

The background of the page is a semi-transparent image of a train station platform. A train is visible in the center, with the word "Northbound" written on its side. The platform has several tall, thin light poles. In the foreground, there is a dark silhouette of a city skyline with various building shapes. The overall color palette is muted, with greys, blues, and yellows.

# SECTION C

## TECHNOLOGY EVALUATION

## **Section C: Technology Evaluation**

This section includes the Technology Review Technical Memorandum from February 17, 2005 created as part of the RTD 3 Corridors Scoping Study. This technology review provides a brief comparison of LRT and commuter rail (specifically FRA compliant DMU) technologies and operating characteristics. The purpose of this memo is to assist RTD in selecting a preferred technology for the North Metro corridor. The analysis for the DMU vehicles was based on a maximum of 55 MPH in a direct comparison with the LRT vehicles. The potential maximum speed for the DMU can exceed 55 MPH.

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## TECHNICAL MEMORANDUM

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**DATE:** February 17, 2005 (Original Date)

**TO:** David Hollis, RTD

**SUBJECT:** Technology Review – Light Rail and Commuter Rail Vehicles

**FROM:** Parsons Corporation

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### **Introduction**

As part of the RTD 3 Corridors Scoping Study, Parsons was asked to provide a brief comparison of LRT and commuter rail (specifically DMU) technologies and operating characteristics to assist RTD in selecting a preferred technology for the North Metro corridor; this technical memorandum provides that summary.

The terms “Light Rail” and “Commuter Rail” describe two similar services for the transportation of commuters. Light Rail Transit (LRT) uses rail-borne vehicles that are not compliant with Federal Railroad Administration’s (FRA’s) standards for crashworthiness. While they may be operated on the General Railroad System, they cannot be co-mingled (in operation at the same time on the same track network) with freight or conventional railroad passenger trains. Examples of this type of service are the San Diego Trolley, Baltimore’s Central Light Rail Line, and the New Jersey Transit River Line. In each case, freight trains are restricted to operation within a specific time period (temporal separation), during which time, light rail vehicles cannot be operated in revenue service (while carrying passengers). Commuter rail equipment is compliant with FRA regulations and can be co-mingled with other types of FRA compliant railroad equipment. The cars are larger and heavier than light rail vehicles (LRV’s). Examples are Chicago’s Metra suburban lines and the Long Island Railroad.

Both Light Rail and Commuter Rail represent a level of capacity, in terms of passengers carried per unit of time, that is lower than “heavy rail” transit (rapid transit, or subway/elevated), and both are less expensive to implement. The terms “heavy” and “light” refer to the passenger carrying capacity per unit of time, not the weight of the vehicles. Heavy rail can carry significantly more passengers per hour than the other services, thanks to higher speeds, faster boarding from floor-level platforms through wider doors, and fewer stops. Heavy rail is appropriate for the very high concentrations of commuters such as those found in New York, Chicago, Boston, and Washington, DC.

The important difference between LRT and Commuter Rail is that Commuter Rail equipment is fully compatible with the general railroad system, and light rail is not. Light rail equipment lacks

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the minimum “buff strength” structural requirement necessary to operate on the same tracks at the same time as intercity passenger and freight trains.

In the last thirty years, sixteen new LRT systems have commenced operation in North America, in addition to older systems in cities such as Boston, Cleveland, Philadelphia, San Francisco, and Toronto. LRT consists of lightweight passenger rail cars operating singly or in multiple on a right-of-way (ROW) that may be either shared with motor vehicle traffic or restricted for exclusive use. Denver presently has a 16-mile LRT system with twenty-four stations, using a fleet of 49 electric light rail vehicles (LRV), with as many as three cars per consist in peak hours. Electric power is drawn from an overhead contact system (OCS).

Two FRA non-compliant low-floor diesel LRV systems are presently in operation in North America. One is the 35-mile New Jersey Transit (NJT) River Line in southern New Jersey, between Trenton and Camden. It was opened in 2004, utilizing a fleet of 20 diesel LRV’s. During peak period service, 2-car trains are operated. The other light rail diesel LRV operation is the O-train, in Ottawa, a 5-mile line opened in 2001, with a fleet of three diesel LRV’s, operated as single units. Both diesel LRV systems share the tracks with low volume freight service operations on a strict basis of temporal separation. This is necessary because neither of these light rail systems operates vehicles that are structurally compliant with Federal Railroad Administration’s standards for crashworthiness.

### **Regulation of Commuter Rail Operations**

FRA and the Federal Transit Administration jointly issued in July, 2000, a *Statement of Agency Policy Concerning Jurisdiction Over the Safety of Railroad Passenger Operations and Waivers Related to Shared Use of Tracks of the General Railroad System*. This has resulted in a broadening of the scope of commuter rail service that is subject to FRA safety oversight. Essentially, if a rail line, even one with exclusive tracks within a shared right-of-way, has the dominant characteristic of a residence-to-work-to-residence, non-intra municipal commuter rail operation, the probability is reasonably high that FRA will consider the line to be a commuter railroad, and subject to its safety regulation. The granting of waivers is, of course, part of the regulatory regimen. See Appendix B for excerpts from the Policy Statement.

Should the FRA choose to exercise its oversight, the service, whether it uses light rail vehicles or commuter rail vehicles, could be subject to FRA oversight in such areas as:

- track safety standards
- workplace safety
- operating rules
- communications
- hours of service
- safety appliance standards
- signal systems, including grade crossing warning devices
- passenger equipment safety standards
- passenger train emergency preparedness

This does not preclude the independent operation of non-compliant LRVs in the same ROW. FRA defines a *shared right-of-way* for either FRA-compliant or non-compliant vehicles

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operating on separate tracks as one where the track centers are less than 25 feet apart. FRA defines *Shared Corridor* for compliant or non-compliant vehicles as where the track centers are no more than 200 feet from the tracks on which compliant vehicles/freight cars operate. The key factor is whether the tracks used by the non-compliant vehicles are separated or not. As long as the tracks are completely separated (there are no turnouts allowing a train to move from one line to the other), non-compliant vehicles may be operated independently. The only exception permitted is an interchange track that might see occasional use to move work equipment and material onto the light rail line from the railroad line. Movement between the two on a regular basis is not acceptable.

### **Technologies**

Three basic technologies for rail transit equipment are described in the following sections.

- Section 1. Electric light rail vehicles (LRV) compatible with the existing RTD system (FRA non-compliant)
- Section 2. Diesel light rail vehicles (diesel LRV), such as the NJT River Line vehicle (FRA non-compliant)
- Section 3. Commuter rail Diesel Multiple Units (DMU), such as the Colorado Railcar DMU (FRA-compliant) in both single (3a) and bi-level configurations (3b).

Figures 1 and 2, below, show the NJT River Line diesel LRV manufactured by Switzerland's Stadler Rail Group, and the SFRTA/Tri-Rail Demonstration Project vehicle, Colorado Railcar Manufacturing's heavy rail, single level DMU.



**Figure 1**  
NJT River Line Diesel Light Rail Vehicle



**Figure 2**  
Colorado Railcar Commuter Rail DMU

***1. Electric Light Rail Transit Vehicles compatible with existing RTD system***

For purposes of analysis, the RTD's light rail design criteria (revised October 2000) are appropriate since the criteria for existing and future expansion of RTD are contained therein. Presently, RTD has a fleet of 49 vehicles manufactured by Siemens Duwag, referred to as the SD100 model. The LRV's are 6-axle, single articulated, bi-directional vehicles that may operate as a single unit, or in multiple up to three units. The vehicles are approximately 80 feet long, 8'9" wide, and 13 feet high above the rail. The vehicles weigh approximately 41 tons and have high-level floors.

LRV's are powered by OCS at a nominal voltage of 750 Vdc and are capable of speeds up to 55 MPH. Each vehicle seats 64 passengers and will accommodate up to 61 standing passengers at a normal load level. Additional standees can be accommodated at crush load level of 150 passengers. The SD100 has proven itself in the environmental conditions of the Denver area, including ambient temperature ranging from -30°F to +110°F, heavy snowfall, ice conditions, and 5,000 feet elevation.

Table 1, on the next page, summarizes characteristics of the Denver LRV.

**Table 1**  
**Selected RTD Light Rail Vehicle Characteristics**

Vehicle tare weight	89,000 lbs
Weight in pounds per foot of vehicle length	1,106 lbs
Length of car over coupler faces	80.5 feet
Maximum width of car (excluding mirrors)	8.83 feet
Maximum roof height (excluding pantograph)	12.5 feet
Minimum door bottom clearance above top-of-rail	10.25 inches
Pantograph operating height	22.97 feet
Seating capacity	64
Maximum operating speed	55 mph
Minimum horizontal curve radius	82 feet
Maximum gradient	7%
Acceleration (non-crush load)	3.0 mphps
Instantaneous service brake deceleration	3.5 mphps

Source: RTD Light Rail Design Criteria, October 2000

## **2. Diesel Light Rail Vehicles**

A diesel LRV is similar to an electric LRV, except that it carries its own power supply, rather than collecting current from an overhead supply. A diesel-propelled vehicle tends to be heavier and slower to accelerate than a comparable electric LRV. However, it is considerably less expensive to construct/implement a service because the OCS and the related power distribution system are not required.

In 2004, New Jersey Transit's River Line between Camden and Trenton commenced revenue service with diesel powered LRV's on a 34-mile line that operates primarily on the Bordentown Secondary line of Norfolk Southern Railway (with at-grade highway crossings), as well as on the streets in downtown Camden. Because the vehicle does not meet the FRA crashworthiness standard, River Line passenger and NS freight service must be operated in temporal separation. Freight service is conducted between approximately 10 p.m. and 6 a.m., when passenger service is not operating.

NJT River Line diesel LRV's were manufactured in Switzerland and Germany by Stadler Rail Group, in partnership with Bombardier Transportation. The River Line has a fleet of twenty articulated cars that operate on 15-minute headways during peak periods, and 30-minute headways at other times. All trains run the length of the route, as there are no turn-back schedules. Each car has a low floor section constituting 66 percent of the vehicle's passenger compartment. Traction equipment is housed in a separate drive module with a 32-inch aisle for passengers. Each car has a seating capacity of 90, including 20 fold-up seats. At crush-load, the vehicle capacity is 164 passengers. The maximum speed in service is 60 MPH. Additional selected data on the NJT River Line vehicle is contained in Table 2, on the next page. The lighter weight of the NJT River Line diesel LRV provides a modest fuel efficiency advantage over the heavy rail DMU.

**Table 2**  
**Selected Data for the NJT River Line Diesel LRV**

Vehicle tare weight	120,560 lbs
Pounds per foot of vehicle length	1,176 lbs
Overall length	102'6"
Vehicle width	9'10"
Height (rail to roof)	12'10"
Seating capacity	90
Minimum horizontal curve radius	131 feet
Diesel engine	diesel electric, 550 kW
Maximum acceleration at GVW	2.1 mphps
Maximum deceleration	4.7 mphps
Maximum operating speed	60 mph

Source: Stadler Rail Group AG

**3a. Heavy Rail Single-level DMU (Colorado Railcar)**

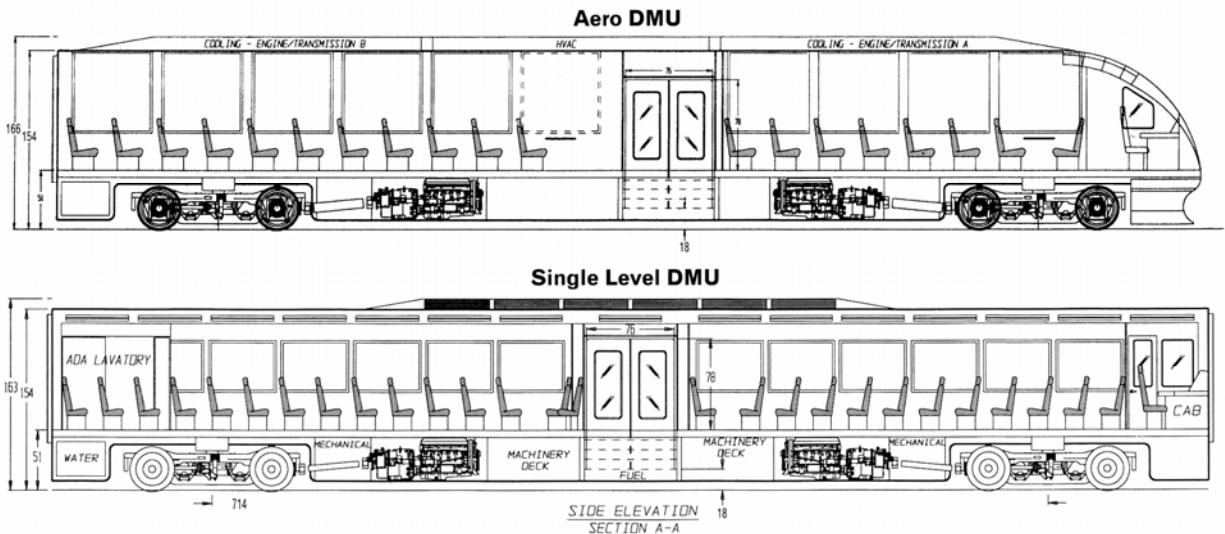
Self-propelled rail cars with internal combustion power have had a long history of service by the privately owned U.S. railways and the railways of Canada. The last significant fleets of self-propelled rail diesel cars (RDC's) operated by the North American railway companies were cars manufactured by the Budd Company in the 1950's. Budd RDC's were 85 feet long, the same as a standard railroad passenger car, and were designed to operate either as a single unit or in multiple. Trinity Rail Express (TRE) in Dallas commenced service in 1996 utilizing 13 re-built Budd RDCs acquired from VIA Rail Canada. Budd RDC bodies are now nearly fifty years old and do not present a feasible equipment option for a new start-up service. TRE switched to locomotive-hauled trains for the expansion of service to Fort Worth in 2001, using re-built bi-levels acquired from GO Transit in Toronto, and cab control cars manufactured by Bombardier.

DMUs are widely used in Europe today, with active production lines by several manufacturers. The train operating companies in the United Kingdom are particularly active customers for non-electrified lines. A complication for potential U.S. operations is that these European DMU's do not meet Federal Railroad Administration (FRA) crashworthiness standards for joint passenger and freight train operations in the U.S.

A DMU that is structurally compliant with Federal Railroad Administration (FRA) standards entered revenue service in South Florida in February 2004. It was a "demonstrator" produced by Colorado Railcar Manufacturing LLC, in Fort Lupton, Colorado. In March 2004, the South Florida Regional Transportation Authority (SFRTA/Tri-Rail), representing FRA and the Florida DOT in a joint procurement agreement, approved a DMU Demonstration Project that included acquisition of three commuter rail cars. The single-level DMU demonstrator has been purchased. A double-deck DMU and a double-deck, low floor trailer coach have been ordered from Colorado Railcar for delivery in April, 2005.

FRA-compliant DMU cars are heavier per foot of length than diesel LRV's because of greater structural strength required, thereby being less energy efficient, especially when frequent stops are required. Also, a non-articulated heavy rail car, typically 85 feet in length, has less capability in negotiating tight horizontal and vertical curves.

The single-level Colorado Railcar DMU recently toured the country as a demonstrator. This car may be viewed as a generational successor to the RDC. Colorado Railcar states that the vehicle is the first rail diesel car certified by the FRA to operate simultaneously on rail lines with freight service. The vehicle has passed all FRA tests for crashworthiness, and emissions related to noise and air quality. The Power car is available in an aerodynamically designed profile, as well as a conventional form, with trailer cars available to match. A fully seated Power car can accelerate to 55 mph in 43 seconds. Figure 3 presents a schematic of the Colorado Railcar DMU in an aerodynamic profile and in a conventional profile.



**Figure 3 – Colorado Railcar Single Level DMU’s**

Single-level trains can be operated with a single Power car with up to 98 seats in a 2-2 seating configuration. Operating flexibility can be achieved as indicated in Table 3 below.

**Table 3  
Single-Level Train Consist Flexibility  
Colorado Railcar DMU Commuter Car**

Seats	Train Consist
98	Power car
200	Power car - Trailer with cab controls
298	Power car – Trailer - Power car
400	Power car - Trailer, Trailer - Power car

Source: Colorado Railcar

The Colorado Railcar DMU is constructed of tubular Corten steel in a truss design, to protect passengers from sidewall intrusion. Passenger boarding/alighting is via mid-car double doors, with a boarding height of 18” above the top of rail.

Selected car specification data and performance statistics for the single-level Colorado Railcar are contained in Table 4, on the next page.

**Table 4**  
**Single-Level Colorado Railcar DMU Commuter Car**  
**Selected Specification Data**

Length (over couplers)	85' 0"
Width	10' 0"
Height (rail to roof)	13' 7"
Height (rail to lower floor)	4' 3"
Tare Weight – Cab Car	148,000 lbs
Tare Weight – Trailer Car	142,000 lbs
Seating Capacity	
Cab Car	98
Trailer Car	102
Service braking	1.5 mph per second
Emergency braking	1.8 mph per second
Minimum horizontal curve radius	250'
Power supply	Two 600 hp Detroit Diesel engines
Maximum operating speed	90 mph

Source: Colorado Railcar

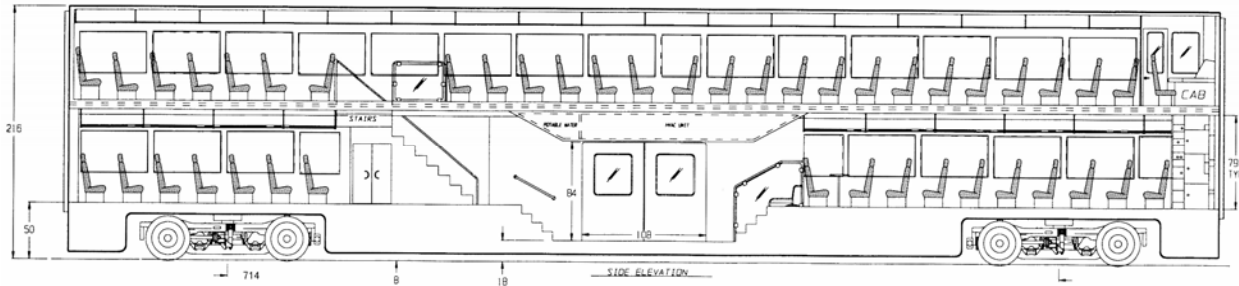
The capability of the Colorado Railcar DMU to haul a trailer is a feature not available in the previous generation of rail diesel cars. Budd RDCs required that each unit have its own power train system. The Power car of a Colorado Railcar DMU consists of two Detroit Diesel series 60 engines with electronic fuel control. Each engine is rated at 600 hp, with 500 hp available for final drive state and 100 hp dedicated to power supply. The transmissions consist of two Voith Turbo, Inc. (York, PA) units, T212 BRE with KB190 retarder. Fuel mileage is between 1.5 – 2.0 miles per gallon.

During a demonstration on the Alaska Railroad, a Colorado Railcar DMU pulling a passenger car was purposely stopped on a 3.2% grade, and then accelerated to track speed at 15 mph. The Colorado Railcar specification is capable of operating on a 6% grade, including grades associated with commuter rail “fly-overs”.

A Power car of Colorado Railcar, seating 92 passengers, costs approximately \$2.9 million, about the same price as a new diesel-electric locomotive or an LRV. A cab control, 92 seat, DMU trailer is about \$1.9 million. A completely powered push/pull train with a capacity of about 184 seated passengers is approximately \$5.8 million dollars.

**3b. Heavy Rail Bi-Level DMU – (Colorado Railcar)s**

Colorado Railcar Manufacturing, LLC, also offers a DMU bi-level (Figure 4, on the next page) with seating up to 185, permitting more passenger carrying capacity with a modest increase in operating cost. This model is included in the order by SFRTA/Tri-Rail for delivery in April 2005. The bi-level power car is designed to provide sufficient horsepower to pull a trailer in a consist with another power car, with a total seating capacity of up to 560. A fully seated Colorado Railcar bi-level DMU can accelerate to 55 mph in 58 seconds. The bi-level equipment is also suitable for circumstances of limited terminal platform capacity, as well as major seating capacity expansion and flexibility. The DMU bi-level option is not available with electric LRV's or the NJT River Line diesel LRV equipment.



**Figure 4 – Colorado Railcar Bi- Level DMU’s**

Bi-level trains can be operated with a single Power car with up to 185 seats in a 2-2 seating configuration. Operating flexibility with can be achieved as indicated in Table 5, below.

**Table 5  
Bi-Level Train Consist Flexibility  
Colorado Railcar DMU Commuter Car**

Seats	Train Consist
185	Power car
560	Power car - Trailer - Power car
1120	Power car – Trailer – Trailer - Power car

Source: Colorado Railcar

Selected car specifications for the Colorado Railcar bi-level DMU are in Table 6, below.

**Table 6  
Bi-Level Colorado Railcar DMU Commuter Car  
Selected Specification Data**

Length (over couplers)	85' 0"
Pounds per foot of vehicle length – motored cab car	1,918 lbs
Pounds per foot of vehicle length – trailer car	1,847
Width	10' 0"
Height (rail to roof)	18'
Height (rail to lower floor)	4' 3"
Tare Weight – Cab Car (motored)	163,000 lbs
Tare Weight – Trailer Car	157,000 lbs
Seating Capacity	
Cab Car	185
Trailer Car	190

Source: Colorado Railcar

Selected performance statistics for the Colorado Railcar bi-level DMU are indicated in Table 7, found on the next page.

**Table 7**  
**Performance and Design Features of Colorado Railcar Bi-Level DMU**

Maximum Operating Speed	90 mph
Service Braking Rate	1.5 mph per second
Emergency Braking Rate	1.8 mph per second
Minimum Horizontal Curve Radius	250'
Power Supply	480 V, 3 ph, 60 Hz head-end power

Source: Colorado Railcar

### **Factors Concerning Shared Use of Tracks/Right-of-Way (with freight trains)**

The North Metro line between Denver Union Station and 162<sup>nd</sup> Avenue is approximately 18.8 miles in length. The line utilizes about 10 miles of the Union Pacific Railroad's (UP) Boulder Industrial Lead track commencing in the vicinity of Sand Creek (Crossing of Union Pacific, and Burlington Northern and Santa Fe railroads). UP operates a local freight service one time per week, serving two customers on the Boulder Industrial Lead track. Assuming the continued presence of these rail freight customers, there is the issue of integration of freight and passenger service on the line. This issue can be addressed in three ways:

1. Using FRA-compliant passenger vehicles operating at any time on two tracks;
2. Using non-compliant diesel LRV equipment, such as on the NJT River Line, with temporal separated operations on two tracks; or
3. Having complete physical separation on three tracks as available ROW allows.

### **North Metro Operating Headways**

A FasTracks Operating Plan Memorandum, dated February 1, 2004, indicates a conceptual run time of 25 minutes between Denver Union Station and 124<sup>th</sup> Avenue. The FasTracks plan projects 15-minute peak period headway and 30-minute off-peak headway to 124<sup>th</sup> Avenue.

At this writing, North Metro service to 162<sup>nd</sup> Avenue is projected at 30-minute headways at peak, and hourly at off peak periods. The North Metro line as proposed would average about 2.4 miles between stations.

The North Metro line commuter corridor is a typical application for a commuter rail DMU service with 30-minute intervals operating in peak periods. A train with a three-car consist would have a seating capacity of about 270 using diesel LRV's, and about 298 using heavy rail single level DMUs (Colorado Railcar).

### **Vehicle Run-time Demonstration**

An important question regarding vehicle technology is the effect of the LRV's acceleration advantage over diesel powered vehicles, and the potential difference in run-time between the two technologies. To gain an understanding of this run-time difference, a demonstration simulation was run.

Vehicle run-times were estimated by using Union Pacific track chart data (curvature and profile), between Sand Creek and 162<sup>nd</sup> Avenue. As the alignment between Denver Union Station (DUS) and the UP Boulder Industrial Lead has not been determined at this writing, alignment assumptions were made for this segment. These assumptions include:

- 35-40 mph speed limit in the vicinity of DUS to reflect probable curvature in that area
- Use of the BNSF route between and DUS and Sand Creek
- North Metro track alignment and profile on the BNSF route will support 55 mph operation

Additional assumptions used to make this demonstration include:

- The North Metro line is double-track
- The North Metro line is grade-separated from the UP and BNSF mainline freight railroad operations
- Maximum Authorized Speed (MAS) is limited to 55 mph (some alignment segments may be suitable for higher speeds, but engineering feasibility was not evaluated herein)

The demonstration simulation used the acceleration and deceleration rates of the Denver RTD light rail vehicles, Colorado Railcar single level DMU’s, and NJT River Line diesel LRV’s. Based on these assumptions, the run times presented herein are representative of the performance to be expected over the North Metro route.

For this demonstration, a train consisting of two RTD LRV’s was compared to the following:

- A Colorado Railcar DMU with a non-powered trailer car
- Two powered Colorado Railcar DMU’s
- Two Stadler diesel LRV’s (as used on NJT River Line)

Table 8, below, summarizes the comparative performance on northbound runs for the proposed North Metro 18.8-mile run between Denver Union Station and 162<sup>nd</sup> Avenue, with 7 intermediate station stops.

**Table 8  
Comparative Run-times on Proposed North Metro Line**

Vehicle Type	Train Consist/ Seated Capacity	Train Run Time (minutes)	Time vs. LRV (minutes)	Average Speed (mph)
RTD LRV	2 LRV’s/128	27.0	-----	41.7
Colorado Railcar DMU	DMU w/trailer/200	31.9	+4.9	35.4
Colorado Railcar DMU	2 DMU’s/196	29.1	+2.1	38.8
Stadler Diesel LRV (NJT)	2 DLRV’s/180	28.9	+1.9	39.0

As noted in Table 8 above, the higher acceleration rate advantage of the LRV does produce a 1.9 to 4.9-minute run-time advantage for an electrified operation. It should be noted; however, that this LRV acceleration speed advantage might be offset by the higher speed capabilities of the DMU (90 mph) and diesel LRV (60 mph). Maximum operating speed is limited to 55 mph in this demonstration to specifically test the acceleration variance between the LRV and the diesel powered vehicles.

A Colorado Railcar DMU with a non-powered trailer requires about 2.8 minutes longer run-time than a train consisting of two powered Colorado Railcar DMU's. A difference of about 2 minutes exists between the diesel powered vehicles (with no unpowered trailers) and the electric LRV. This time difference may not have a significant impact on ridership. Train performance graphs corresponding to Table 8 are contained in Appendix A of this document.

The seated capacity of the two-car Colorado Railcar DMU train is 196, compared with 128 seated for a 2-car LRV train, or 180 for the two-car NJT Stadler diesel LRV.

### Capital Costs

Based on the assumption that the Metro North track structure cost, including signaling, stations and yard tracks, will be comparable for either electrified or DMU operation; these costs are not addressed herein. Equipment acquisition unit costs for single-level DMU's, bi-level DMU, and LRV's and catenary costs for electrification are presented in Table 9.

**Table 9**  
**Unit Capital Costs**  
(\$millions, except seat costs)

System Element	RTD LRV	River Line Diesel LRV	Colorado Railcar Single-Level DMU	Colorado Railcar Bi-Level DMU
Vehicles, each	\$2.8	\$3.7	\$2.9	\$3.9
Seats	64	90	92	185
Per seat capital cost	\$43,750	\$41,110	\$31,520	\$21,100
Electrification per double track route-mile including substations	\$3			
Refueling facility		\$2.0	\$2.0	\$2.0

Source: RTD, New Jersey Transit, and Colorado Railcar

A Colorado Railcar low-floor trailer with cab is approximately \$2.0 million and seats 92 passengers.

The NJT River Line diesel LRV model, manufactured by the Swiss firm Stadler Rail, AG, averaged \$3.7 million each, as part of the order for 20 DMU's for the River line at a total cost of \$74.0 million, including design, construction and delivery costs.

Assuming 20 miles of double-track electrification, the capital cost of electrification would be approximately \$42.0 million.

### Conclusions

Ultimate technology selection hinges on a number of factors summarized in Table 10, found on the next page.

**Table 10**  
**Vehicle Use Characteristics**

Element	Suitability		
	LRV	Diesel LRV	DMU
Integrated with freight operations			●
Future line expansion i.e. 50-70 mile line			●
Dense ridership/short distance between stations	●		
Street running	●	●	
Less dense ridership/longer run between stations			●
Bi-level capability			●
Vehicle capital cost per seat (single level)	\$43,750	\$41,110	\$31,520
Performance – highest acceleration rate	●		
Performance – maximum operating speed (mph)	55	60	90

The technology selection process entails balancing a number of factors such as the strategic vision for the service area, including outer reaches of the envisioned network, the role of Denver Union Station as a multi-modal and as a multi-rail technology hub, and the region’s anticipated demographic changes anticipated in the long term.

The general transit characteristics of the North Metro Corridor can be summarized as follows:

- Moderate station spacing,
- Moderate passenger density,
- Potential for future long distance expansion, 20-50 miles,
- No street running, and
- Integration with freight operations is necessary (at this writing)

Based on the above characteristics, at this writing it appears that the DMU vehicle most closely fits the working parameters needed to operate within the above characteristics.

In addition, the DMU has the lowest capital cost per seat as compared with the other technologies, and has the highest operating speed. High operating speed may offset the acceleration advantage of an LRV over long distances, and longer distance between station stops.

The foregoing should not be taken as a recommendation, as the planning for the North Metro project is in very preliminary stages and changes may occur that could alter this initial indication. For example, this initial indication could be affected by an agreement with the UP granting temporal time limits, at which time the diesel LRV could come under consideration. Additionally, operating and maintenance costs for all technologies should be fully evaluated. These O&M costs are not readily available at the time of this examination due to limited DMU operations currently in place.

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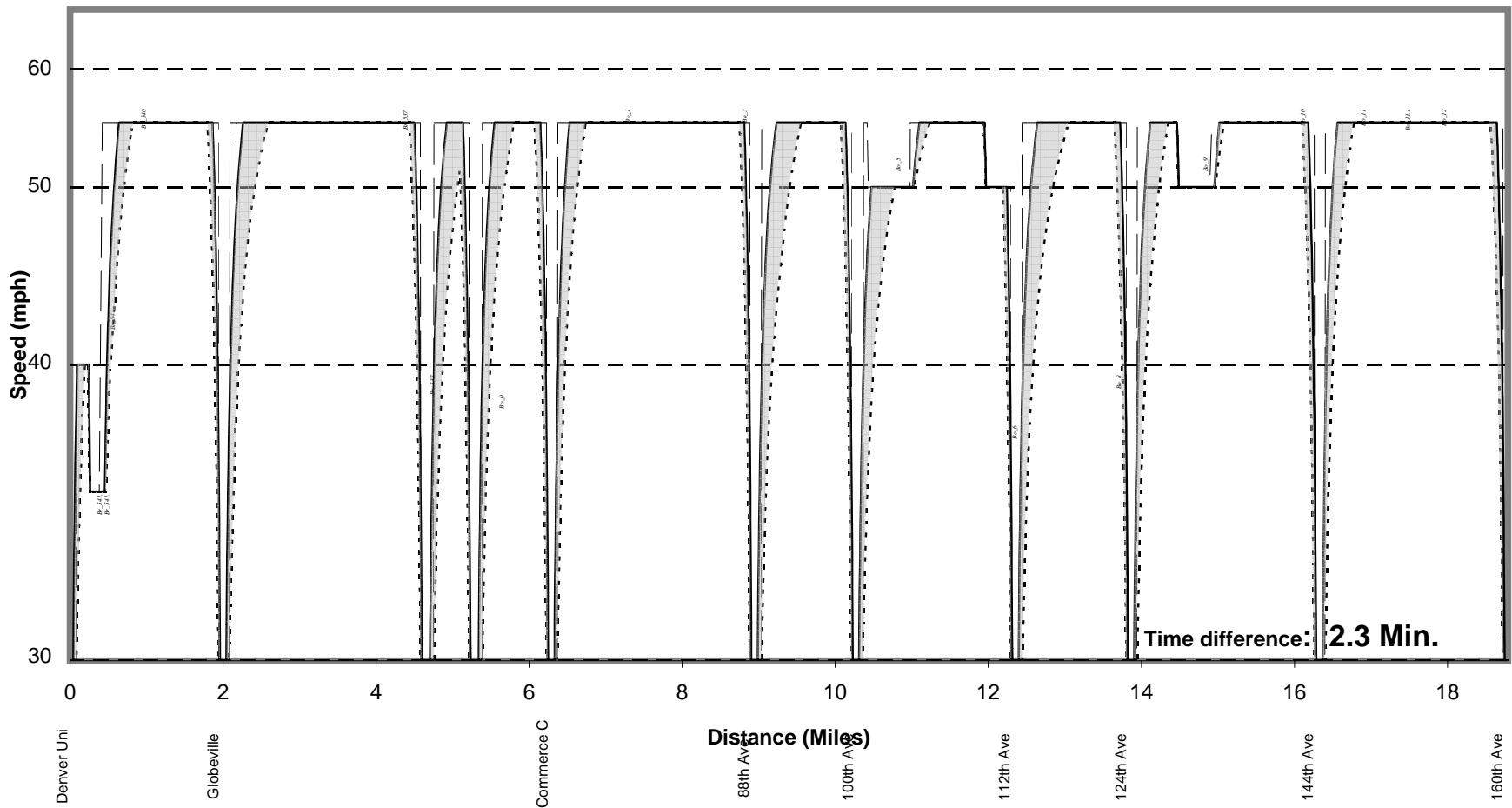
**APPENDIX A**

**TRAIN PERFORMANCE COMPARISON**

**TIME DIFFERENCE**  
**DENVER TO 160TH AVENUE**  
**2 DMU (NJT River Line/Stadler) vs**  
**2 RTD LRV's**

Note: Graph does not show 0-30 MPH speed regime. Shaded area represents speed differential.

- - - - - DMN\_WB\_SET2GTW26 2xV-0Trailing Cars    — — — — — Base Speed Limit    — — — — — DMN\_WB\_SET2DART 2xLRV-0Trailing Cars



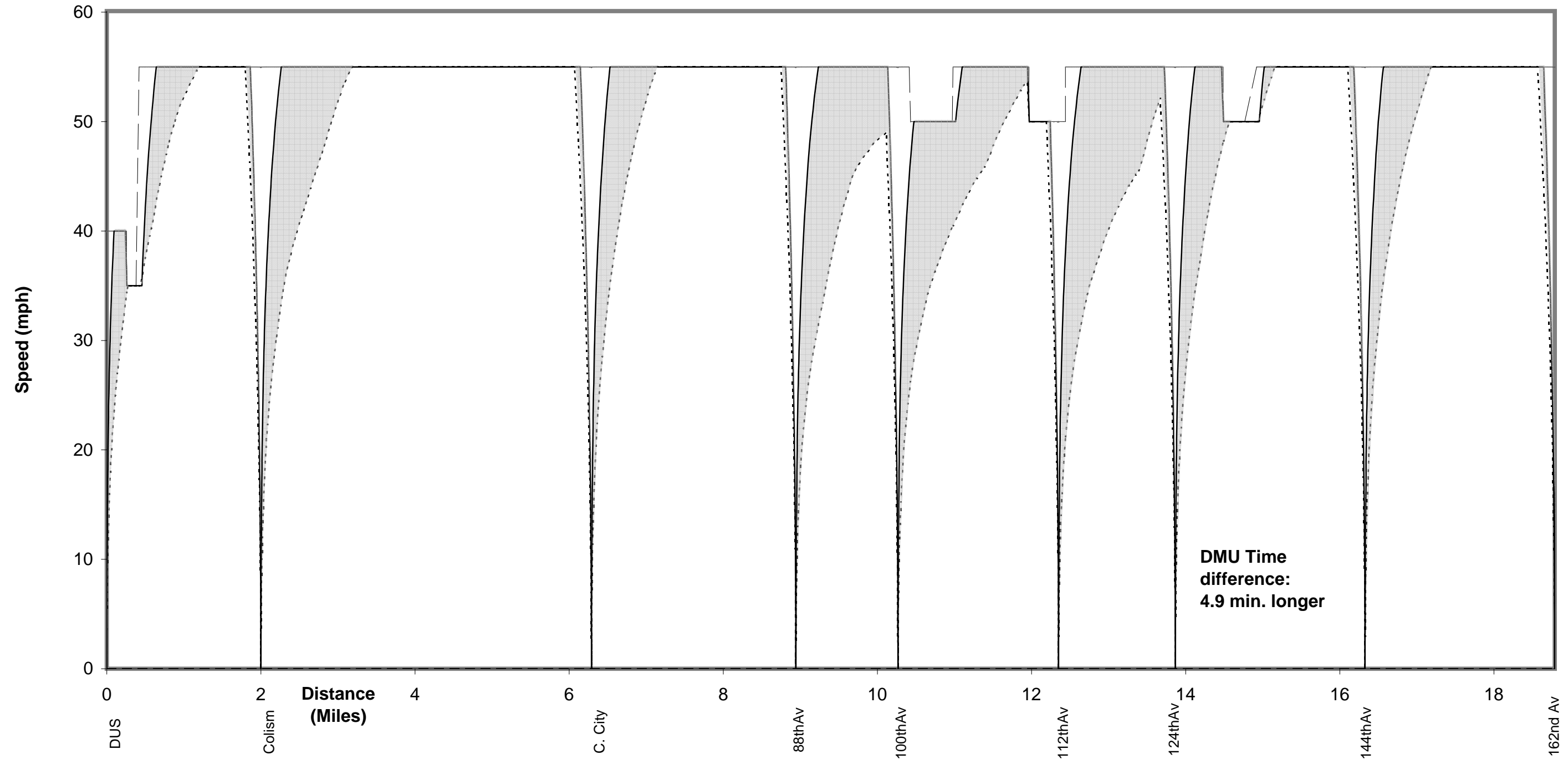
# TIME DIFFERENCE

DENVER TO 162nd Avenue

Colorado Railcar DMU with trailer vs 2 RTD LRV's

Shaded areas represent the speed differential between DMU and LRT.

----- Colorado Railcar DMU with Trailer    — - Base Speed Limit    — RTD LRV





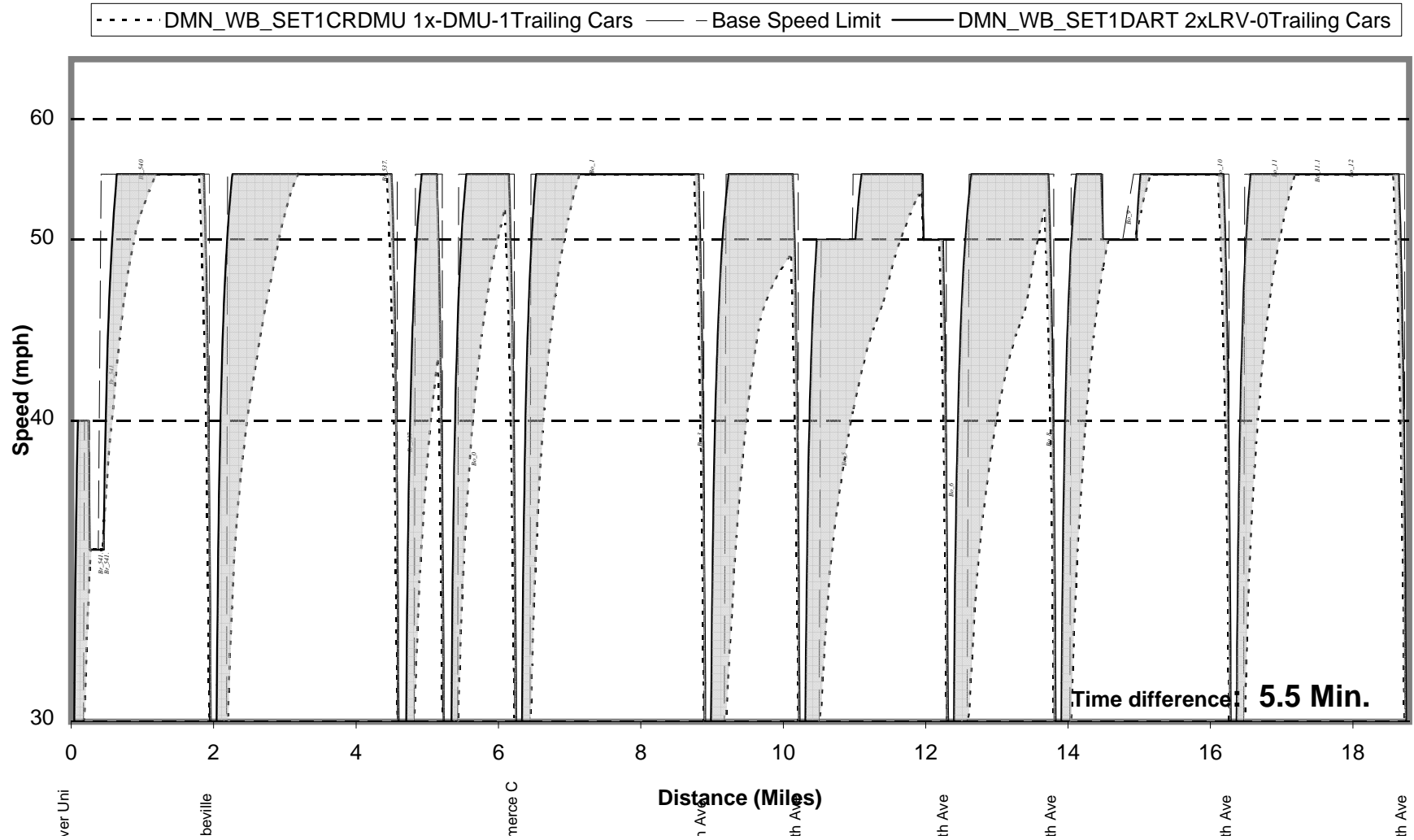
# TIME DIFFERENCE

## DENVER TO 160TH AVENUE

### Colorado Railcar single-level DMU with trailer vs. 2 RTD LRV's

Note: Graph does not show 0-30 MPH speed regime because differences are slight.

Shaded areas represent the speed differential between LRT and DMU.



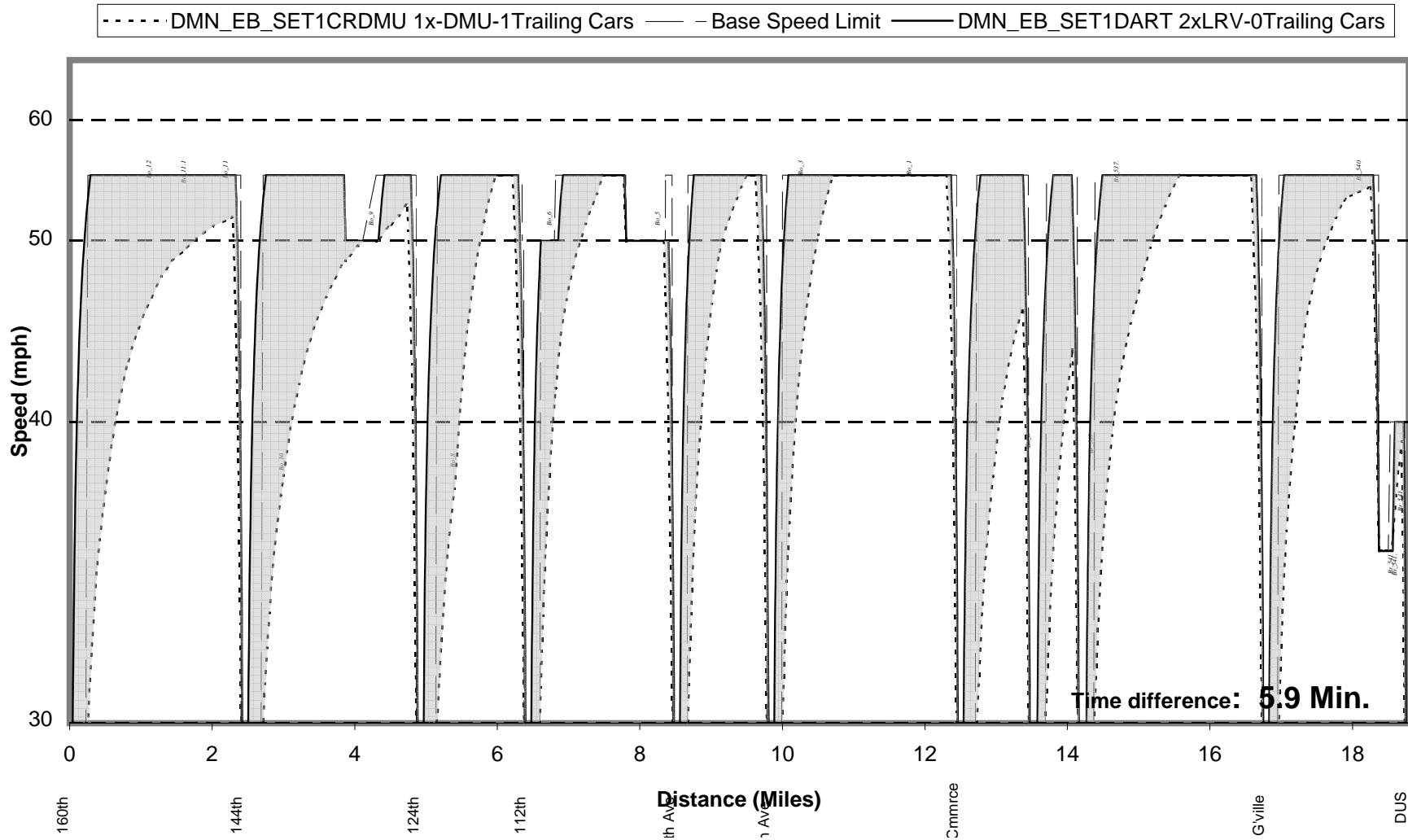
# TIME DIFFERENCE

## 160TH AVENUE TO DENVER (Eastbound)

### Colorado Railcar single-level DMU with trailer vs. 2 RTD LRV's

Note: Graph does not show 0-30 MPH speed regime because differences are slight.

Shaded areas represent the speed differential.



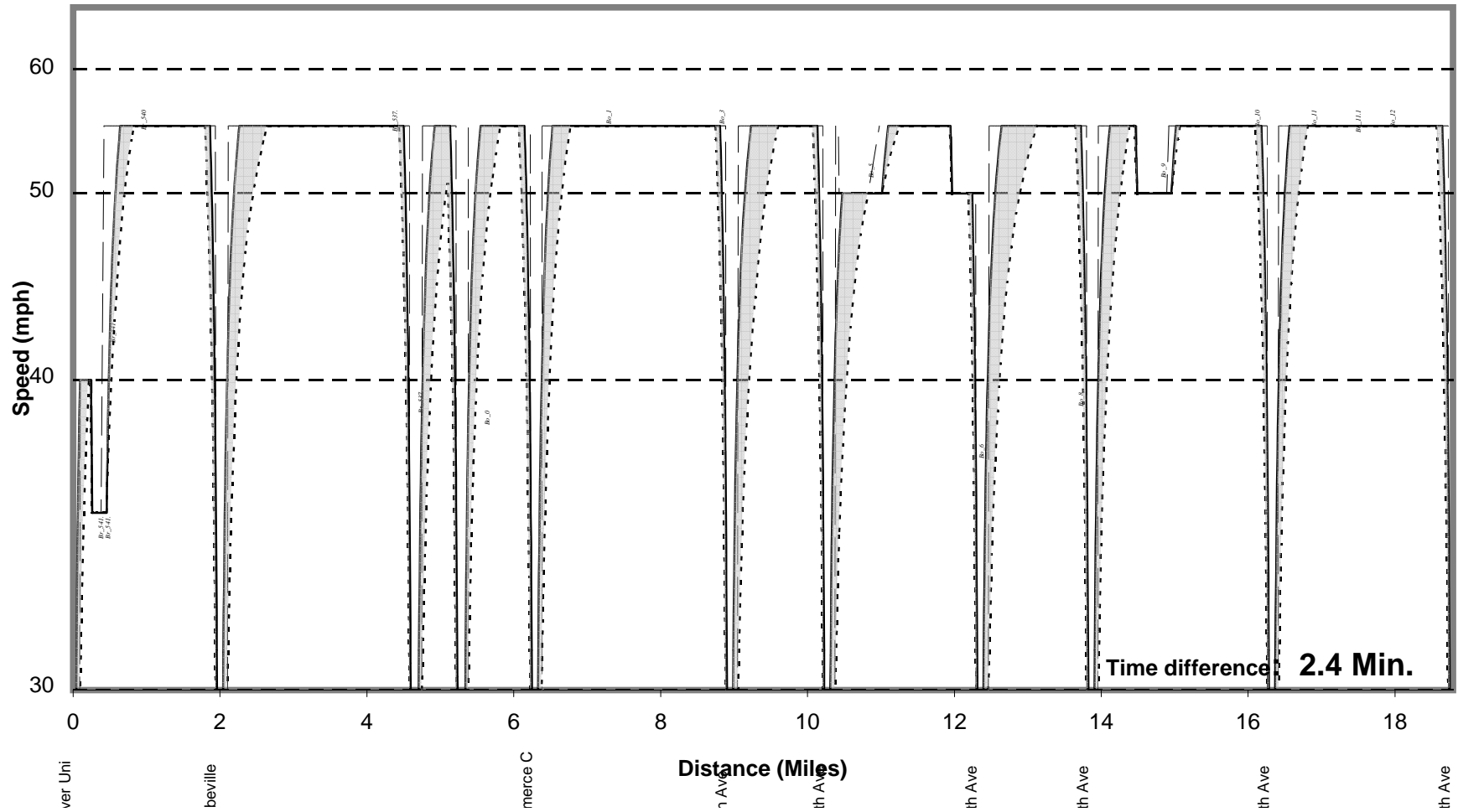
# TIME DIFFERENCE

## DENVER TO 160TH AVENUE

### 2 Colorado Railcar DMU's vs 2 RTD LRV's

Note: Graph does not show 0-30 MPH speed regime because differences are slight.  
Shaded areas represent the speed differential between LRT (solid line) and DMU (dotted line).

----- DMN\_WB\_SET2CRDMU 2x-DMU-0Trailing Cars    — Base Speed Limit    — DMN\_WB\_SET2DART 2xLRV-0Trailing Cars



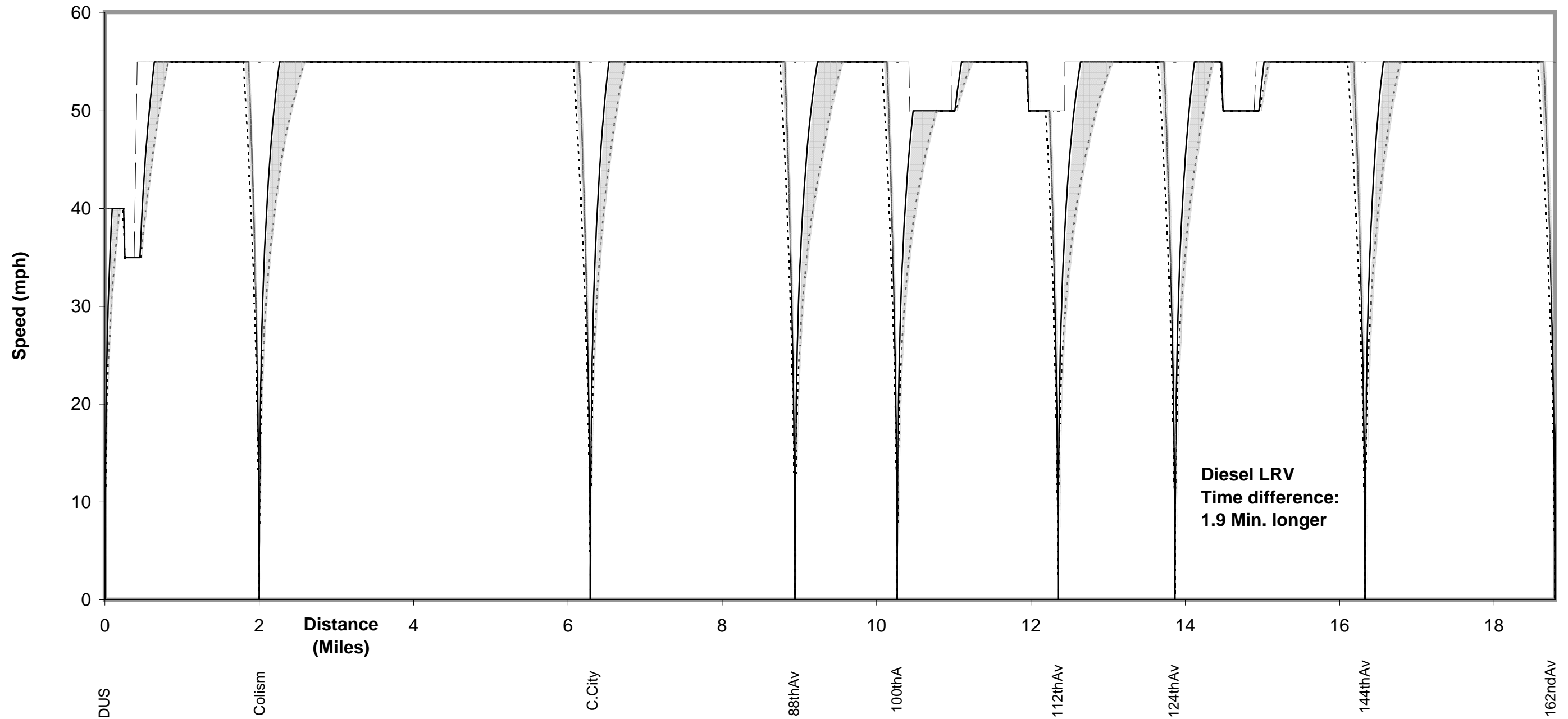
# TIME DIFFERENCE

DENVER TO 162nd Avenue

2 Diesel LRV's (NJT River Line/Stadler) vs 2 RTD LRV's

Shaded areas represent the speed differential between diesel LRV and RTD LRV

..... Diesel LRV    — Base Speed Limit    — RTD LRV



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## APPENDIX B

### Regulatory Policy Regarding Shared Use

#### Excerpts from the July, 2000, a *Statement of Agency Policy*

The primary issue addressed by this policy statement is the means by which FRA and FTA propose to coordinate their safety programs with regard to rail transit systems that share tracks with freight railroads. Although compatible in terms of track gauge, these two forms of rail service are incompatible in terms of equipment. A collision between a light rail transit vehicle with passengers aboard and heavy-duty freight or passenger equipment would be catastrophic.

#### **Potential for a Collision**

The most important safety issue related to shared use of general [railroad] system trackage is the potential for a catastrophic collision between conventional rail equipment and rail transit equipment of lighter weight. Because of the significantly greater mass and structural strength of conventional equipment, the two types of equipment are simply not designed to be operated in a setting where there is any appreciable risk of their colliding.

#### **Shared Use of Highway-Rail Grade Crossings**

For decades, the greatest cause of death associated with railroading in America has been collisions between railroad vehicles and highway vehicles at grade crossings. ...[S]hared-trackage light rail operations on the general [railroad] system will typically involve train movements through highway grade crossings. To the extent train movements through grade crossings increase, the collision exposure to the highway user increases.

A related issue is the prevalence of death and serious injury to trespassers on railroad property. Trespasser fatalities have recently outpaced grade crossing accidents as the leading cause of death on the nation's railroads. To the extent that shared use of general [railroad] system trackage results in a substantial increase in the number of pedestrians crossing by foot in the path of trains, the potential for additional deaths to trespassers is very real and should be addressed in planning these operations.

#### **Shared Infrastructure**

Light rail operations on general [railroad] system tracks will affect and be affected by the track, bridges, signals, and other structures on the line. The light rail and conventional systems may also share a communications system. The responsibility for operating and maintaining this shared infrastructure may vary according to the agreements reached between the parties. However, even if the light rail operator has no direct responsibility for maintenance, there will need to be sufficient coordination to alert the light rail operator to related safety problems and to ensure the light rail operator conveys relevant information (e.g., readily apparent track defects or signal failures) to the party responsible for operation and maintenance.

#### **Employee Safety**

Employees who operate trains on general [railroad] system track, control movements over that system, or maintain its infrastructure are provided certain protections under the Federal railroad

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safety laws. Light rail employees will be entitled to appropriate protections during shared-track operations. In addition, the light rail operators will need to observe rules designed to protect employees of other organizations who may be working along the right-of-way.

## **Approaches to Various Forms of Shared Use**

### **Operations on the General [railroad] system**

Local rail transit operations conducted over the track of the general [railroad] system become part of that system and necessitate FRA safety oversight of rail transit operations to the extent of such shared use. This does not mean that all of FRA's regulations will be applied to all aspects of these operations. First, FRA has no intention of overseeing rail transit operations conducted separate and apart from general [railroad] system tracks, i.e., the street portion of that service. (As noted above, FRA regulates commuter operations without regard to their general [railroad] system connections.) Second, FRA anticipates granting appropriate waivers of its rules to permit shared use of general [railroad] system track by light rail and conventional equipment where the applicant transit systems and railroads commit to alternative safety measures and FRA finds that those measures will ensure safety. FRA has now granted two temporal waivers: Utah Transit Authority on December 2, 1999 and the New Jersey Transit Corporation on December 3, 1999, and is currently evaluating a waiver request filed by the Santa Clara Valley Transportation Authority.

Where complete temporal separation between light rail and conventional operations is achieved, the risk of collision between the two types of equipment can be minimized or eliminated. Temporal separation involves operating conventional and light rail equipment at completely distinct periods of the day (in San Diego, for example, conventional rail movements occur only between 1:30 a.m. and 4 a.m.) and establishing procedures to ensure strict observation of the defined operating windows. Under these circumstances, FRA will grant necessary waivers concerning rules related to design of the passenger equipment, although other safety concerns (e.g., highway grade crossings) not addressed by temporal separation may not permit waivers. . . . FRA may permit simultaneous joint use of track by conventional and light rail equipment where the petitioner meets the steep burden of demonstrating that alternative safety measures will reduce the risk of a collision between these types of equipment to an acceptable level.

### **Operations Outside the Shared-Track Area**

Where local rail transit operations consist of segments that involve shared track with conventional equipment connected to segments that do not involve shared track (e.g., street railway segments), FRA does not currently intend to exercise its jurisdiction over operations outside the shared-track area. Instead, FRA will coordinate with the state oversight agency to ensure effective and non-duplicative monitoring of the safety of the different segments of the operation. FRA will make every effort in its waiver process to give due weight to elements of the operation's system safety plan that carry over into the shared-track portion of the system.

### **Operations Within a Shared Right-of-Way**

Although this policy statement addresses shared-track operations, it is important to also acknowledge the situations in which light rail transit operations share a right-of-way, but no

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trackage with conventional railroads. An example is a light rail system whose tracks run parallel to but between the tracks of a freight line. Where such systems share highway-rail grade crossings with conventional railroads, FRA expects both systems to observe its rules on grade crossing signals that, for example, require prompt reports of warning system malfunctions. In addition, and apart from their safety regulatory programs, FRA and FTA are eager to coordinate with rapid transit agencies and railroads wherever there are concerns about sufficient intrusion detection and related safety measures designed to avoid a collision between rapid transit trains and conventional equipment.

**Operations Through a Rail-Rail Crossing at Grade and Other Limited Connections**

Similarly, where a rail transit system crosses a conventional railroad at grade, but has no other connection to the general [railroad] system, FRA and FTA will coordinate with the transit system and railroad to ensure safety at the crossing. FRA does not consider a switch that merely permits the transit system to receive shipments for its own use a connection significant enough to warrant application of FRA's rules.