

# 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.

Page Intentionally Left Blank

# Table of Contents

**Preface.....i**

**1 High-Speed Rail Planning Process.....1-1**

1.1 Study Objectives..... 1-1

1.2 Alternatives Development and Business Planning Process ..... 1-3

1.3 Public Involvement Process..... 1-5

1.4 Peer Review Process ..... 1-6

1.5 Study Process..... 1-6

1.6 Report Structure ..... 1-8

**2 Target Markets .....2-1**

2.1 Background ..... 2-1

2.2 Demographics and Settlement Pattern of Colorado..... 2-7

2.2.1 Tourism and Mineral Development ..... 2-9

2.3 Intercity Passenger Markets..... 2-12

2.3.1 Highway Travel ..... 2-12

2.3.2 Air Service..... 2-15

2.3.3 Passenger Rail Service ..... 2-18

2.3.4 Intercity Bus..... 2-21

2.4 Preliminary Intercity Travel Market..... 2-26

2.5 Conclusion..... 2-28

**3 Infrastructure Needs .....3-1**

3.1 Introduction ..... 3-1

3.2 Engineering Assessment ..... 3-2

3.3 Guidance from the Federal Railroad Administration (FRA)..... 3-4

3.4 Technology Considerations ..... 3-5

3.5 Engineering Assessment: I-25 South Corridor - Denver to Trinidad..... 3-6

3.5.1 Existing Rail Rights-of-Way ..... 3-6

3.5.2 Potential Greenfield Routes..... 3-7

3.5.3 Findings of Field Inspection and Selection of Representative Routes ..... 3-7

3.5.4 Proximity of Representative Routes to Intermodal Sites..... 3-13

3.5.5 Proximity of Representative Routes to Population Centers..... 3-15

3.5.6 Geometry of Representative Routes ..... 3-15

3.5.7 Capacity of Representative Routes ..... 3-16

3.6 Engineering Assessment: I-25 North Corridor – Denver to Cheyenne..... 3-20

3.6.1 Existing Rail Rights-of-Way ..... 3-20

3.6.2 Potential Greenfield Routes..... 3-21

3.6.3 Findings of Field Inspection and Selection of Representative Routes ..... 3-21

3.6.4 Proximity of Representative Routes to Intermodal Sites..... 3-33

3.6.5 Proximity of Representative Routes to Population Centers..... 3-33

3.6.7 Geometry of Representative Routes ..... 3-33

3.6.8	Capacity of Representative Routes.....	3-34
3.7	Engineering Assessment: I-70 Corridor – Denver to Grand Junction.....	3-38
3.7.1	Access to I-70 Corridor from Denver to Golden.....	3-39
3.7.2	I-70 Corridor from Golden to Minturn .....	3-43
3.7.3	I-70 Corridor from Minturn to Grand Junction .....	3-48
3.7.4	Findings of Field Inspection and Definition of Representative Routes.....	3-53
3.7.5	Proximity of Representative Routes to Intermodal Sites.....	3-55
3.7.6	Proximity Representative Routes to Population Centers .....	3-55
3.7.7	Geometry of Representative Routes.....	3-55
3.7.8	Route Capacity .....	3-55
3.8	Typical Infrastructure Needs for Steel Wheel/Steel Rail Technology .....	3-56
3.8.1	Trackwork Elements.....	3-56
3.8.2	Structures –Approaches, Flyovers, Bridges, and Tunnels.....	3-59
3.8.3	Systems.....	3-63
3.8.4	Curves.....	3-64
3.8.5	Highway Grade Crossings.....	3-67
3.9	Infrastructure Needs for Maglev Technology .....	3-68
3.9.1	At-Grade Guideway .....	3-68
3.9.2	Aerial Guideway – Type B, Straddle Bents .....	3-69
3.9.3	Bridge Structures.....	3-70
3.9.4	Tunnels.....	3-70
3.9.5	Maglev Propulsion, Communication and Controls .....	3-72
3.9.6	Operations and Maintenance Facilities: Rail and Maglev .....	3-73
3.10	Summary .....	3-74
<b>4</b>	<b>Route and Technology Options .....</b>	<b>4-1</b>
4.1	Potential Stations.....	4-1
4.2	Representative Technologies .....	4-4
4.3	Generic Technology Categories.....	4-5
4.4	Technical Characteristics of Steel Wheel Technology .....	4-11
4.4.1	FRA Regulatory Requirements .....	4-11
4.4.2	Rail Acceleration Curves.....	4-15
4.4.3	Rail Tractive Effort or Adhesion .....	4-18
4.5	Maglev Capabilities .....	4-21
4.6	Matching Equipment Capabilities to Representative Routes.....	4-23
4.7	Summary .....	4-33
<b>5</b>	<b>Operating Plans.....</b>	<b>5-1</b>
5.1	I-25 Corridor .....	5-3
5.1.1	North I-25 Corridor.....	5-3
5.1.2	South I-25 Corridor .....	5-10
5.2	I-70 Corridor .....	5-20
5.2.1	I-70 Corridor East of Avon.....	5-20
5.2.2	I-70 Corridor West of Avon .....	5-28
5.3	Summary Travel Time Comparison .....	5-31
5.4	Train Service and Frequencies.....	5-32
5.5	Fleet Requirements.....	5-37

- 5.6 Winterization Requirements ..... 5-37
- 5.7 Summary ..... 5-38
- 6 Travel Demand and Forecasting .....6-1**
- 6.1 The Zone System ..... 6-1
- 6.2 Stated Preference Survey..... 6-4
  - 6.2.1 Survey Methodology ..... 6-5
  - 6.2.2 Survey Implementation..... 6-6
  - 6.2.3 Survey Demographic Characteristics ..... 6-8
  - 6.2.4 Value of Time and Value of Frequency by Trip Purpose and Mode ..... 6-10
  - 6.2.5 Comparison with Other Studies ..... 6-11
- 6.3 Socioeconomic Baseline and Forecasts ..... 6-12
- 6.4 Transportation Networks..... 6-15
- 6.5 Origin-Destination Data ..... 6-16
  - 6.5.1 Rail Mode ..... 6-17
  - 6.5.2 Air Mode ..... 6-17
  - 6.5.3 Bus Mode ..... 6-17
  - 6.5.4 Auto Mode ..... 6-17
  - 6.5.5 Model Validation ..... 6-18
- 6.6 Modeled Rail Network Strategies ..... 6-19
- 6.7 Other Modeled Mode Network Strategies..... 6-20
  - 6.7.1 Congestion ..... 6-20
  - 6.7.2 Gas Prices ..... 6-24
- 6.8 High-Speed Rail Forecasts ..... 6-26
  - 6.8.1 Ridership Forecast ..... 6-26
  - 6.8.2 Market Shares ..... 6-27
  - 6.8.3 Ridership Composition ..... 6-29
  - 6.8.4 Revenue Forecast ..... 6-30
- 6.9 Sensitivity Analysis..... 6-31
  - 6.9.1 Socioeconomic Sensitivity ..... 6-32
  - 6.9.2 Gas Price Sensitivity ..... 6-34
  - 6.9.3 Seasonal and Weekday/Weekend Sensitivity ..... 6-36
- 6.10 Validation..... 6-37
  - 6.10.1 Northeast Corridor Comparison..... 6-37
  - 6.10.2 California Corridor Comparison ..... 6-40
- 6.11 Summary ..... 6-42
- 7 Operating Costs.....7-1**
- 7.1 Variable Costs ..... 7-4
  - 7.1.1 Train Equipment Maintenance..... 7-4
  - 7.1.2 Train and Engine Crew Costs..... 7-5
  - 7.1.3 Fuel and Energy ..... 7-6
  - 7.1.4 Onboard Services (OBS)..... 7-8
  - 7.1.5 Insurance Costs ..... 7-9
- 7.2 Fixed Route Costs..... 7-10
  - 7.2.1 Track and Right-of-Way Costs ..... 7-10
  - 7.2.2 Station Operations ..... 7-13

- 7.3 System Overhead Costs..... 7-14
- 7.4 Key Cost Results..... 7-15
- 8 Capital Costs .....8-1**
- 8.1 Introduction ..... 8-1
- 8.2 Engineering Assessment ..... 8-2
- 8.3 Development of Unit Construction Capital Costs ..... 8-3
  - 8.3.1 Base Set of Unit Costs ..... 8-3
  - 8.3.2 Relative Costs ..... 8-4
  - 8.3.3 Cost Escalation ..... 8-4
  - 8.3.4 Unit Price Adjustment..... 8-4
  - 8.3.5 Unit Capital Costs for Colorado – Steel Wheel/Steel Rail ..... 8-5
  - 8.3.6 Unit Costs for Colorado – Maglev ..... 8-12
- 8.4 Other Costs..... 8-15
  - 8.4.1 Contingency ..... 8-15
  - 8.4.2 Professional Services and Environmental ..... 8-15
  - 8.4.3 Placeholders..... 8-16
- 8.5 Infrastructure Capital Costs..... 8-16
- 8.6 Summary ..... 8-21
- 9 Evaluation of Alternatives .....9-1**
- 9.1 Introduction ..... 9-1
- 9.2 Measures of Efficiency ..... 9-2
  - 9.2.1 Key Assumptions ..... 9-3
  - 9.2.2 Cost Benefit Requirements..... 9-4
  - 9.2.3 Estimate of Economic Benefits ..... 9-5
- 9.3 Results of Preliminary Analysis ..... 9-8
- 9.4 Refinement of Base Alternatives ..... 9-11
  - 9.4.1 Truncation Analysis..... 9-11
  - 9.4.2 Mix and Match Analysis ..... 9-14
  - 9.4.3 Western Strategies..... 9-17
- 9.5 The FRA “Developed” Option ..... 9-19
- 10 Implementation Plan and Rail Right-of-Way Risk Analysis .....10-1**
- 10.1 Implementation Phase Definition ..... 10-1
- 10.2 Implementation Phase Timings..... 10-4
- 10.3 Capital Requirements ..... 10-7
  - 10.3.1 Phase I – Denver International Airport to Denver to Colorado Springs ..... 10-7
  - 10.3.2 Phase II – Denver to Keystone/Breckenridge and Copper Mountain..... 10-8
  - 10.3.3 Phase III – Colorado Springs to Pueblo and Denver to Fort Collins..... 10-9
  - 10.3.4 Phase IV – I-70 Copper Mountain to Eagle County Airport and  
Black Hawk Branch..... 10-10
  - 10.3.5 Implementation Phase Timings ..... 10-11
- 10.4 Financial Results..... 10-12
- 10.5 Cost Benefit Results for the FRA Developed Option ..... 10-13
- 10.6 Freight Railroad Right-of-Way Risk Analysis ..... 10-18
  - 10.6.1 Infrastructure Mileage Comparison ..... 10-24
  - 10.6.2 Station Comparisons..... 10-24

- 10.6.3 Running Time and Mileage Comparison – Preferred vs. Bypass Options..... 10-25
- 10.6.4 Bypass Options: Revenue and Ridership Performance ..... 10-27
- 10.6.5 Risk Analysis Capital Costs..... 10-28
- 10.6.6 Non Compliant Equipment Savings ..... 10-31
- 10.6.7 Economic Results ..... 10-32
- 10.6.8 Risk Analysis Conclusion ..... 10-35
- 11 Funding Alternatives .....11-1**
- 11.1 Federal Funding Programs ..... 11-1
  - 11.1.1 Passenger Rail Investment and Improvement Act of 2008..... 11-2
  - 11.1.2 American Recovery and Reinvestment Act: Capital Assistance for High-Speed Rail Corridors and Intercity Passenger Rail Service (ARRA)..... 11-2
- 11.2 Federal Credit Programs ..... 11-2
  - 11.2.1 Transportation Infrastructure Finance and Innovation Act..... 11-2
  - 11.2.2 Railroad Rehabilitation and Improvement Financing (RRIF)..... 11-4
- 11.3 State and Local Financing ..... 11-4
  - 11.3.1 Delayed or Tapered State/Local Match..... 11-5
  - 11.3.2 Credit for Acquired Land ..... 11-5
  - 11.3.3 Using Federal Funds as Match..... 11-5
  - 11.3.4 Local Funding..... 11-5
- 11.4 Private Sector Contributions..... 11-6
  - 11.4.1 Joint Development ..... 11-6
  - 11.4.2 Freight Railroads..... 11-6
- 11.5 Debt Financing..... 11-6
  - 11.5.1 Bond Issuance..... 11-7
  - 11.5.2 Tax-Exempt Bonds..... 11-7
  - 11.5.3 American Reconstruction and Rehabilitation Act (ARRA) Bonds..... 11-8
  - 11.5.4 Use of Proceeds and Source of Repayment ..... 11-8
  - 11.5.5 Establishment of New or Expanded Debt ..... 11-8
  - 11.5.6 Structuring Considerations..... 11-8
  - 11.5.7 Grant Anticipation Notes..... 11-8
  - 11.5.8 Leasing..... 11-9
  - 11.5.9 Off-Shore or Cross-Border Leasing ..... 11-9
  - 11.5.10 Certificates of Participation ..... 11-10
- 11.6 Funding Summary ..... 11-10
- 12 Conclusions and Next Steps .....12-1**
- 12.1 Introduction ..... 12-1
- 12.2 Statewide Mobility ..... 12-2
- 12.3 Environmental Benefits ..... 12-2
- 12.4 Challenges ..... 12-2
- 12.5 FRA Criteria for Corridor Designation ..... 12-3
- 12.6 Key Findings ..... 12-4
- 12.7 Further Development of I-25 South Greenfield Option ..... 12-6
- 12.8 I-70 West Programmatic Environmental Impact Statement..... 12-7
- 12.9 Proposed Next Steps..... 12-8

## Appendices

- A Membership and Membership by Jurisdiction
- B COMPASS™ Model
- C Zone System and Socioeconomic Data
- D Stated Preference Survey Forms
- E Capital Cost Detailed Segment Schematics and Data
- F Unit Price Regional & Escalation Analysis
- G Rail Tunnel Evaluation
- H Grade Options for I-70: 4% vs. 7%
- I Colorado Springs Alignment
- J AGS Technology Performance Criteria: I-70 Coalition Technical Committee  
Recommendations
- K Novel Technologies
- L FRA Developed Option: Train Schedules
- M RMRA Public Involvement Process

**List of Exhibits**

**Chapter 1**

Exhibit 1-1: Potential Colorado High-Speed Rail Corridors ..... 1-1  
 Exhibit 1-2: Business Plan Six-Step Process..... 1-4  
 Exhibit 1-3: Interactive Analysis Process..... 1-7

**Chapter 2**

Exhibit 2-1: Old Oregon Trail..... 2-1  
 Exhibit 2-2: Santa Fe Trail ..... 2-2  
 Exhibit 2-3: I-70 Corridor Profile ..... 2-3  
 Exhibit 2-4: City of Denver’s Connectivity to Markets and Ports ..... 2-4  
 Exhibit 2-5: Overnight and Day Trips to Colorado in 2007..... 2-5  
 Exhibit 2-6: Colorado Skier Visits..... 2-6  
 Exhibit 2-7: Colorado Population Density..... 2-7  
 Exhibit 2-8: Socioeconomic Data for Colorado Metropolitan Statistical Areas (2006) ..... 2-8  
 Exhibit 2-9: Colorado Household Income ..... 2-9  
 Exhibit 2-10: Colorado Ski Resorts along the I-70 Corridor ..... 2-11  
 Exhibit 2-11: Statewide AADT Counts ..... 2-13  
 Exhibit 2-12: AADT on I-25 and I-70 (2007) ..... 2-14  
 Exhibit 2-13: AADT on I-70 (2007)..... 2-14  
 Exhibit 2-14: I-70 Corridor Weekday and Weekend Daily Vehicle Trips (Year 2000)..... 2-15  
 Exhibit 2-15: Annual Air Travel between Colorado and the Rest of the U.S. (2005) ..... 2-16  
 Exhibit 2-16: Colorado Airports..... 2-17  
 Exhibit 2-17: Flight Information between DIA and 13 Commercial Airports in Colorado (2007)..... 2-17  
 Exhibit 2-18: Colorado Amtrak Passenger Rail Map ..... 2-18  
 Exhibit 2-19: Amtrak FY2007 - Facts about Serving Colorado..... 2-19  
 Exhibit 2-20: Amtrak California Zephyr Fare in Colorado ..... 2-19  
 Exhibit 2-21: Amtrak California Zephyr Fare per Mile in Colorado..... 2-19  
 Exhibit 2-22: Amtrak Southwest Chief Fare in Colorado ..... 2-20  
 Exhibit 2-23: Amtrak Southwest Chief Fare per Mile in Colorado ..... 2-20  
 Exhibit 2-24: Ski Train Route ..... 2-20  
 Exhibit 2-25: Intercity Bus Service Frequency in the Corridors..... 2-22  
 Exhibit 2-26: Intercity Bus Fares ..... 2-23  
 Exhibit 2-27: Intercity Bus Travel Times..... 2-24  
 Exhibit 2-28: Bus Ridership and Trip Purpose..... 2-25  
 Exhibit 2-29: RTD Bus Ridership and Seasonality (in thousands trips) ..... 2-26  
 Exhibit 2-30: Preliminary Assessment of Major Production and Attraction Centers for Annual  
 Intercity Trips..... 2-27

**Chapter 3**

Exhibit 3-1: RMRA High-Speed Rail Feasibility Study Corridors ..... 3-1  
 Exhibit 3-2: Map of All Representative Routes in I-25 South Corridor ..... 3-10  
 Exhibit 3-3: Map of Existing Rail Representative Route in I-25 South Corridor ..... 3-11  
 Exhibit 3-4: Map of Greenfield Representative Route in I-25 South Corridor..... 3-12  
 Exhibit 3-5: View showing commercial development constructed on the southern approach to DUS.... 3-13  
 Exhibit 3-6: Area between Denver Union Station and the BNSF/UPRR Joint Line (existing rail) ..... 3-14  
 Exhibit 3-7: Littleton Trench on the BNSF/UPRR Joint Line between DUS and C-470 ..... 3-16  
 Exhibit 3-8: View south at Palmer Lake near MP 52.0 County Line Rd..... 3-18

Exhibit 3-9: View north at Route 105 of Abandoned BNSF in Monument .....	3-18
Exhibit 3-10: I-25 at MP 125 South of Colorado Springs, View North.....	3-19
Exhibit 3-11: BNSF at Lime Road View North.....	3-19
Exhibit 3-12: BNSF Spanish Peaks Sub at County Rd 103 View North .....	3-20
Exhibit 3-13: Potential Routes within the I-25 North Corridor.....	3-24
Exhibit 3-14: Screened Alternative, BNSF Route Denver to Cheyenne.....	3-25
Exhibit 3-15: Screened Alternative, UP Route Denver to Cheyenne .....	3-26
Exhibit 3-16: UP Route Denver to Fort Collins GWRCO Option .....	3-27
Exhibit 3-17: UP Route Denver to Fort Collins Milliken Option.....	3-28
Exhibit 3-18: Airport Access route Denver to DIA.....	3-29
Exhibit 3-19: Greenfield Option following E-470 and I-25 Denver to Fort Collins.....	3-31
Exhibit 3-20: Greenfield Connection option using the Boulder Industrial Lead.....	3-30
Exhibit 3-21: View north of I-25 North of State Highway 470 .....	3-32
Exhibit 3-22: View north at I-25 MP 235 at State Highway 52 Overpass .....	3-32
Exhibit 3-23: View north along Mason St in Fort Collins near MP 73.54 .....	3-34
Exhibit 3-24: View east toward DIA along 96th Street .....	3-35
Exhibit 3-25: View east toward DIA at crossing of BNSF existing route with 96th St .....	3-35
Exhibit 3-26: View south along SH-2 approaching 72nd St. ....	3-36
Exhibit 3-27: View south at UPRR MP 5.0, Sand Creek Junction .....	3-37
Exhibit 3-28: View south, UPRR Greeley sub MP 13.6 at 120th Ave. ....	3-37
Exhibit 3-29: View east along GRWCO MP 83.8 at County Road 13.....	3-38
Exhibit 3-30: I-70 Corridor from Denver to Grand Junction, Aspen and Craig .....	3-39
Exhibit 3-31: I-70 Corridor from Denver to Golden .....	3-40
Exhibit 3-32: US-6 with frontage roadways on each side of the alignment .....	3-41
Exhibit 3-33: US-6 near Denver city limits in a very constrained area .....	3-41
Exhibit 3-34: View west along BNSF Golden Subdivision near Golden .....	3-42
Exhibit 3-35: View west in Golden from the intersection of SH-58 and Ford St .....	3-43
Exhibit 3-36: I-70 Corridor from Golden to Avon showing two Greenfield Route Options .....	3-44
Exhibit 3-37: View west on US-6 in the Clear Creek Canyon .....	3-45
Exhibit 3-38: View west in the vicinity of MP 230 approaching Georgetown.....	3-46
Exhibit 3-39: View of south of I-70 in vicinity of Georgetown .....	3-46
Exhibit 3-40: Typical condition of SH-9 and US-6 with space for guideway.....	3-47
Exhibit 3-41: View north along SH-91 between Copper Mountain and Pando Junction.....	3-48
Exhibit 3-42: View west to National Park between SH-91 and Pando Junction.....	3-49
Exhibit 3-43: I-70 Corridor from Avon to Grand Junction .....	3-49
Exhibit 3-44: Typical View of condition of UPRR Tennessee Pass Subdivision.....	3-49
Exhibit 3-45: View west of UPRR and I-70 through Glenwood Canyon.....	3-50
Exhibit 3-46: View east along the I-70 corridor (MP 124) through Glenwood Canyon.....	3-50
Exhibit 3-47: View west toward Dotsero along the UPRR.....	3-51
Exhibit 3-48: View south on the UP Branch line to Bond at CP 153 near Toponas.....	3-51
Exhibit 3-49: View north on the Rio Grande bike trail near Aspen .....	3-52
Exhibit 3-50: Rail Section: Double Track Electrified Rail Section; Signals, Communications & Dispatch	3-58
Exhibit 3-51: Double Track Retained Earth Fill .....	3-59
Exhibit 3-52: Example of Approach Embankment for Double Track .....	3-60
Exhibit 3-53: Example of Low Level Double Track Elevated Structure .....	3-60
Exhibit 3-54: Rail Section: High Level Structure for Double Track.....	3-61

Exhibit 3-55: Tunnel section showing crossovers, connecting galleries, and emergency stations .....	3-62
Exhibit 3-56: Curve Degrees versus Radius .....	3-64
Exhibit 3-57: Passenger Reference Speeds* .....	3-66
Exhibit 3-58: At-Grade Guideway .....	3-68
Exhibit 3-59: Aerial Guideway, Type A .....	3-69
Exhibit 3-60: Straddle Bent over Highway Lanes.....	3-69
Exhibit 3-61: Bridge Structure, SANDAG Maglev Study Phase 1, Final Report.....	3-70
Exhibit 3-62: Type A Shallow or Short Maglev Tunnel.....	3-71
Exhibit 3-63: Type B Deep or Long Tunnel .....	3-71
Exhibit 3-64: Maglev Propulsion, Communication and Controls .....	3-72
Exhibit 3-65: Proposed Central Maintenance Facility (Pittsburgh, PA) .....	3-73

**Chapter 4**

Exhibit 4-1: Station Spacing Increasing with Speed .....	4-2
Exhibit 4-2: Potential Station Locations .....	4-3
Exhibit 4-3: Generic Technology Categories by Speed Range .....	4-4
Exhibit 4-4: Conventional Rail – Representative Trains .....	4-6
Exhibit 4-5: High-Speed Rail – Representative Trains .....	4-7
Exhibit 4-6: High-Speed Maglev – Representative Trains.....	4-8
Exhibit 4-7: Very High-Speed Rail – Representative Trains .....	4-9
Exhibit 4-8: Ultra High-Speed Maglev – Representative Train .....	4-10
Exhibit 4-9: Acela Train Set.....	4-11
Exhibit 4-10: Train Type/Technology Acceleration Curves: Straight and Level Track .....	4-17
Exhibit 4-11: Power System Performance, Speed versus Grade.....	4-18
Exhibit 4-12: Definition of Coefficient of Adhesion .....	4-19
Exhibit 4-13: 1st Generation Locomotive-Hauled ICE-1 Train – Maximum Gradient Capability .....	4-20
Exhibit 4-14: 3rd Generation EMU ICE-3 Train – Maximum Gradient Capability .....	4-20
Exhibit 4-15: Technical Specifications for Transrapid Maglev .....	4-22
Exhibit 4-16: Transrapid Maglev – Equilibrium Speed as a Function of Gradient .....	4-22
Exhibit 4-17: Comparison of Tilt Capabilities – Maglev vs. Tilt Train .....	4-23
Exhibit 4-18: Unconstrained I-70 Network with Existing Rail in I-25 and West of Eagle.....	4-25
Exhibit 4-19: I-70 Right-of-Way Network with Greenfield’s in I-25 and West of Eagle.....	4-26
Exhibit 4-20: Equipment and Route Pairings Matrix .....	4-27
Exhibit 4-21: Technology Definitions .....	4-30
Exhibit 4-22: Route Definitions .....	4-31

**Chapter 5**

Exhibit 5-1: Speed Profile – BNSF Denver to Cheyenne via Boulder .....	5-5
Exhibit 5-2: Speed Profile – UP Denver to Cheyenne via Greeley .....	5-5
Exhibit 5-3: Speed Profile – Cheyenne to Denver via Fort Collins and Greeley GWRCO.....	5-6
Exhibit 5-4: Speed Profile – Cheyenne to Denver via Fort Collins and Milliken .....	5-7
Exhibit 5-5: Speed Profile – Cheyenne to Denver via Fort Collins and I-25 (220-mph Electric) .....	5-7
Exhibit 5-6: Speed Profile – Cheyenne to Denver via Fort Collins and I-25 (300-mph Maglev) .....	5-9
Exhibit 5-7: Schedule Time Summary for the I-25 North Corridor.....	5-9
Exhibit 5-8: I-25 South Existing Rail Corridor, Curvature Degrees per Mile by Line Segment .....	5-11
Exhibit 5-9: Proposal for Separating Freight from Passenger Operations on the Joint Line .....	5-13
Exhibit 5-10: Mileage Comparison Greenfield vs. Existing Rail on I-25 South .....	5-15
Exhibit 5-11: Speed Profile – Pueblo to Denver – Joint Line Current Geometry .....	5-15

Exhibit 5-12: Speed Profile – Pueblo to Denver – Joint Line Improved Geometry .....	5-16
Exhibit 5-13: Speed Profile – Pueblo to Denver – Greenfield w/Rail Option (220-mph Electric) .....	5-16
Exhibit 5-14: Speed Profile – Pueblo to Denver – Greenfield w/Rail Option (300-mph Maglev) .....	5-17
Exhibit 5-15: Speed Profile – Pueblo to Denver – Pure Greenfield Option (220-mph Electric).....	5-17
Exhibit 5-16: Speed Profile – Pueblo to Denver – Pure Greenfield Option (300-mph Maglev).....	5-18
Exhibit 5-17: Speed Profile – Trinidad to Pueblo.....	5-19
Exhibit 5-18: Schedule Time Summary for the I-25 South Corridor .....	5-20
Exhibit 5-19: Speed Profile – DIA to Avon – 220-mph Electric Rail Technology (45 mph on Grades) .....	5-23
Exhibit 5-20: Speed Profile – DIA to Avon– 220-mph Electric Rail Technology (60 mph on Grades) .....	5-23
Exhibit 5-21: Speed Profile – DIA to Avon– 220-mph Electric Rail Technology (I-70 Unconstrained).....	5-24
Exhibit 5-22: Mileage Comparison I-70 ROW vs. Unconstrained on I-70 East of Avon .....	5-26
Exhibit 5-23: Time Comparison I-70 ROW vs. Unconstrained on I-70 East of Avon .....	5-26
Exhibit 5-24: Speed Comparison I-70 ROW vs. Unconstrained on I-70 East of Avon.....	5-26
Exhibit 5-25: Schedule Time Summary for the I-70 Corridor East of Avon.....	5-27
Exhibit 5-26: Speed Profile – Grand Junction to Avon.....	5-28
Exhibit 5-27: Speed Profile – Craig to Dotsero.....	5-29
Exhibit 5-28: Speed Profile – Glenwood Springs to Aspen Airport.....	5-29
Exhibit 5-29: Schedule Time Summary for the I-70 Corridor West of Avon .....	5-31
Exhibit 5-30: Auto Travel Time Comparisons .....	5-32
Exhibit 5-31: Service Frequency and Base Fare as a Function of Train Speed .....	5-33
Exhibit 5-32: Train Service Pattern for 79-mph Diesel Rail Option.....	5-34
Exhibit 5-33: Train Service Pattern for 110-mph Diesel Rail Option.....	5-34
Exhibit 5-34: Train Service Pattern for 125-mph Maglev Option .....	5-35
Exhibit 5-35: Train Service Pattern for 150-mph Electric Rail Option .....	5-35
Exhibit 5-36: Train Service Pattern for 220-mph Electric Rail Option .....	5-36
Exhibit 5-37: Train Service Pattern for 300-mph Maglev Option .....	5-36
Exhibit 5-38: 2020 Startup Fleet Requirements for Each Scenario.....	5-37
<b>Chapter 6</b>	
Exhibit 6-1: RMRA Zone System .....	6-1
Exhibit 6-2: Colorado Zone System Showing MPOs .....	6-2
Exhibit 6-3: DRCOG – Denver TAZ Based Zones .....	6-3
Exhibit 6-5: Modes and Trip Purpose Basis of Stated Preference.....	6-5
Exhibit 6-6: Locations of Surveys.....	6-6
Exhibit 6-7: The Target /Actual Number of Surveys.....	6-7
Exhibit 6-8: Trip Purposes by Modes .....	6-8
Exhibit 6-9: Household Income by Modes .....	6-9
Exhibit 6-10: Comparison of Household Income Distribution.....	6-10
Exhibit 6-11: Value of Time by Trip Purpose and Mode (\$/hour).....	6-10
Exhibit 6-12: Value of Frequency by Trip Purpose and Mode (\$/hour) .....	6-11
Exhibit 6-13: Comparison of VOT (\$/Hour) .....	6-11
Exhibit 6-14: Summary of Base and Projected Socioeconomic Data: Population (in Million).....	6-12
Exhibit 6-15: Summary of Base and Projected Socioeconomic Data: Employment (in Million) .....	6-12
Exhibit 6-16: Summary of Base and Projected Socioeconomic Data: Average Household Income (in Thousand \$2007) .....	6-13
Exhibit 6-17: Colorado Population Projections.....	6-13

Exhibit 6-18: Employment Projection.....	6-14
Exhibit 6-19: Household Income Projection.....	6-14
Exhibit 6-20: Sources of Total Travel Data by Mode.....	6-16
Exhibit 6-21: Coverage of Existing Colorado Intercity Trips (> 55 miles).....	6-18
Exhibit 6-22: Base Year Trips by Mode.....	6-18
Exhibit 6-23: Comparison of CDOT AADT with COMPASS™ Estimate.....	6-19
Exhibit 6-24: Alternative Rail Options Evaluated.....	6-19
Exhibit 6-25: Frequency and Fares of Options Evaluated.....	6-20
Exhibit 6-26: I-70 Average Weekend Hourly Traffic Volumes: Glenwood Springs to Eagle County Line Eastbound.....	6-21
Exhibit 6-27: I-70 Average Weekend Hourly Traffic Volumes: Glenwood Springs to Eagle County Line Westbound.....	6-21
Exhibit 6-28: I-70 Average Weekend Hourly Traffic Volumes: Silverthorne to Loveland Pass Interchange Eastbound.....	6-22
Exhibit 6-29: I-70 Average Weekend Hourly Traffic Volumes Silverthorne to Loveland Pass interchange Westbound.....	6-22
Exhibit 6-30: I-25 Hourly Traffic Volumes Castle Rock-South of Plum Creek Parkway Northbound.....	6-23
Exhibit 6-31: I-25 Hourly Traffic Volumes Castle Rock-South of Plum Creek Parkway Southbound.....	6-23
Exhibit 6-32: U.S. Crude Oil Composite Acquisition Cost by Refiners - Historic Data and the Forecast.....	6-24
Exhibit 6-33: U.S. Retail Gasoline Prices as a Function of Crude Oil Prices (1993 –2008).....	6-25
Exhibit 6-34: U.S. Retail Gasoline Prices - Historic Data and the Forecast.....	6-25
Exhibit 6-35: Annual High-Speed Rail Ridership (millions of trips).....	6-26
Exhibit 6-36: Annual Ridership Forecast* (millions of trips).....	6-26
Exhibit 6-37: 79-mph, 110-mph, 125-mph Options – 2035 Market Share.....	6-27
Exhibit 6-38: 150-mph, 220-mph, 300-mph Options – 2035 Market Share.....	6-28
Exhibit 6-39: 79-mph, 110-mph, 125-mph Options – 2035 Ridership Breakdown.....	6-29
Exhibit 6-40: 150-mph, 220-mph, 300-mph Options 2035 Ridership Breakdown.....	6-30
Exhibit 6-41: Revenue Forecast by Option (Millions \$2008).....	6-31
Exhibit 6-42: Revenue Forecast (Millions \$2008).....	6-31
Exhibit 6-43: Ridership vs. Socioeconomic Sensitivity Analysis (in millions).....	6-32
Exhibit 6-44: Revenue vs. Socioeconomic Sensitivity Analysis (Millions \$2008).....	6-33
Exhibit 6-45: Ridership vs. Gas Price Sensitivity Analysis (Central Socioeconomic Scenario).....	6-34
Exhibit 6-46: Revenue vs. Gas Price Sensitivity Analysis (Central Socioeconomic Scenario).....	6-35
Exhibit 6-47: Ridership of Seasonal Weekday/Weekend Comparison (millions of trip).....	6-36
Exhibit 6-48: Revenues of Seasonal Weekday/Weekend Comparison (Millions \$2008).....	6-36
Exhibit 6-49: Key Components of Ridership Forecast.....	6-37
Exhibit 6-50: “Apples-to-Apples” Comparison of North East Corridor – NEC (1) and Colorado(2) (1-25/I-70) (Ridership, million of trips).....	6-39
Exhibit 6-51: “Apples-to-Apples” Comparison of Colorado and California Public Mode Markets (Ridership, million of trips).....	6-41
<b>Chapter 7</b>	
Exhibit 7-1: Operating Cost Categories and Primary Cost Drivers.....	7-2
Exhibit 7-2: Equipment Maintenance Cost per Mile (\$2008).....	7-5
Exhibit 7-3: Energy and Fuel - Cost per Mile (\$2008).....	7-8
Exhibit 7-4: Track Maintenance Cost Function (in \$2002).....	7-11
Exhibit 7-5: Guideway Maintenance – Cost per Track Mile (\$2008).....	7-12

Exhibit 7-6: Capital Cost Ramp-Up Following Upgrade of a Rail Line..... 7-13

Exhibit 7-7: Total Annual Operating Cost Breakdown by Technology..... 7-15

Exhibit 7-8: Average Cost per Train Mile by Technology ..... 7-16

**Chapter 8**

Exhibit 8-1: Engineering Project Development Phases and Levels of Accuracy Development ..... 8-2

Exhibit 8-2: Unit Capital Costs, Track work and Land Acquisition, in \$2008 ..... 8-8

Exhibit 8-3: Unit Capital Costs, Structures in \$2008..... 8-9

Exhibit 8-4: Unit Capital Costs, Systems, in \$2008 ..... 8-11

Exhibit 8-5: Unit Capital Costs, Crossings, in \$2008 ..... 8-11

Exhibit 8-6: Unit Capital Costs, Railroad Station/Maintenance Facilities, in \$2008..... 8-12

Exhibit 8-7: Unit Capital Costs, Right-of-Way, in \$2008..... 8-13

Exhibit 8-8: Unit Capital Costs, Maglev Guideway & Track, in \$2008..... 8-14

Exhibit 8-9: Unit Capital Costs, Maglev Systems, in \$2008..... 8-14

Exhibit 8-10: Unit Capital Costs, Maglev Maintenance Facilities in \$2008 ..... 8-15

Exhibit 8-11: Unit Capital Costs, Stations & Parking in \$2008..... 8-15

Exhibit 8-12: Incremental Rail in I-25 Upgrade Costs ..... 8-17

Exhibit 8-13: High-Speed Rail in Both I-25 and I-70 Upgrade Costs ..... 8-18

Exhibit 8-14: Major Capital Cost Segments ..... 8-19

Exhibit 8-15: Capital Cost Distribution for Unconstrained I-70/Existing Rail on I-25:  
 150-mph Electric..... 8-20

Exhibit 8-16: Capital Cost Distribution for I-70 Right-of-Way/Greenfield on I-25:  
 220-mph Electric Rail..... 8-20

**Chapter 9**

Exhibit 9-1: Consumer Surplus Concept ..... 9-6

Exhibit 9-2: Operating Ratio Results: Full-Network – 2035 – Central Case (Millions \$2008)..... 9-9

Exhibit 9-3: Economic Evaluation of Full Network – 2035 – Central Case (Millions \$2008) ..... 9-10

Exhibit 9-4: Operating Ratio Results: Truncated – 2035 – Central Case (Millions \$2008)..... 9-12

Exhibit 9-5: Economic Evaluation: Truncated – 2035 – Central Case (Millions \$2008) ..... 9-13

Exhibit 9-6: Mix-and-Match Applied to Truncated Networks ..... 9-14

Exhibit 9-7: Operating Ratio Results: Mix and Match – 2035 – Central Case (Millions \$2008)..... 9-15

Exhibit 9-8: Economic Evaluation of Mix and Match – 2035 – Central Case (Millions \$2008) ..... 9-16

Exhibit 9-9: Western Expansion Phase Alternatives ..... 9-17

Exhibit 9-10: Operating Ratio Results: Western Expansion – 2035 – Central Case (Millions \$2008)..... 9-18

Exhibit 9-11: Economic Evaluation of Western Expansion – 2035 – Central Case (Millions \$2008)..... 9-18

Exhibit 9-12: FRA Developed Rail Network for Detailed Evaluation ..... 9-20

Exhibit 9-13: FRA Developed Network with Western Extensions..... 9-21

Exhibit 9-14: FRA Developed Rail Network Alignments Map..... 9-22

Exhibit 9-15: FRA Developed Option, Summary of Key Results ..... 9-24

**Chapter 10**

Exhibit 10-1: Phase I – DIA to Colorado Springs..... 10-2

Exhibit 10-2: Phase II – Denver to Summit County Resorts..... 10-3

Exhibit 10-3: Phase III – I-25 Extensions to Pueblo and Fort Collins ..... 10-3

Exhibit 10-4: Phase IV – I-70 Extensions to Eagle Airport and Black Hawk..... 10-4

Exhibit 10-5: Proposed RMRA Implementation Plan ..... 10-6

Exhibit 10-6: Estimated Capital Cost by Project Element (Phase I)..... 10-7

Exhibit 10-7: Estimate Capital Cost by Project Element (Phase II)..... 10-8

Exhibit 10-8: Estimate Capital Cost by Project Element (Phase III) ..... 10-9  
Exhibit 10-9: Estimate Capital Cost by Project Element (Phase IV) ..... 10-10  
Exhibit 10-10: Projected Allocation of Construction and Equipment Costs ..... 10-11  
Exhibit 10-11: Pro-Forma Financials, Colorado FRA Developed Option, 2021-2050 ..... 10-14  
Exhibit 10-12: Comparison of Revenue and Consumer Surplus ..... 10-16  
Exhibit 10-13: Operating Ratio and Cost Benefit Calculation – 2010-2050 ..... 10-17  
Exhibit 10-14: Denver Metro Area: Risk Analysis Routes ..... 10-20  
Exhibit 10-15: I-25 North Risk Analysis Routes ..... 10-21  
Exhibit 10-16: I-25 South Risk Analysis Routes ..... 10-21  
Exhibit 10-17: I-70 West Risk Analysis Routes ..... 10-22  
Exhibit 10-18: Option 1 Elevated Option for Denver ..... 10-23  
Exhibit 10-19: Time and Mileage Comparison – I-25 North Corridor ..... 10-25  
Exhibit 10-20: Time and Mileage Comparison – I-25 South Corridor ..... 10-25  
Exhibit 10-21: 2035 Revenue and Ridership Performance of Bypass Options ..... 10-27  
Exhibit 10-22: 2035 Corridor Impact of Bypass Options ..... 10-27  
Exhibit 10-23: Risk Analysis Capital Costs ..... 10-30  
Exhibit 10-24: Non Compliant Equipment Cost Savings ..... 10-32  
Exhibit 10-25: Economic Results: Best/Worst Case NPVs ..... 10-33  
Exhibit 10-26: Economic Results: Best/Worst Case Cost Benefit Ratios ..... 10-34  
Exhibit 10-27: Economic Cost Benefit Range Results ..... 10-34

Page Intentionally Left Blank