1] This alignment would bring I-25 service from Pueblo and Colorado Springs first to downtown Denver and then continue on to DIA.

12.6 Key High Speed Rail Feasibility Study Findings

Under the direction of the Rocky Mountain Rail Authority Board of Directors and its designated Feasibility Study Steering committee, this study has assessed a wide range of alternatives for developing a high-speed rail system in the I-25 and I-70 corridors of Colorado. Key findings of the study are:

- A Cost Benefit assessment of a wide range of technology options has been performed using USDOT / FRA criteria. Several alternative options developed in the RMRA study pass the FRA tests for both financial and economic feasibility and would provide significant benefits to the I-25 and I-70 corridors, the State of Colorado, and to the US economy as a whole. These alternatives provide a strong case for building high-speed rail in both the I-25 corridor between Pueblo and Fort Collins and in the I-70 corridor between DIA and Eagle Airport.
- Economic feasibility as defined by the FRA proved to be the most difficult criteria for the RMRA study alternatives to overcome. The 220-mph Electric Rail technology option had the highest economic feasibility score of all alternatives evaluated in the RMRA study with a Cost Benefit ratio of 1.28, and was selected for more detailed evaluation as the FRA Developed Option as a result. Further fine-tuning applied to the FRA Developed Option further improved the Cost Benefit result to a comfortable 1.49.
- Strongest ridership in the Colorado system would occur when a "single seat" ride from I-25 communities to the mountain resorts is possible in both the summer and winter. This is because so many of the people who live along the I-25 front range use the I-70 resorts and facilities for recreation, creating a strong synergy between the two corridors. The avoidance of any requirement for transfers would be especially important to skiers and overnight travelers who may have extensive luggage and recreational equipment with them.
- In the I-25 corridor the strongest technologies were the 220-mph and 150-mph Electric Rail technologies, and the 110-mph Diesel Rail technology. Maglev systems were found to be significantly more expensive than Rail technologies in capital investment although the 300-mph maglev alternative would provide the highest ridership and best Operating Ratio numbers of all alternatives evaluated.
- Technology findings for the I-70 corridor demonstrate that 110-mph diesel could only be used west of Eagle Airport or west of Silverthorne, Dillon, and Frisco if the Tennessee Pass route via Pando rather than Vail Pass were adopted. From DIA to Eagle Airport only the Maglev and 220-mph electric rail technologies could be used, since the route options include 7 percent grade segments.
- Maglev can work in the I-70 corridor, but if used for the Colorado network (i.e. both I-70 and I-25 corridors) and along the same alignment, it would be almost twice the capital cost of a 220-mph electric rail system. It is worth noting however, that the cost of a Maglev alternative in the I-70 corridor is only slightly higher than the 220-mph rail alternative due the extensive tunneling and elevated structure required. In order to achieve FRA economic feasibility, a Maglev system selected for the I-70 corridor would need to be linked to a lower capital cost electric or diesel train in the I-25 corridor with a transfer for feeding passengers from the I-25 communities.

- The system would take 12 to 15 years to implement largely due to the extensive program development and environmental process required both under NEPA and by the state of Colorado. However the process could be expedited through the use of the Context Sensitive Solution process, which is standard practice today, by the Colorado Department of Transportation.
- The Implementation Plan for the FRA Developed Option using 220-mph electric rail technology was disaggregated into four implementation phases that spread the construction period over eight years. Given the sensitivity of the I-70 environment it is not surprising that this would be a lengthy process. Nonetheless, given the 2020 startup date now proposed by California High Speed Rail with a completed EIS, a 2025 target date for the Colorado system completion does not seem unreasonable.
- Rail connections to DIA will ensure the ability of tourists to reach key attractions along I-70 despite the growing difficulties due to growing I-70 highway congestion.
- Rail connections would support daily business, commuter and social travel in the I-25 corridor, and would also provide access to DIA and to day trip recreational destinations along I-70. Rail would make weekend trips to I-70 tourist attractions much quicker, safer and more affordable from all the communities along the I-25 corridor.
- The economic impact of developing the rail system would be considerable. It would generate significant construction jobs, permanent rail jobs, and many additional indirect jobs over the life of the project.
- Passenger rail service would spur economic growth activity, travel and tourism, property values, downtown redevelopment, and a tax base expansion due to the extra employment. The investment would make a positive contribution to the development of the national, state and local economies without being accompanied by any long-term subsidy burden.
- This study has concluded that there are financially and economically feasible alternatives for developing a high-speed rail system in Colorado.

12.7 Further Development of I-25 South Greenfield Options

This study assessed several route alternatives for the I-25 South corridor from Denver to Pueblo. Early in the study, a greenfield alignment was proposed as an alternative to using existing rail in the corridor. The original greenfield alignment used the former Rock Island right of way to regain access to the historical Colorado Springs train station downtown.

However, variants on this greenfield option were later considered as part of the Freight Rail Risk Assessment. This risk assessment developed alternatives to avoid or minimize the use of existing rail alignments through downtown Denver and Colorado Springs. In Colorado Springs a greenfield alignment was extended south past the Colorado Springs airport rather than using the existing rail right-of-way through downtown. In response to the risk assessment, representatives of El Paso County suggested further refined alignment options that are documented in Appendix I. It is recommended that these options be studied in subsequent phases of development of the Colorado high-speed rail system.

12.8 I-70 West Programmatic Environmental Impact Statement

The I-70 West Programmatic Environmental Impact Statement performed under direction of the Federal Highway Administration and the Colorado Department of Transportation is scheduled for a Record of Decision in 2011. Prior to the completion of this Feasibility study, the Colorado Department of Transportation and the Federal Highway Administration convened a group of 27 diverse stakeholders in 2008 (named the Collaborative Effort Group) to develop a consensus for the preferred alternative in the I-70 West PEIS study. The Collaborative Effort Group agreed upon a preferred alternative that includes an Advanced Guideway System (AGS) from Golden to Eagle County Airport as part of a joint highway and transit improvement solution for the I-70 mountain corridor. The AGS alternative contemplates an advanced fixed guideway transit technology such as magnetic levitation for traversing the corridor's difficult mountain terrain that would have greater performance capabilities than traditional steel wheel on steel rail technologies.

The I-70 Corridor Coalition and I-70 Collaborative Effort Group have recommended criteria, listed in Appendix J[2] for the implementation of an advanced transit system in the I-70 Mountain Corridor. It should be noted that the I-70 Collaborative Effort Group along with the I-70 Corridor Coalition have voiced a specific preference for an elevated low noise and environmentally friendly advanced fixed guideway system for the mountain corridor over a conventional on-grade rail solution.

Because of the I-70 coalition's strong preference for AGS rather than a rail solution, the initial screening of alternatives for this study developed a hybrid alternative "Option 9" in Section 9.4.2. This option coupled a 300-mph maglev solution in I-70 with a 110-mph rail service on I-25. This particular combination of technologies produced a marginally positive Cost Benefit ratio of 1.04, indicating the potential viability of this option. This result could perhaps have been improved by additional work for fine-tuning of that alternative.

However, the 220-mph electric rail technology for I-70 (with a Greenfield alignment in I-25) produced much stronger economic results, so in spite of the I-70 coalition's AGS preference, the RMRA Steering Committee selected an interoperable rail system for more detailed analysis as the FRA Developed option. As well as having a lower capital cost, a rail system could provide a single-seat ride between the I-25 and I-70 corridors. This would optimize the ability of I-25 to feed traffic into I-70, as opposed to a maglev solution that would require a transfer with luggage and recreational equipment. Since the FRA Developed option incorporates both I-25 and I-70, the increased ridership justifies the extra cost for a higher quality greenfield on I-25, instead of using an existing rail alignment.

[2] Source: http://rockymountainrail.org/documents/Criteria_Public.pdf

Although the I-70 Programmatic Environmental Impact Statement NEPA evaluation favors a completely elevated maglev solution in the I-70 corridor due to reduced environmental impacts over at-grade rail, FRA economic criteria favor development of a rail system for Colorado at this time. Given the demand for service and lower capital costs for at-grade construction, additional mitigation measures such as wildlife overpasses and underpasses[3] can be added to the at-grade rail solution at a very low cost.

It should be noted that the purpose of this study was only to determine whether any combination of technologies and routes could be found that would satisfy FRA's Economic criteria. That objective has been attained. This study has developed a clear economic justification for proceeding with a rail system solution. It has not however, ruled out the potential viability of an AGS solution in the I-70 corridor. However this study did clearly find that the economic viability of the I-70 corridor does depend on development of an effective I-25 feeder system, as well as direct DIA connectivity.

The ultimate selection of routes and technologies was not the objective of this Feasibility study. Rather, it was understood that the level of detailed analysis required to make an ultimate selection could not be performed within the limited scope and resources available to this study. Such decisions would be made in the context of a formal NEPA evaluation, such as that provided by the I-70 West Programmatic Environmental Impact Statement, where enough resources could be made available to support a sufficiently in-depth evaluation of not only the financial and economic, but also the environmental tradeoffs implicit in such choices.

12.9 Proposed Next Steps

Concurrent with the RMRA and Colorado DOT's continuing effort to broaden and strengthen support for the Colorado high-speed rail passenger system with citizens, local state and federal stakeholders, business community and regional transport authorities, there will be a need to advance the technical planning for the proposed system. This should include financial planning, development of public-private partnerships, and organization of the necessary institutional arrangements needed to secure funds for additional planning, environmental, and engineering work. This would include design and construction of infrastructure and equipment needed for implementation.

Next steps involve continued public outreach, environmental and engineering reviews and analysis, coordination with the railroads as needed, and attaining Federal and state support for the project.

Short-term actions should include:

- The development of a comprehensive Colorado State Rail plan, which is a prerequisite for funding eligibility under ARRA and PRIIA[4].
- Supply-side Economic Impact for identifying Joint Development opportunities, and the possibility for local and private matching funding contributions

[3] Highways through Habitats, *TR News #249*, Transportation Research Board, March-April 2007, page 14.
[4] ARRA: American Recovery and Reinvestment Act of 2009; PRIIA: Passenger Rail Investment and Improvement Act of 2008.

- Environmental Assessments
- Finance and Funding Plans
- Grassroots support for the project
- Discussions with freight railroads
- Further Alternatives Analysis
- Preliminary Engineering
- Generation of a performance matrix / specification to be discussed with potential system suppliers, in support of a Train Procurement Process

A possible means of advancing the Colorado passenger rail system would be through a program development process including environmental analysis, designed to be completed in two to three years while creating the potential to carry out Tier 2 Environmental Assessment (EA) or Environmental Impact Study (EIS) that is a key component of the project development process. This would provide:

- Delineation of "Purpose and Need" for the passenger rail system
- Alternatives Analysis of alternative feasible technology and route alternatives
- Development of institutional structure to handle corridor development
- Preliminary Engineering (up to 30 percent)
- Economic Impact Studies
- Identification of levels of environmental analysis, and initiation of tiered studies.

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