Metro

DIESEL MULTIPLE UNIT (DMU) TECHNICAL FEASIBILITY ANALYSIS

Contract No. PS4370-2064

Prepared for

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by

LTK Engineering Services

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1.0 EXECUTIVE SUMMARY

1.1 Purpose of the DMU Technical Feasibility Study

The purpose of this study was to determine if Diesel Multiple Unit (DMU) trains (diesel, self-propelled railcars capable of coupling with other like cars to run as a single train) could be used to provide additional passenger rail service to Los Angeles County residents by either supplementing the existing Southern California Regional Rail Authority (SCRRA) Metrolink locomotive-haul peak hour service, and/or providing new off-peak service on the LA County, Metro-owned portion of three Metrolink corridors; viz., Ventura County, Antelope Valley and San Bernardino. We termed this "DMU overlay service". We examined the viability of this concept from a variety of perspectives, including:

- ☐ DMU vehicle availability
- ☐ DMU vehicle performance, including fuel efficiency, and emissions profile
- ☐ DMU fuel options, including clean fuel alternatives
- ☐ Corridor operational capacity to accept DMU overlay service
- ☐ Corridor infrastructure improvements needed to support the overlay service
- ☐ DMU fleet maintenance requirements
- ☐ Community impacts
- ☐ Potential funding sources
- ☐ Overall implementation cost
- ☐ Cost effectiveness of the concept as compared to the addition of Metrolink locomotive-hauled rolling stock

A number of assumptions were made for conducting this study. These include the following:

- ☐ The "DMU overlay service" resultant from the study effort must not negatively impact any existing service (Metrolink, Amtrak, freight)
- ☐ The DMU service would be used to provide at least hourly off-peak service
- ☐ Supplemental DMU overlay service during peak hours would be considered *only* if there would be no impact to the existing commuter service
- ☐ Routes not terminating at Union Station could be considered
- ☐ Metrolink would be the likely DMU operator

The approach to the study was designed to accommodate each of the above noted perspectives. Briefly, the study areas included the following:

1.1.1 Review of Existing Studies

Eight previous studies with varying relevance to the DMU technical feasibility analysis were reviewed. Information of value to the study, gleaned from these reports, included:

- ☐ There are several areas along the target alignments where signal and/or track improvements could significantly enhance operational capacity
- ☐ Union Station's capacity to accommodate additional service, especially during rush hours, could pose a problem
- ☐ Certain costs were identified which were accommodated in our costing model
- ☐ Certain ridership forecasts were found to be relevant

1.1.2 Technical Definition of the Three Study Corridors

The scope of the DMU overlay analysis was limited to those portions of the three Metro-owned Metrolink corridors located within Los Angeles County. A technical definition of each corridor, from both an operations and infrastructure perspective, was necessary in order to build computer models of the network for both a diesel propulsion analysis and an operations simulation. To this end, we identified each corridor's infrastructure (distances, grades, curves, signal blocks, stations, etc.) and operations network (schedules of all Metrolink, Amtrak and freight traffic). These parameters were input to the various computer simulations we constructed.

One significant outcome of the technical definition task was the understanding that the freight operators and Metrolink have both adopted a "12 axle" rule for all trains; that is, there can be no trains with less than 12 axles permitted on the system. The reason for this is to ensure reliable "shunting" of the track circuits used to detect both block occupancy (signal system) and train proximity (grade crossing warning devices). The 12 axle rule affects the DMU overlay concept in that it necessitates that the minimum length for a DMU train is three cars (12 axles). This precludes the advantage of using the self-contained DMUs as one or two car trains on low ridership routes.

1.1.3 DMU Market Survey

The three study corridors are part of the "General Railway System of Transportation", and, as such, are subject to the Federal Railroad Administration (FRA) rules and regulations. The FRA has strict rules governing the design and construction of rail vehicles to be operated on the General Railway System. It was concluded that FRA rule-compliant ("compliant") DMUs are required for the intended service. If the alternative vehicle technology, non-compliant DMUs, were to be used, it would be necessary to physically separate these DMUs in time from the FRA compliant freight and passenger traffic. Given the high volume and around the clock use by both passenger and freight traffic on these corridors, this would be neither practical nor desired.

An important part of the DMU Technical Feasibility Analysis was to determine the availability of compliant DMUs in the marketplace. At the time the study commenced, there was only one manufacturer in the United States, Colorado Rail Manufacturing (CRM, formerly, Colorado Railcar). However, CRM has suffered financial losses, and ceased operations on December 31, 2008. We have identified several manufacturers including Bombardier, CAF, Nippon Sharyo, Rotem and Siemens, who may be interested in designing and manufacturing compliant DMUs, if the order size were to be large enough; say, more than 25 cars. (Enough to reduce the non-recurring or mobilization costs to less than $1 million per car.)

1.1.4 DMU Propulsion Investigation

One aspect of this study was to compare DMU and locomotive-haul trains from several technical perspectives, such as fuel-efficiency and engine emissions. In this regard, we conducted a comparative analysis (via computer simulation) of DMU and locomotive-haul operation over the same route, with conditions as similar as we could make them (one locomotive and three passenger cars vs. three DMU-type cars).

We investigated the use of alternative fuels, including ultra-low sulfur diesel, biodiesel, ethanol, natural gas, hybrid drives and fuel cell technology for possible use in the DMU fleet. We contrasted the energy efficiency of these fuels against their likely ability to meet Tiers 3 and 4 emission standards of the EPA, one of which will be in effect depending on when the DMUs are ordered. Finally, we evaluated the concept of electrification and the use of Electrical Multiple Units (EMU). However, due to the extremely high infrastructure costs, including acquisition of additional right-of-way for the overhead infrastructure and required environmental clearances, that option was not further considered as an alternative.

The optimum approach was determined to be "clean diesel"; that is, ultra low sulfur diesel used in combination with exhaust after-treatments (filtration and catalytic conversion). Our simulations indicate that the equivalent DMU train using "ultra-low sulfur diesel fuel" would have the same schedule performance as a locomotive-haul train, but be about 29% more fuel-efficient, and generate less harmful emissions.

1.1.5 Review of Existing Operating Agreements

A review of all existing operating agreements was undertaken to ensure that there were no legal prohibitions to Metro operating a DMU commuter service on any of the target corridors within LA County. No conflicts were found.

1.1.6 Corridor Operational Capacity Study

Consistent with the purpose of this study, it was necessary to build a computer model of the network operations to establish a baseline and identify any operations "voids" where DMU service could be implemented. Rail Traffic Controller (RTC) was the software used for the simulation effort as this is the same software used by Metrolink for scheduling purposes. Following establishment (and verification) of a baseline model (which includes existing Metrolink, Amtrak and various freight train traffic), and the addition of DMU trains to the extent practical and useful, the model was run and examined to determine if any infrastructure changes could be made to enhance operational capacity and diminish the impact of the additional DMU service. The seven infrastructure changes listed below were then defined at a level of detail for which a rough order of magnitude (ROM) cost estimate could be generated. Finally, the changes were implemented in the model and the simulation re-run and refined to the point of optimum utilization of the DMU fleet. General results were as follows:

- ☐ Time slots were found for 46 daily DMU trains in the network. These include the following:
  - — 16 DMU trains between Los Angeles Union Station (LAUS) and Chatsworth
  - — 6 DMU trains between Burbank Bob Hope Airport and Chatsworth
  - — 16 DMU trains between LAUS and Via Princessa
  - — 8 DMU trains between LAUS and Claremont
- ☐ Seven infrastructure changes were identified and added to the model. These changes increased network capacity.
  - — Chatsworth Station layover track
  - — Second main track from Van Nuys to Chatsworth
  - — Second platform at Van Nuys Station
  - — Via Princessa Station layover track
  - — Second main track from Newhall to Saugus
  - — New center platform at Glendale Station between the two main tracks
  - — Claremont Station layover
- ☐ Adding the infrastructure changes to the network model not only reduced the impact of 46 DMU trains to baseline service levels to no disruption, but baseline performance for Metrolink and Amtrak actually improved in most areas.

1.1.7 DMU Fleet Maintenance Plan

DMUs are significantly different from locomotive-haul rolling stock. DMUs have the ability to run as single cars, and are thus self-contained. Locomotive-haul passenger vehicles rely on the locomotive for propulsion and "head-end power" to drive the auxiliary features, such as air conditioning. As a consequence, the life cycle maintenance requirements for a DMU differ from those requirements for either locomotives or passenger coaches. Nine trains, plus one spare, are required to provide 46 daily DMU train runs. Three-car trains would be used to comply with the 12 axle rule. Maintenance service capacity for 30 DMUs would need to be provided. In order to maintain a DMU fleet, two options were identified:

(1) A new shop facility; or

(2) Modification to the present Metrolink Central Maintenance Facility (CMF) used in combination with the planned Eastern Maintenance Facility (EMF)

Our study indicated that a new facility, capable of maintaining 30 DMUs, could be built for a ROM figure of $55 million, including real estate acquisition estimated at $20 million. Alternatively, the CMF could be modified to maintain DMUs, in combination with the EMF, for a ROM figure of $20 million (no additional real estate needed). Use of the CMF/EMF facilities for maintaining the DMU fleet could be problematic. Although the capacity for an additional 30 cars marginally exists, there are bound to be operational and maintenance conflicts which would not occur were a separate shop for DMU maintenance to be constructed. Additionally, using the CMF for DMU fleet maintenance would necessitate the need for round-the-clock operations, which could raise quality-of-life issues (noise, light and exhaust pollution) in the surrounding environs. A more in-depth industrial engineering study would be required before the appropriate maintenance alternative could be identified.

1.1.8 Community Opportunities and Constraints for Overlay DMU Service

The addition of a DMU overlay service to the existing rail network, which includes Metrolink, Amtrak and freight railroads, could have community impacts, both positive and negative. On the positive side, many alignment locations would welcome the transportation alternative provided by a DMU overlay service. On the negative side, the addition of DMU service could have some undesirable effects, such as increased traffic, noise, etc. Our study included identification of those geographic locations which could be impacted, positively or negatively, by the addition of DMU overlay service, and the rough number of affected locations in each corridor. In this regard, we took the following approach:

- For each of the candidate corridors, we examined a mile-wide "strip" along the alignment and considered this as a potential "impact zone".
- Each potential impact zone was divided into a number of segments. Each segment generally included two or three stations. The average segment is from five to ten miles in length, which would make each impact zone five to ten square miles in area.
- Those location types identified as possibly being affected by the DMU overlay service, either positively or negatively, include:

  Positive impacts; opportunities for utilization of DMU overlay service:

  - Commercial centers
  - Cultural and historic centers
  - Public assembly sites
  - Transportation centers
  - Communities and neighborhoods
  - Planned major developments and/or planned land use changes

Negative impacts; facilities and location types which may require impact mitigation measures include:

- — Medical facilities
- — Parks and recreation areas
- — Residential communities
- — Schools

The segment rating system established for positive impacts was based upon the number of locations within each segment. The segment rating system established for negative impacts was based on the percentage of sensitive land use area within each segment. This ultimately resulted in the finding that, from the standpoint of community opportunities and constraints (least impacts and highest benefits), the Ventura County Line ranked highest for the implementation of a DMU overlay service.

1.1.9 Costing Methodology | Capital Costs

Three separate capital cost alternatives were evaluated:

(1) DMU vehicles | New maintenance facility
(2) DMU vehicles |CMF + EMF
(3) Electrical Multiple Unit (EMU) vehicles | New maintenance facility

The key costing elements which were used to develop estimates in 2008 dollars for the three alternatives are described below:

Vehicles

The cost to purchase a 20 car DMU fleet and a 10 car TMU (Trailer Multiple Unit) fleet. The TMU is similar to the DMU, but has no diesel power for either propulsion or auxiliaries. This fleet cost has been roughly identified as $150 million.

Maintenance Facility (Shop)

The cost to provide maintenance facilities for the above fleet was broken down into two options:

- ☐ A new facility to be used exclusively for the DMUs. This cost is approximately $35 million, not including ROM real estate costs of $20 million.
- ☐ Use of the existing CMF and EMF to maintain the fleet. This cost is approximately $20 million.

Infrastructure Improvements

The cost to implement seven specific corridor infrastructure changes which will increase network capacity and permit better utilization of the DMU fleet was determined to be $125 million.

EMU Fleet

Costs associated with an alternative EMU (Electrical Multiple Unit) fleet were assembled as well.

Fleet Purchase:	$103 million
Catenary & Substations:	$170 million
Shop:	$ 35 million

The total capital cost to provide an EMU fleet would be roughly $453 million, significantly more than the cost of a DMU overlay ($330 million). As a result, EMU service was not further considered as an alternative in this study.

A summary of the costs for each alternative is found in the following table:

Capital Construction and Engineering Costs

Cost Components (2008 Dollars)	Alternative 1 DMU | New MF	Alternative 2 DMU | CMF & EMF	Alternative 3 EMU | New MF
Vehicle Fleet (& catenary for EMU)	$150,000,000	$150,000,000	$273,000,000
Infrastructure Changes	$125,000,000	$125,000,000	$125,000,000
Maintenance Facility	$ 35,000,000	$ 20,000,000	$ 35,000,000
Land Acquisition	$ 20,000,000	--	20,000,000
TOTAL	**$330,000,000**	**$295,000,000**	**$453,000,000**

TABLE 1: Capital Costing Alternatives

1.1.10 Costing Methodology | Operating Costs

Operating costs for a DMU overlay service were estimated on the basis of Metrolink's costs, and were compared to locomotive-haul costs on a per-mile basis. DMU operating costs were found to be approximately 5% lower than locomotive-haul costs. The per-mile operating costs have three components; viz., agency costs (operations, insurance, overhead, etc.), fuel, and maintenance.

Metrolink's costs for these components, in 2008 dollars, are as follows:

Agency costs:		$62.96 per train-mile
Fuel costs:		$8.57 per train-mile
Maintenance costs:		$9.22 per train-mile
	Total	$80.75 per train mile

Projected DMU costs for these components, in 2008 dollars, are as follows:

Agency costs:		$62.96 per train-mile
Fuel costs:		$6.17 per train-mile
Maintenance costs:		$7.38 per train-mile
	Total	$76.51 per train mile

It is noted that a DMU train can provide 230 seats. With ridership projected at 60 riders per train, the result is an excess capacity of 74%. A comparable Metrolink train can provide 420 seats, resulting in an excess capacity of 86%.

1.1.11 Potential Funding Approaches

The scope of this sub-task was to look for funding opportunities outside of the traditional sources used by Metro for the DMU overlay fleet. The most lucrative revenue source from the DMU overlay service could be advertising (print media or video/digital media) and vehicle/station naming rights, which in some circumstances might potentially generate $1 million in revenues.

However, Metrolink's stations are owned by the cities within which the stations are located, and any advertising opportunities would need to be negotiated with the station owners.

1.2 Summary of Major Findings

Major study findings included the following:

- The 12 axle rule necessitates that a minimum of three DMUs be included on each train, even though in many time slots, it would be more cost effective to operate only 1 or 2 car trains.
- With the seven major infrastructure improvements noted in the study, the three corridors have the capacity to accommodate 46 additional daily DMU trains. These infrastructure improvements also improved baseline Metrolink performance.
- FRA-compliant DMUs will be required.
- A three-car DMU train is more fuel-efficient and has a (generally) more environmentally friendly emissions profile than a three-car locomotive-haul train.
- "Clean diesel" is the optimum fuel choice for a DMU.
- The Ventura County Line would experience the least impacts and gain the highest positive benefits from a DMU overlay service.
- A minimum fleet of 30 DMUs would be required to meet the objectives of the DMU overlay service.
- Ridership forecast estimated to be 60 riders per train in 2010, equaling an average weekday ridership of 2,800 passengers.
- Because of better fuel efficiency and cheaper life cycle maintenance costs, it would cost 5% less to operate DMUs in the overlay service described herein than to use Metrolink's locomotive-haul fleets for the overlay service. The difference in cost would be dramatic, if an alternative to the 12-axle rule were to be found.
- Some "transit" service (service which operates without a stop at Union Station), as opposed to "commuter" service (service in and out of Union Station) is possible, i.e., between Burbank Bob Hope Airport and Chatsworth.
- Two possibilities exist for DMU maintenance: Constructing an entirely new facility, or modifying the existing Metrolink CMF and planned EMF to accommodate a DMU overlay fleet.

1.3 Conclusions

DMU technology offers a number of benefits to the County's Metrolink service region. The major benefits which the utilization of DMUs could offer include:

- The ability to provide a more cost-effective vehicle technology solution for small trains than using an equivalent locomotive-haul consist, both from a capital and an operations cost perspective
- The ability to run single car trains, matching demand with capacity, if alternate technical solutions to insuring track and grade crossing shunting can be developed and implemented
- More energy-efficient operation than for equivalent locomotive-haul trains
- A more environmentally-friendly emissions and noise profile than for equivalent locomotive-haul trains

However, while this study has demonstrated the feasibility of implementing DMU technology on Metro's rights of way, the real benefits of utilizing DMUs for commuter service are constrained by the 12 axle rule and the need to utilize FRA-compliant equipment. These current constraints make it difficult to suggest DMU as a cost-effective strategy for implementing overlay service on the three Los Angeles County corridors at this time.

2.0 TECHNICAL DEFINITION OF AVAILABLE ROUTES

One of the initial tasks was to define each of the three corridors from both an infrastructure and an operations perspective. This was needed to assemble the baseline data for input to our two models: RR, (Rail Road Simulator), a train performance simulator used to determine performance, fuel consumption and the emissions profile, and RTC (Rail Traffic Controller), a software simulator used by SCRRA for simulating operations on the network.

The three study corridors were the Ventura County Line, the Antelope Valley Line and the San Bernardino Line. Since the scope of our investigation was to consider only those portions of the subject corridors within Los Angeles County, our study included only the following for each line:

Ventura County:	From Union Station to Chatsworth
Antelope Valley:	From Union Station to Lancaster (all stations are within LA County)
San Bernardino:	From Union Station to Claremont

These lines are principally served by Metrolink, with additional passenger service by Amtrak, and some freight service. Summary level alignment and rail traffic information for each corridor is given below. Detailed information regarding each of the corridor alignment infrastructures and train schedules can be found in our report for Task 2.2, *Technical Definitions of Three Candidate Corridors.*

An overview of all three corridors is provided in the following Figure:

FIGURE 1: Ventura County, Antelope Valley and San Bernardino Lines

2.1 Ventura County Line

2.1.1 Alignment Description

The Ventura County Line runs northwest out of Union Station to Downtown Burbank, then west-northwest to Chatsworth and beyond into Ventura County. (See Figure 1, above) The last station within LA County is Chatsworth. Following is a list of stations along the Ventura alignment, with both distance from Union Station and station-to-station distances indicated. There are five additional stations beyond the County Line which are not included in the analysis. These are marked with an asterisk in the table below.

There are no significant infrastructure constraints to DMU overlay service on the Ventura County Line; however, some infrastructure improvements have been identified which could enhance service performance. These improvements are noted later in this report.

Station	Mile Post	Distance from LAUS	Distance from Prior Station
LAUS	0.0	0.0	0.0
Glendale	5.8	5.8	5.8
Downtown Burbank	10.8	10.8	5.0
Burbank Airport	460.6	13.3	2.5
Van Nuys	455.0	18.9	5.6
Northridge	449.3	24.6	5.7
Chatsworth	445.5	28.4	3.8
*Simi Valley**	*437.9*	*36.0*	*7.6*
*Moorpark**	*427.1*	*46.8*	*10.8*
*Camarillo**	*413.6*	*57.0*	*10.2*
*Oxnard**	*404.8*	*65.8*	*8.8*
*Montalvo**	*400.4*	*70.2*	*4.4*

TABLE 2: Ventura County Line

2.1.2 Rail Traffic

A summary of all existing rail traffic on the Ventura County Line corridor is as follows:

Metrolink: 10 round trips each weekday; no service on weekends

Amtrak: 5 *Pacific Surfliner* round trips, and 1 *Coast Starlight* round trip every day

Freight: 5 Union Pacific through freight round trips, plus local switching

2.2 Antelope Valley Line

2.2.1 Alignment Description

The Antelope Valley Line runs northwest out of Union Station to Newhall, northeast to Acton, then due north to Lancaster. All of the stations along the Antelope Valley Line are within LA County, as given in Table 3 below. We only applied the concept of DMU overlay service between Union Station and Via Princessa, as the three remaining stations, Acton, Palmdale and Lancaster, are only served infrequently by Metrolink. These stations are quite far apart. The distance between Via Princessa and Lancaster is 39 miles, with no population centers in-between, except for Acton and Palmdale. This low ridership rail environment is adequately served by the existing locomotive-haul service, and would not benefit from a DMU overlay. Consequently, we truncated DMU service at Via Princessa, as indicated by the bold line following this station in Table 3 below.

A major bottleneck on this line is the 1.3 mile long single-track tunnel between Sylmar and Newhall stations. This presents a severe constraint to the addition of DMU overlay service to this line. Costs to increase tunnel capacity by adding a second track (actually, a second tunnel would have to be constructed; the most practical approach would be to construct a new, double track tunnel dedicated to passenger traffic and use the existing tunnel for freight) are prohibitive, and were not included in the costs to implement DMU service. Following is a list of stations along the Antelope Valley alignment, with both distance from Union Station and station-to-station distances indicated.

Station	Mile Post	Distance from LAUS	Distance from Prior Station
LAUS	0.0	0.0	0.0
Glendale	5.8	5.8	5.8
Downtown Burbank	10.8	10.8	5.0
Sun Valley	15.4	15.4	4.6
Sylmar/San Fernando	21.9	21.9	6.5
Newhall	30.0	30.0	8.1
Santa Clarita	34.2	34.2	4.2
Via Princessa	37.9	37.9	3.7
Vincent Grade/Acton	61.6	61.6	23.7
Palmdale	69.2	69.2	7.6
Lancaster	76.6	76.6	7.4

TABLE 3: Antelope Valley Line

2.2.2 Rail Traffic

A summary of all existing rail traffic on the Antelope Valley Line corridor is a follows:

Metrolink: Metrolink provides the only passenger service on the Antelope Valley Line north of the Burbank Junction (where the Ventura and Antelope Valley Lines split).

There are 12 weekday round trips, with morning runs originating in either Via Princessa or Santa Clarita, and a few operating the full distance from Lancaster. Six round trips are provided on Saturdays, and three on Sundays.

Amtrak: There is no Amtrak service on the Antelope Valley Line

Freight: Union Pacific operates six round trips (12 trains) daily

2.3 San Bernardino Line

2.3.1 Alignment Description

The San Bernardino Line extends 56 miles due east of Union Station to San Bernardino. The LA County portion extends only to Claremont, 33 miles east of Union Station. The most serious constraint on this line, a section of single track from Cal State LA to El Monte, occurs in LA County. This section of track is about nine miles long, and runs down the median of the I-10 Freeway, making an upgrade to double track extremely problematic (would require the removal of a freeway lane). The following chart provides the station and mileage information for the entire line. Stations not within LA County are marked with an asterisk.

Station	Mile Post	Distance from LAUS	Distance From Prior Station
LAUS	0.0	0.0	0.0
Cal State LA	4.6	4.6	4.6
El Monte	12.6	12.6	8.0
Baldwin Park	18.8	18.8	6.2
Covina	23.0	23.0	4.2
Pomona North	31.0	31.0	8.0
Claremont	33.0	33.0	2.0
*Montclair**	*34.2*	*34.2*	*1.2*
*Upland**	*36.9*	*36.9*	*2.7*
*Rancho Cucamonga**	*42.0*	*42.0*	*5.1*
*Fontana**	*49.0*	*49.0*	*7.0*
*Rialto**	*52.9*	*52.9*	*3.9*
*San Bernardino**	*56.2*	*56.2*	*3.3*

TABLE 4: San Bernardino Line

2.3.2 Rail Traffic

A summary of all existing rail traffic on the San Bernardino Line corridor is as follows:

Metrolink: 17 round trips each weekday; 10 round trips on Saturday and 7 round trips on Sunday

Amtrak: There is no regularly scheduled Amtrak service on the San Bernardino Line; however, from time-to-time, at the dispatcher's discretion, the *Sunset Limited* is sometimes routed on the San Bernardino Line instead of UP's Alhambra Line.

Freight: UP and BNSF provide freight service on parts of the San Bernardino Line. There are quite a few local switching moves every day to service industrial clients. On average, there are about four freight round trips per day.

3.0 DMU MARKET SURVEY

DMUs are designed to be either FRA (US Federal Railroad Administration) compliant, or non-FRA compliant. Generally speaking, all rail passenger equipment which runs on the "General Railroad System" is required to be FRA-compliant unless separated in time from all other rail traffic ("temporal separation"). The issue of whether or not the proposed DMU overlay service would need to use FRA-compliant rolling stock is examined below.

Once the issue of FRA-compliance was decided, the next step toward fleet acquisition was to survey those DMU designs available in the market place that would be applicable to the DMU overlay service proposed in this study.

3.1 Need for FRA-Compliant DMUs

3.1.1 Regulatory Background

The three study corridors, Ventura, Antelope Valley and San Bernardino, are part of the General Railroad System of Transportation, and, by Federal law, come under the regulatory purview of the FRA, part of the US Department of Transportation. FRA regulations governing railroads operating on the General Railroad System can be found within a large body of rules known as the Code of Federal Regulations, or CFRs. The CFR is divided into 50 titles. Title 49 addresses transportation issues; "Parts" 200 through 299, published separately in a 900 page volume, contain the FRA regulations under which the three corridors must operate. 49CFR 238 is entitled "Passenger Equipment Safety Standards". Subpart C of Part 238, Subsections 221 through 237, address "Specific Requirements for Tier 1 Passenger Equipment". Tier 1 passenger equipment would include DMUs operating at less than 125 mph on the General Railroad System. Those portions of Subpart "C" most relevant to the required structural design of DMUs are as follows:

- ☐ Subsection 238.203, *Static End Strength*, which requires that vehicles be capable of resisting an end static load of 800,000 pounds.
- ☐ Subsection 238.205, *Anti-Climbing Mechanism*, which requires anticlimbers at both ends of the vehicle capable of resisting an upward or downward vertical force of 100,000 pounds without failure
- ☐ Subsection 238.211, *Collision Posts*, which require collision posts at the end of each car, at the one-third points of vehicle width (laterally), with an ultimate shear strength of 300,000 pounds
- ☐ Subsection 238.213, *Corner Posts*, which requires full height corner posts capable of resisting 150,000 pounds at the point of attachment to the underframe without failure.
- ☐ Subsection 238.223, *Locomotive Fuel Tanks*, which specifies fuel tank construction standards typical of mainline locomotives, but which also apply to DMUs.

The above requirements, taken in combination, result in a very robust and heavy design. DMUs meeting all these requirements, and a few others not noted herein, are known as "FRA-Compliant" DMUs. Unless specific exemption is granted, DMUs operating on the three study corridors are required by Federal law to be FRA-compliant.

3.1.2 Temporal Separation

In some cases, rolling stock equipment operating within the General Railroad System have been given an exemption from the above structural requirements. North County Transit District's Sprinter vehicles manufactured by Siemens-Germany, operating in Oceanside, CA, is one such case. In order to be granted an exemption such as the one received in Oceanside, the agency responsible for service must petition the FRA for a waiver of the vehicle design requirements noted above. The basis for the waiver in Oceanside was "temporal separation"; that is, separation in time and physical separation of the operation of rolling stock that is FRA compliant from the rolling stock that is non-compliant. Practically speaking, in Oceanside, this translated to daytime operation of non-compliant DMUs vs. nighttime operation of FRA-compliant locomotive-hauled freight trains. Separation in time is achieved by the establishment of a buffer period (approximately one-half hour) in both the early morning and late evening when no railcar traffic is permitted on the alignment, and the exchange of services can be confirmed.

Oceanside took the above regulatory approach in order to be able to utilize the higher performance and greater availability of non-compliant DMUs in the marketplace. We have taken a serious look at this possibility with regard to the DMU overlay service (reference our report for Task 2.4, *Regulatory Issues*) and concluded that temporal separation would not be possible on any of the three study corridors. The combined volume of Metrolink, Amtrak and freight traffic is simply too high throughout the course of the day to provide both temporal and physical separation of non-compliant DMUs from other corridor traffic. This is best illustrated by the following three graphs which indicate the present (not including any planned DMU overlay service) service levels on each of the corridors. These graphs confirm the total lack of any opportunity for temporal separation of non-compliant and compliant services.

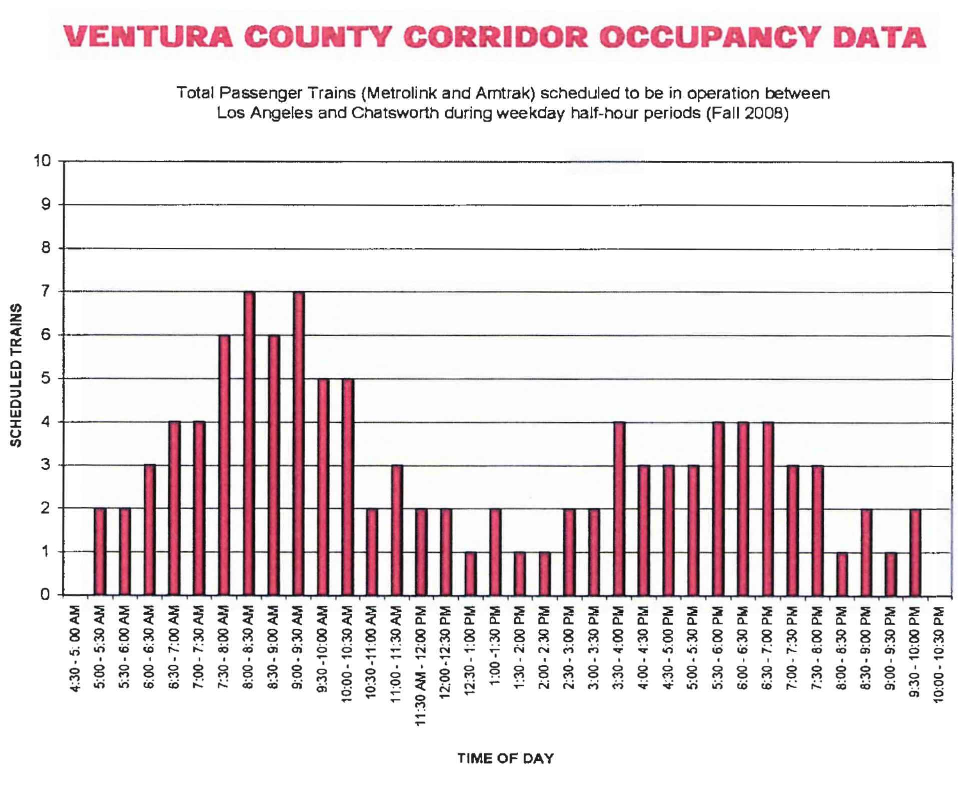

FIGURE 2: Ventura County Corridor Occupancy Data

LTK
LTK Engineering Services

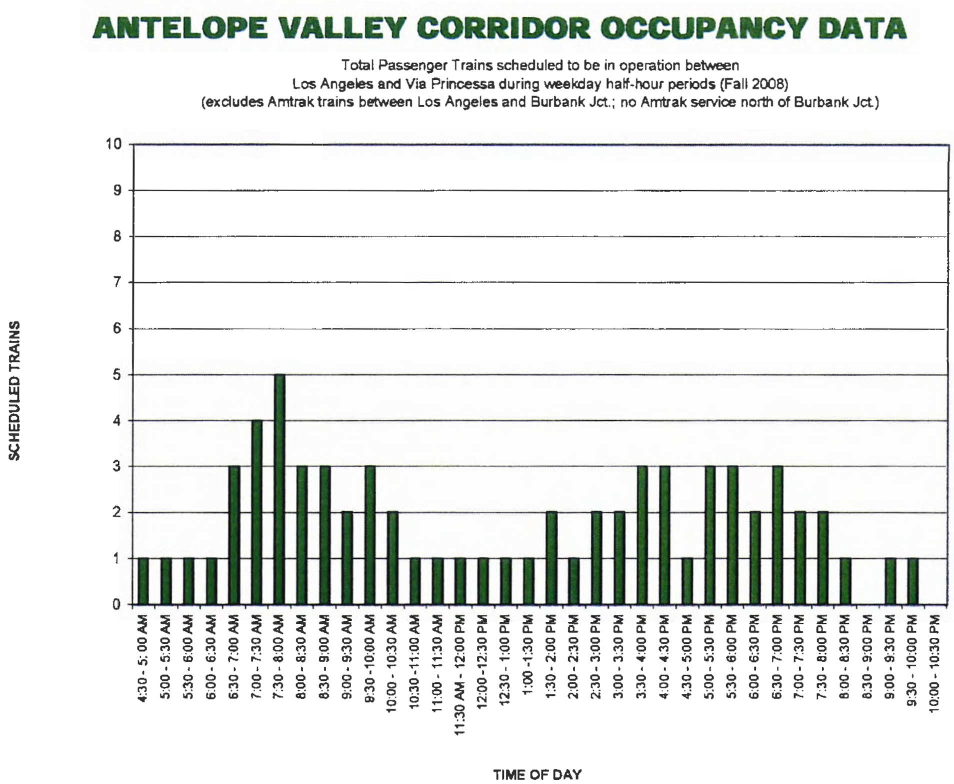

FIGURE 3: Antelope Valley Corridor Occupancy Data

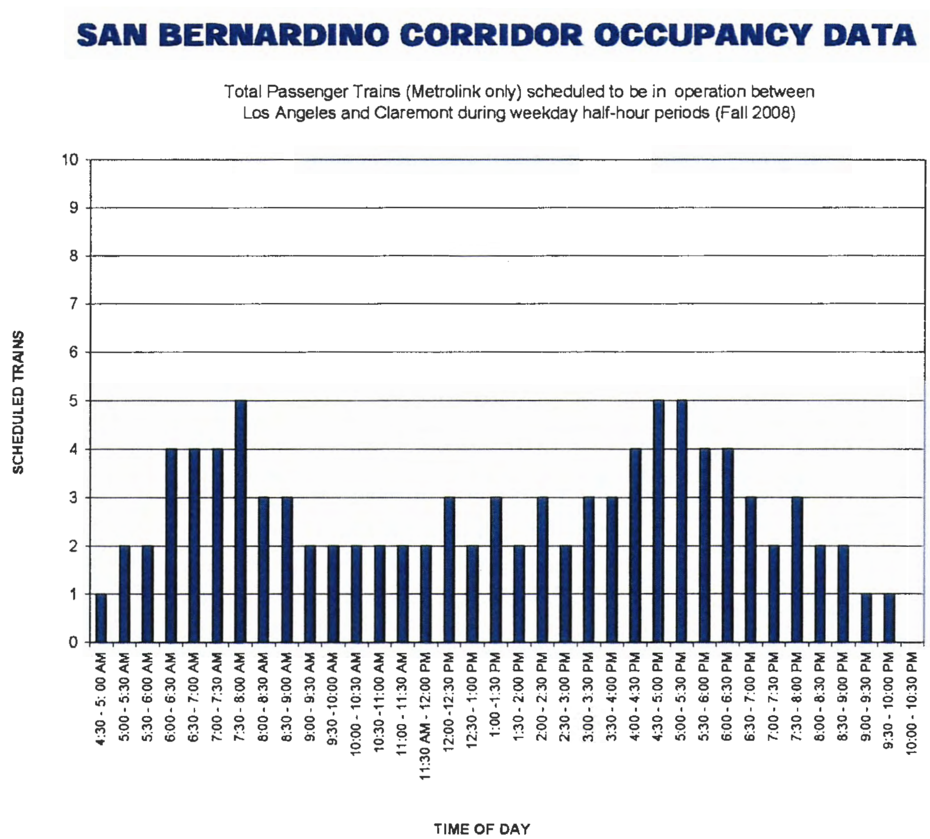

FIGURE 4: San Bernardino Corridor Occupancy Data

3.1.3 Additional Requirements for Operating on the Three Corridors

As previously discussed in Section 3.1.1, one aspect of the FRA approach to insuring passenger safety has been to require extremely robust railcars, such that there is minimum structural failure in collisions. An alternative approach, popular in Europe, has been to use advanced train signaling systems in order to minimize the likelihood of a collision, and to design "crashworthy" railcar structures; that is, structures which fail in a predictable manner and absorb energy in a collision, rather than transmit the collision energy to the passengers. Although the FRA has not yet embraced this approach, it is considering an alternative to their standard structural requirements for Caltrain, the Peninsula Corridor operator, who would like to procure a fleet of non-compliant Electric Multiple Units (EMUs) for its San Jose-San Francisco service. Caltrain's petition for relief is based on providing an advanced signaling system in tandem with a crashworthy design, and temporal separation from the freight service on the line. This approach is being evaluated by FRA; however, the evaluation and subsequent change to rules (if the results are positive) could take years to implement.

The concept of crashworthiness, *per se*, is relevant to this study. Rail vehicle safety came under intense scrutiny in the wake of the Metrolink Glendale collision in 2005. Following the accident, Metrolink officials made a conscious effort to improve passenger survivability. Their determination was that requiring a crashworthiness design, modeled on the European approach, *in addition to* the FRA-mandated structural requirements, would provide as much passenger safety as reasonably possible. Metrolink has required that their newest fleet of passenger coaches and cab cars, now under construction by the Hyundai Rotem Corporation of Korea, be built to a crashworthiness design which emphasized energy absorption in addition to carshell rigidity. It is certain that any DMUs purchased for operation on Metrolink-operated corridors will be required to apply these same design standards. Although no DMUs exist which are built to both FRA and Metrolink crashworthiness design standards, Hyundai Rotem has proposed compliant DMUs for operation at Triangle Transit in North Carolina. The order was eventually cancelled due to lack of funding, although Hyundai Rotem did complete the design and could likely merge the two requirements into a DMU design acceptable to both the FRA and Metrolink.

3.2 Available Market for FRA-Compliant DMUs

Given that the only near-term (next five years) technological solution would be the procurement of FRA-compliant DMUs, we researched the available market. Carbuilders either offering FRA compliant DMUs, or who would be likely to bid on an FRA compliant DMU design, include the following:

3.2.1 Colorado Railcar Manufacturing (formerly Colorado Railcar)

Colorado Railcar Manufacturing (CRM) is the only manufacturer who has recently manufactured FRA compliant DMUs. We have used their design in our computer simulations. They have supplied FRA compliant DMUs to both South Florida Regional Transportation Authority (SFRTA) and Washington County, Oregon. Although at the time CRM developed their FRA compliant model, it appeared that DMU service in the United States was a new emerging market, this market never materialized in sufficient quantities to make FRA compliant DMU manufacturing a viable product line. As a result, CRM has gone out of business.

3.2.2 Bombardier (Canada)

Following several mergers and acquisitions, Bombardier is the largest manufacturer of railcars in the world. One of their products is a fully FRA-compliant EMU for the Long Island Railroad, the M7. Bombardier has also expressed an interest in the DMU market. Were there to be an order of sufficient quantity (say, 25 cars), it is likely they would propose a modified version of their M7, designed for diesel operation.

3.2.3 Hyundai Rotem (Korea)

Hyundai Rotem is presently building FRA-compliant coaches and cab cars for Metrolink. They, too, have expressed an interest in the FRA-compliant DMU market. They were the successful bidder for Triangle Transit Authority's FRA-compliant DMU solicitation (32 cars). Funding became an issue for this project (it was eventually cancelled due to lack of funding), but Hyundai Rotem proceeded with the design development while awaiting Notice to Proceed (NTP). Insofar as we have been able to determine, this design has never been used.

3.2.4 Nippon Sharyo (Japan)

Nippon Sharyo has expressed interest in supplying an FRA-compliant DMU to the American market although they have never done so. They did bid on the Metra (Chicago) FRA-compliant DMU order, but this work never materialized. Nippon Sharyo has no FRA-compliant DMU in service or production, and it is unclear how far they have taken the design. Regardless, for a sufficiently sized order (25 DMUs or more), they would probably be interested in reviving their Metra design.

3.2.5 Siemens (Germany/USA)

Over the course of the last several years, Siemens has expressed an interest in the FRA-compliant DMU market. To date, however, Siemens has not publically released any plans or drawings to illustrate any concepts.

4.0 DMU PROPULSION TECHNOLOGIES INVESTIGATION

DMUs are diesel-motor driven. As such, they require a combustible substance to fuel the diesel engines. The products of combustion, the "emissions", are becoming an increasing consideration in our communal efforts to maintain a clean air environment, especially here in Los Angeles. The purpose of this portion of the study was to conduct an in-depth examination of the various fuels available to drive diesel[1] engines, and to determine if the selection of DMU technology would equal or better an equivalent use of locomotive-haul technology to provide the same service level. Topics covered in this portion of the analysis include:

- ☐ Current EPA requirements for DMUs
- ☐ Available (and potential) fuels and fuel treatments for DMUs
- ☐ Alternative technologies (hybrid drive; fuel cell)
- ☐ The cost to provide Electrical Multiple Units (EMUs)
- ☐ A simulated comparison of DMU and locomotive-haul technology to determine comparative energy consumption and fuel efficiencies

4.1 EPA Emission Requirements

The EPA governs the generation of emissions for diesel engines used in transit applications. The EPA emission requirements are different for DMUs and locomotives. For transit operations, the following categories apply:

- ☐ Highway engines (buses)
- ☐ Off-road engines (DMUs)
- ☐ Locomotives

DMUs fall within the off-road category in that their horsepower rating typically falls between that of a bus and a locomotive. As it turns out, DMU emissions requirements are more restrictive than for locomotive emissions. The EPA emission limits are established in "Tiers". These tier levels are defined as a function of the various contaminants commonly found in diesel exhausts. The following table lists the allowable emission levels for each defined tier.

EPA Regulated Contaminant	Substance	grams/kilowatt-hour			
		Tier 2	Tier 3	Tier 4 int *	Tier 4
		2001	2006	2011	2014
CO	Carbon Monoxide	3.487	3.487	3.487	3.487
PM10	Particulate Matter (course)	0.201	0.201	0.020	0.020
PM2.5	Particulate Matter (fine)	-	-	0.013	0.013
NO_x	Nitrogen Oxide	-	-	2.012	0.402
NMHC	Non-Methane Hydrocarbon	-	-	0.188	0.188
NO_x + NMHC	Nitrogen Oxide + Non-Methane Hydrocarbon	6.437	4.023	2.199	0.590
* Tier 4 int is an intermediate step to Tier 4, which brings the U.S. Tier 3 limits in line with the European EURO 4 limits					

TABLE 5: DMU (130 to 560 kW; 175 to 750 hp)

[1] The term "diesel" refers to the *type* of engine, named after its inventor, Otto Diesel, not the fuel. In fact, diesel engines can run on a variety of fuels, including CNG and biodiesel.

The current requirement for DMUs is Tier 3, but this will change to Tier 4 in 2014 (that is, for all DMUs ordered in 2014 and beyond). It is anticipated that the DMU which is the focus of this study would be ordered prior to 2014, so Tier 3 compliance was assumed in our computer simulations. For locomotives, a Tier 2 emissions profile was assumed, as that is their current requirement.

4.2 Alternative Fuels and Technologies

4.2.1 Clean Diesel

Clean Diesel is not simply just a fuel. It is a combination of a fuel (ultra low sulfur diesel) and (presently) two exhaust after-treatments; a particulate filter and an SCR (Selective Catalyst Reduction) which converts nitrogen oxide to nitrogen and water. The catalyst for this process is ammonia. This would necessitate the addition of an ammonia tank to the DMU. These two devices will reduce particulate matter (PM) content by 50%, and nitrous oxide (NO_x) by up to 97%. Ultra Low Sulfur Diesel (ULSD) has a maximum sulfur content of 15 ppm (parts per million) compared to Low Sulfur Diesel, which has a sulfur content of 500 ppm — a reduction of 97% in sulfur content. Both ULSD and exhaust after-treatments will be necessary in order to meet the EPA's Tier 4 emissions requirements.

ULSD is presently available and is being used in a number of truck and bus applications. The two exhaust after-treatments noted above are still in the developmental stage, however. SCRRA has one of their F59PH locomotives on test with ULSD and the exhaust after-treatments noted above. Results of this testing are not yet available.

4.2.2 Biofuels

Diesel engines are relatively forgiving in the type of fuel that they use. In fact, diesel fuel can be synthesized from many types of organic matter. Diesel fuels synthesized from organic matter are known as biofuels. Some agencies are experimenting with mixtures of biofuel and ULSD by adding in quantities of 5% to 20% biodiesel (B5 to B20). The use of biodiesel reduces most emissions, with the exception of nitrous oxide. In fact, the use of biodiesel increases the release of NO_x, which in turn increases ozone levels (smog) at ground levels. Because of this, most engine manufacturers no longer approve the use of biodiesel in their engines. Following is Table 6 showing the reduction or increase in the emission of select contaminants for 100% biodiesel (B100):

Substance	Amount
Hydrocarbon (HC):	- 67%
Carbon Dioxide (CO):	- 47%
Nitrogen Oxide (NO_x):	+10%
Particulates:	- 48%
Sulfur Dioxide (SO_2)	No emission

TABLE 6: Emissions Comparison (Petrodiesel vs. 100% Biodiesel)

Another potential drawback to the use of biofuels is the danger it poses to virgin forests as they are cleared to make way for biofuel crops. Moreover, the switch to the use of crops for biofuel may eventually divert crop production away from food, raising prices for corn, soybeans, etc.

This concern may be alleviated if the technology to produce biofuel from grass or algae ultimately becomes viable. Such technology is nowhere near mature, however.

4.2.3 Ethanol

Ethanol is derived from sugar cane. It has been used as an automotive fuel for decades, primarily in Brazil. Ethanol is not used in rail vehicles, however, due to its lower energy content as compared to diesel fuel.

4.2.4 Natural Gas

There are two proven natural gas technologies, CNG (Compressed Natural Gas) and LNG (Liquefied Natural Gas), in motive applications. These technologies are rarely used in rail transit, however, due to their lower energy content as compared to diesel. Although natural gas has a fairly "clean" emissions profile, its lower energy content necessitates the use of more of it for equivalent performance to diesel driven systems. For example, CNG has only 25% the energy content of diesel, and LNG has only (at most) 50%.

CNG is a mature technology, generally used in automotive applications. It requires a very high pressure to store the gas (up to 2900 lbs/sq. inch), however. LNG must be stored at -256°F. In both cases, this presents storage and logistical problems.

There are no CNG- or LNG-powered DMUs in the market. With the development of clean diesel, interest in natural gas powered MUs has diminished significantly. A DMU could be retrofitted to burn natural gas; however, the tank design needed to contain the gas at either high pressure or low temperatures would have a resultant low capacity (due to the low energy content of natural gas), and would be very thick-walled and heavy.

4.2.5 Hybrid Drives

Hybrid technology incorporates the use of a smaller internal combustion (IC) engine to both assist in the mechanical drive (parallel hybrid) of the vehicle, and/or charge on-board batteries used to drive electric motors (series hybrid). The theory is that the IC engine can be run continuously at some optimal rotational speed at which a minimum of fuel is used. The engine is used to charge a rack of batteries which in turn drive the vehicle's electric motors. The fuel savings comes in not having to operate the diesel engine at either low or high RPM, where mechanical efficiencies are low. Additionally, and especially in a series hybrid (where the IC engine is dedicated to battery charging and does not provide a mechanical assist to the drive train), the electric propulsion motors can be (electrically and instantaneously) converted to generators during braking and store a large portion of the vehicle kinetic energy in the batteries.

The hybrid concept is well-suited to DMU technology, with the exception that the battery capacity needed for a successful hybrid drive in a railcar would be very large. Railcars generally travel at higher speeds, are much heavier than automotive vehicles and buses, and would require huge amounts of energy storage in order to be able to utilize the hybrid concept. Battery technology isn't quite there yet, but could conceivably be available within a few years if the economic incentives towards developing higher efficiency batteries persist. Other energy storage devices, such as super-capacitors and flywheels, are under consideration, but are not sufficiently technologically advanced for a near-term application. This problem aside, DMUs might be adaptable to hybrid technology, but would require a diesel-electric drive, wherein the on-board diesel powers a generator which supplies electrical current to the motor controller. DMUs which incorporate a diesel-electric drive are also known as DEMUs. Presently, there are no diesel-electric drive DMUs which are also FRA-compliant. All of CRM's DMUs are designed with diesel-hydraulic drives, which do not allow energy recovery during braking. South New

Jersey (Riverfront Line) and Austin (Capital Metro) use DEMU technology, but these DMUs are not FRA-complaint. All U.S. manufactured locomotives have diesel-electric drives.

4.2.6 Fuel Cell Technology

Fuel cells, typically considered an emerging technology, were actually invented in the 1800's. In all this time, they have never found a viable, commercial application for two reasons:

(1) Fuel cell technology is intrinsically expensive and inefficient unless an abundant source of hydrogen is made available at low cost (typically not the case)

(2) Investment in a hydrogen refueling infrastructure is very costly and would require sophisticated engineering and present a financial risk for the investors, since it is by no means certain that there would be a sufficient market for hydrogen-powered vehicles to ensure a reasonable return on investment

Fuel cell technology is briefly explained by describing the process in sequential, elemental terms:

- Pressurized hydrogen gas enters the fuel cell on the anode (positive) side. High pressure, supplied externally at an energy cost, forces the hydrogen through the anode catalyst (platinum)
- When a hydrogen molecule (H_2) comes in contact with the platinum catalyst, it splits into two (positively charged) H+ ions, and two (negatively charged) electrons
- The negatively charged electrons are attracted to the positive anode. From the anode they are conducted back to the cathode in an electrical current. While traveling along this path, the electric current does useful work, such as turning a motor.
- On the cathode side, pressurized oxygen (from an external source) is forced through a catalyst, where the O_2 molecules are split into two oxygen atoms, each of which has a negative charge. These negatively charged oxygen atoms attract the H^+ ions through the membrane and combine to form a water molecule, H_2O, electrically neutral.

  The process is described chemically as $2H_2+O_2 \Rightarrow 2H_2O$.

The primary problem in using this process to generate electricity is that hydrogen gas is not readily available. To produce and pressurize hydrogen takes energy, which lowers the overall efficiency of the process. In fact, the end-to-end efficiency of the fuel cell is only about 30%, worse than an internal combustion engine. This does not justify the additional cost of fuel cell vehicles, and the requisite hydrogen infrastructure (filling stations) to support them.

4.3 Electric Propulsion

4.3.1 Infrastructure

Electric propulsion is the cleanest of all the available propulsion modes, yielding zero emissions along the alignment. If emissions are generated, they are generated at the power source. If the power is derived from hydroelectric, wind or solar installations, the emissions profile for the network will be zero. Even if oil or coal (the worst offenders) are used to fire the power plant, it will result in less emissions than fuel-based locomotives or DMUs.

Another advantage to the utilization of a power grid is that all improvements in power generation are automatically applied to the rail network without the need to modify the vehicles or the power distribution system.

A major disadvantage is the need to finance and construct an electric distribution system, including both traction power and the overhead centenary. This could even require property acquisitions for the needed infrastructure.

4.3.2 Costs

Electric propulsion requires an extensive infrastructure to power rail vehicles. This infrastructure consists of:

- ☐ High voltage switching stations to connect the power grid to the traction power substations
- ☐ Traction power substations to transform the utility voltage to 25k Vac. 25k Vac is the voltage planned for the recently approved California High Speed Rail system, and the likely choice for the commuter lines feeding into the system. 25k Vac systems are common throughout the world.
- ☐ Medium voltage switchgear to connect the 25k Vac to the catenary distribution system, and to "sectionalize" (isolate) sections of the distribution system as needed for repair and emergencies.
- ☐ The Overhead Catenary System, which involves a network of poles at regular intervals to support the wires, plus both messenger and contact wires along each track. (Placement of the support poles could involve property acquisitions.)
- ☐ A fleet of electrically powered rail vehicles, capable of operating as single units or in trains. These are referred to as EMUs, or Electric Multiple Units. (The cost of EMUs, generally higher than DMUs, is addressed in our Cost Report)

The costs of providing and operating an electric infrastructure can be assigned to the following categories:

- ☐ Construction: Costs for an electrification system as described above generally run about $1 million per mile; or, from $150 million to $180 million for the three study corridors. This does not include the real estate for the wayside equipment, nor the cost of enlarging the 1.2 mile tunnel between Sylmar and Newhall to provide the additional clearance needed to install a catenary system (electrification was only considered to Via Princessa on the Antelope Valley Line).
- ☐ Maintenance: Based on a recent report authored to address a planned (very similar) 25k Vac system in Denver, the cost to maintain the electrification system ranges between $40,000 and $60,000 per mile per year.

4.4 Run Simulation

In order to determine if DMU technology has any inherent advantages for the three-corridor application, it was necessary to perform a computer simulation of two equivalent trains; one locomotive-haul and one DMU. The computer simulation was designed to compare the following between the two trains:

- ☐ Performance
- ☐ Energy
- ☐ Emissions Profile

4.4.1 Computer Model Construction and Route Selected

It was important that the two train models designed for the simulation be as "equivalent" as possible while reflecting the realities of train technology and SCRRA operating practices. In this regard, the locomotive-haul train selected was an MP36 locomotive, two Bombardier double-deck coaches, and one Bombardier double-deck cab car. A locomotive and three coaches is the typical length train operated by Metrolink. Although it may not always be necessary to use three cars from a passenger-demand perspective, Metrolink chooses to keep trains intact for logistical purposes. This train also satisfies the "12 axle" rule, which states that any train operating on the Metrolink system *must* have a minimum of 12 axles, this to ensure good track signal shunting for both block occupancy detection and grade crossing protection.

In a similar manner, a DMU train consisting of a DMU/TMU/DMU, where the TMU – "Trailer Multiple Unit" – is defined as similar to the DMU in all regards, with the exception that it has no diesel power for either propulsion or auxiliaries. This configuration was chosen for two reasons. First, it was necessary to have three cars in the DMU train in order to meet the 12 axle rule. Second, the middle car was made a trailer in order to match the performance of the locomotive-haul train so that an apples-to-apples comparison could be made with regard to the emissions profiles.

With regard to the simulation software that we used, the program is called "RR" (for Rail Road Simulator). It can be used for a variety of railcar performance applications, including EMUs, DMUs and locomotive-haul trains. Typical inputs to the program include traction power characteristics of the prime mover, train data (weight, length, etc.), route profile and station stopping requirements. Typical outputs would include catenary voltage and line current (for EMU and electric locomotive applications), train performance, energy demands, fuel consumed and emissions profile. This software was developed about 15 years ago, and has been validated by comparison to actual train performance at a number of properties.

The route selected for the simulation was the Ventura County corridor, from Union Station to Chatsworth. This corridor has the largest population, and has the greatest potential for off-peak DMU ridership (16 available time slots for DMU overlay service). We have also identified the Ventura County corridor as having the most opportunities for positive impacts from the provision of a DMU overlay service (See Task 3.1.3, *Community Impact Report*). This line is 28.5 miles long and has a slightly descending grade from Chatsworth to Union Station. Runs were made in both directions. (*Note:* Although there was only a need to perform the RR simulation on a single corridor in order to contrast the performance characteristics of locomotive-haul and DMU trains, an operational analysis using RTC – Rail Traffic Controller – was conducted on each of the three corridors in order to identify *specific* operational time slots for DMU overlay service on each of the individual corridors).

We were not able to obtain an exact emissions profile from the diesel engine manufacturers; presumably, this information is proprietary and competition-sensitive. We were able to confirm, however, that both the MP36 locomotive and the CRM DMU are compliant with the EPA Tier levels governing their respective emissions contents. For the MP36, this would be the "Locomotive Tier 2" level. For the DMU, this would be "Off-Highway Tier 3". For locomotives and DMUs ordered after January 1, 2011, the tier levels will increase and the emissions standards will become more severe. Our approach to determining emissions for the simulated runs was to calculate the ULSD fuel consumed by each train, then assume that each diesel engine was outputting the maximum amount of contaminants allowed by the governing tier level for the respective technology, locomotive or DMU.

The run time was simulated to be approximately 40 minutes in each direction for each type of train, this to allow a more direct comparison of the two train types. Energy and fuel consumption calculations for both trains took into account the auxiliary loads. Consequently, the data presented in the following sections is *per train*, inclusive of all cars and all auxiliaries.

4.4.2 Results of the Computer Simulation

The results of the computer simulation are given below in Table 7 and Table 8. The results are total, *per train*, and include all auxiliary loads.

Westbound: Union Station to Chatsworth "Uphill"			
Parameter	**MP36**	**DMU**	**DMU Change**
Trip Time	40.21 min	40.22 min	0.00%
Energy Consumed	825.67 kW h	759.51 kW h	-8.01%
Fuel Consumed	65.36 gallons	48.72 gallons	-25.46%
Miles Per Gallon	0.43	0.58	+25.86%
CO Emissions	1911 grams	2648 grams	+27.83%
PM10 Emissions	210 grams	153 grams	-27.14%
NO_x + NMHC Emissions	6195 grams	3055 grams	-50.69%
CO_2 Emissions	548,013 grams	487,989 grams	-10.95%

TABLE 7: Computer Simulation Results: Westbound "Uphill"

Eastbound: Chatsworth to Union Station "Downhill"			
Parameter	**MP36**	**DMU**	**DMU Change**
Trip Time	39.53 min	39.08 min	-1.14%
Energy Consumed	540.33 kW h	490.30 kW h	-9.26%
Fuel Consumed	47.59 gallons	32.28 gallons	-32.17%
Miles Per Gallon	0.60	0.88	+46.67%
CO Emissions	1334 grams	1710 grams	+47.83%
PM10 Emissions	133 grams	99 grams	-25.56%
NO_x + NMHC Emissions	3978 grams	1972 grams	-50.43%
CO_2 Emissions	371,033 grams	323,320 grams	-12.86%

TABLE 8: Computer Simulation Results: Eastbound "Downhill"

From the above, it can be concluded that for a DMU and a locomotive-haul train with approximately the same passenger load, and approximately the same schedule performance, then:

- ☐ The DMU consumes about 9% less energy
- ☐ The DMU train consumes about 29% less fuel
- ☐ Except for carbon monoxide, the DMU train emits from 10% to 50% less polluting emissions, including particulate matter, nitrous oxide and carbon dioxide.

5.0 CORRIDOR CAPACITY ANALYSIS AND DMU IMPLEMENTATION PLAN

One portion of the study was dedicated to determining if an "overlay" DMU service can be superposed on the existing rail traffic network in the three corridors. Prior to launching our capacity analysis, certain parameters and guidelines for the overlay service were developed. These included the following:

- ☐ The "DMU overlay service" resultant from the study effort must not negatively impact any existing service (Metrolink, Amtrak, freight)
- ☐ The DMU service would be used to provide at least hourly off-peak service
- ☐ Supplemental DMU overlay service during peak hours would be considered *only* if there would be no impact to the existing commuter service
- ☐ Routes not terminating at Union Station could be considered

Ultimately, by incorporating a number of infrastructure changes in the analysis, the above goals were met.

5.1 Methodology

The first task in designing a DMU overlay service was to precisely chart all existing rail traffic in the study corridors and enter the information into a software program called *Rail Traffic Controller,* or RTC. RTC replicates, kinematically, all rail traffic data entered. It dynamically and graphically illustrates, in a compressed time frame, the actual movements of all traffic in the network. RTC is also the program used by SCRRA in scheduling their train network.

Once all the existing trains have been entered into RTC, the simulation is run to ensure that the model is accurate and precisely matches Metrolink, Amtrak and all freight train performance and the schedule for each corridor. Once this is verified, the *baseline model* is established.

The second task was to carefully examine the baseline model and look for opportunities to run DMU trains. A goal we established was to offer hourly service in each direction throughout the day. What we found was that there were a few opportunities to add DMU trains without impacting the baseline service, but that we needed additional network capacity (more opportunities) to meet our goal of hourly service.

The third task in the development of the DMU overlay service was to study the corridor infrastructure and identify any possible (but reasonable) changes that could be made which would measurably increase capacity. Seven such changes were identified, and discussed in some detail below.

These seven infrastructure changes were then loaded into the RTC software as though they actually existed. Once these changes were embedded in the simulation model, the network was run to determine how these changes affected capacity. In general, the network capacity increased to the point where it could accept DMU trains without impacting the baseline service.

The fourth and final task in the model development was to add additional DMU trains in the new network, and re-run the simulation to ensure that the overlay did not interfere with the baseline schedule in any way. Ultimately, this was confirmed. The DMU overlay service can be effected with nine 3-car DMU trains (DMU/TMU/DMU), and one spare DMU train. The results of our overlay simulation are given later in this section.

5.2 Infrastructure Changes

Following is a brief summary of the "virtual" infrastructure changes inserted into our computer model.

5.2.1 Chatsworth Station Layover Track (Ventura County Line)

This layover track would be located west of the Chatsworth Station. It would be a 1200-foot storage track used to lay up DMU train sets between runs to Los Angeles.

5.2.2 Second Main Track from Van Nuys to Chatsworth (Ventura County Line)

This is a second main line track from Chatsworth to Van Nuys, added to improve capacity in that line section. The distance is about 6.4 miles. Also associated with this change is a second platform and pedestrian underpass at Northridge Station, plus two relocated freight support tracks, modifications to existing signal control points ("CPs") to accommodate new crossovers, a second bridge over Bull Creek, and the addition of a second track at nine grade crossing locations.

5.2.3 Second Platform at Van Nuys Station (Ventura County Line)

A new, second platform at Van Nuys Station would be located between the two main tracks, necessitating shifting the present south main track further south, and relocating the present station building, parking lot, platform and walkways. It would further necessitate construction of a new bridge over Van Nuys Blvd.

5.2.4 Via Princessa Station Layover Track (Antelope Valley Line)

This would be a 1200-foot DMU storage track similar in both purpose and construction approach to the layover track proposed for Chatsworth Station. This layover track would be constructed between Via Princessa Station and the Sierra Highway.

5.2.5 Second Main Track from Newhall to Saugus (Antelope Valley Line)

This would be a second main track from CP Hood (Newhall Station) to CP Saugus, about 2.4 miles north of Newhall (Drayton Ave.) Additionally, there would be modifications to both control points to allow crossovers, a second track added to three grade crossings and a second track bridge over Newhall and Placerita Creeks.

5.2.6 New Center Platform at Glendale Station (Ventura County and Antelope Valley Lines)

This improvement would add a new center platform between the two main tracks at Glendale, a new pedestrian overpass between the new platform and the parking lot/bus terminal north of the main line, and a relocated freight staging track. There would also be modifications made to four control points, and the CMF (Central Maintenance Facility) access track would be relocated to CP Taylor to provide direct DMU train access to the main tracks. A new bridge would be constructed over the CMF access road. The purpose of the additional platform would be to permit simultaneous operation of two trains (Metrolink and/or DMU) at the Glendale Station.

5.2.7 Claremont Station Layover Track (San Bernardino Line)

This layover track and attendant crossover are similar in purpose and design to the layover tracks proposed for the Chatsworth and Via Princessa Stations. It would be used as an end-of-service holding track for DMU trains returning to Los Angeles. The storage track would be located between CP Cambridge and Towne Ave. in the City of Claremont. It would be 1200 feet long.

5.3 Results of the RTC Simulation

As noted previously, three distinct simulation models were created, run, and tested for veracity. They were:

- Baseline: This model contained only the existing rail traffic on the study network, including Metrolink, Amtrak and various freight trains
- Alternative DMU 1: This model included the Baseline rail traffic, plus 46 DMU trains inserted in those operational "voids" identified within the Baseline network
- Alternative DMU 2: This model included the Baseline rail traffic, plus those DMU trains added in Alternative 1, plus those previously noted infrastructure changes designed to increase network capacity

5.3.1 RTC Simulation Outputs

The results of these analyses are indicated in Table 9, following. A few notes regarding the data found in this table:

- The numbers given for "Commuter" trains refer to Metrolink trains only. When DMU trains are added in Alternatives 1 and 2, they are considered as Metrolink trains.
- The numbers given for "Total" trains refer to Metrolink trains (including DMU), Amtrak trains and freight trains
- The table is not organized by "corridor" *per se*, but rather by subdivision, which is how the operators define the various line sections. It was necessary to build our model by subdivision in order to be consistent with the operators, and in order to be able to verify the models via apple-to-apple comparisons. The four subdivisions are defined as follows:

  Ventura: From Burbank Junction to Moorpark (Ventura County Line)

  Valley: From CP Taylor to Lancaster (Antelope Valley Line)

  San Gabriel: (Approximately) from CP Taylor to San Bernardino (San Bernardino Line)

  River: From CP Taylor to Redondo Junction. Essentially, the River Subdivision is the "throat" through which all lines merge in their approach to Union Station

- "Delay" is defined as the amount of delay divided by its theoretically achievable run time. Delay typically occurs when the simulation (RTC program) notes a "conflict." Conflicts occur when two trains are scheduled to occupy the same section of track at the same time going in opposite directions. In such cases, the simulator will hold one train at the nearest siding and allow the other train to proceed. (This is exactly what occurs in the real world). Traffic is prioritized. For example, if a passenger train and a freight train conflict, the movement of the passenger train will be prioritized. If two passenger trains conflict, one of them will suffer a delay.

Subdivision	Distance	Train Type	Base Case			DMU 1			DMU 2		
			No. of Trains	*Avg. Speed MPH*	*Delay %*	*No. of Trains*	*Avg. Speed MPH*	*Delay %*	*No. of Trains*	*Avg. Speed MPH*	*Delay %*
Ventura	37.9 miles	Commuter	176	27.3	4.9	308	24.3	14.0	308	26.3	0.8
		Total	338	26.4	13.4	470	23.9	27.4	470	26.4	5.9
Valley	63.1 miles	Commuter	323	29.6	2.6	499	28.2	3.1	499	28.6	1.2
		Total	511	25.6	9.8	687	25.3	10.0	687	25.6	8.1
San Gabriel	32.2 miles	Commuter	246	30.2	5.1	286	29.9	5.0	286	30.0	5.2
		Total	292	25.7	7.1	336	25.9	5.7	333	25.8	6.7
River	17.61 miles on Ventura subdivision	Commuter	1,009	8.5	1.9	1,225	8.4	2.9	1,225	8.4	4.0
	3.5 miles on Valley subdivision 0.9 miles on San Gabriel subdivision	Total	1,417	9.6	5.5	1,633	9.4	5.9	1,633	9.4	7.0

TABLE 9: LA DMU Operation Simulation Results for a Seven Day Simulation

5.3.2 Discussion of Results: Alternative DMU 1

This simulation included the addition of 46 DMU trains as an overlay to the existing rail network, not including any infrastructure changes except for the necessary layover facilities at the Metro-owned corridor terminals: Chatsworth, Via Princessa and Claremont. These layover installations are necessary so the added DMU trains do not "foul" the mainline tracks at outer terminals. DMU trains were added to the present Metrolink, Amtrak and freight services to fill in timetable gaps, providing for hourly service in both inbound and outbound directions during weekdays. Resultant schedules for Metrolink (including DMU trains) and Amtrak service can be found in Appendix A to our report for Task 2.5.5, *Candidate Corridors Operational Capacity and DMU Implementation Plan Report*. The following trains were added to the baseline service:

- ☐ 16 DMU runs were added to the Ventura County Line service between Los Angeles and Chatsworth
- ☐ 6 DMU runs were added to the Ventura County Line service between Burbank Bob Hope Airport and Chatsworth
- ☐ 16 DMU runs were added to the Antelope Valley Line service between Los Angeles and Via Princessa
- ☐ 8 DMU runs were added to the San Bernardino Line service between Los Angeles and Claremont

As indicated in Table 9, the DMU 1 simulation has a negative impact on both average speed and percent delay as compared to the baseline simulation. Even though layover tracks at each of the three DMU corridor terminals were installed (in the model), these infrastructure changes were insufficient to allow the addition of the new DMU overlay service without bogging down the network. It is also noted that average speeds were impacted the most on the Ventura County Line. This is due to the fact that "dwell" times (station stops and movements to and from layover tracks) are a higher percentage of overall run time for the Burbank-Chatsworth trains than for the longer Union Station-Chatsworth runs. This results in slower average line speeds.

5.3.3 Discussion of Results: Alternative DMU 2

This simulation included the same addition of DMU trains as indicated in Alternative DMU 1; however, for this simulation, *all* of the infrastructure changes noted in Section 5.2 of this report were added to the model, this in order to increase network capacity.

Despite the significant increase in trains with the superposition of the DMU overlay, the average speed between the Base Case and DMU 2 remained about the same, and the percent delay diminished significantly, expect for the San Gabriel Division, which stayed about the same, and the River Subdivision, which suffered somewhat under the vastly increased commuter traffic on the three study corridors.

5.4 Ridership Forecast

A rough order-of-magnitude (ROM) ridership forecast was developed in order to estimate the average ridership of a DMU trainset. The DMU trains in our simulated overlay service (46 daily trains) are oriented towards off-peak service. (No peak time opportunities for DMU service exist in the current schedules.) The following approach was used in developing a ROM estimate for this off-peak ridership:

- ☐ We reviewed the SCRRA *Strategic Assessment Study (January 2007)*, in which a spreadsheet ridership model predicted peak period ridership on the Ventura County, Antelope Valley and the San Bernardino lines for the year 2010.
- ☐ The forecast for off-peak ridership was factored from the peak-period ridership projections from the SCRRA *Strategic Assessment Study*. By prior agreement with Metro, the factors used were developed by comparative analysis of off-peak ridership as a percent of peak ridership on Caltrain, the San Francisco Peninsula rail commuter service.
- ☐ Our analysis indicated that for deployment of 20 trains or more (we are deploying 46 trains in our model), the off-peak ridership would be about 25 percent of peak ridership.
- ☐ It was further noted that the ridership numbers projected in the SCRRA *Strategic Assessment Study* for 2010 are being achieved today due to the overwhelming success of the Metrolink Commuter Service concept. Consequently, we escalated both Metrolink and DMU ridership to account for the two additional years (2008 → 2010) of system growth.

Following is Table 10 which illustrates the results of our analysis:

Candidate Corridor	Off-Peak Trains		Riders		
	Metrolink	DMU	Metrolink	DMU	Per Train
Ventura County Line	6	22	309	720	51
Antelope Valley Line	9	16	555	678	62
San Bernardino Line	13	8	906	488	70

TABLE 10: Weekday Off-peak Riders in 2010 with DMU Implementation

In all, the Implementation Plan anticipates a total of 46 weekday trains on the candidate corridors. Assuming an estimated 60 riders per train, conceptual average weekday ridership would total 2,800 passengers.

6.0 DMU FLEET MAINTENANCE OPTIONS

6.1 Description of Two Alternative Approaches

Following considerable study, two options emerged as the only viable alternatives to the maintenance of a 30 car (20 power DMUs; 10 trailer TMUs) fleet. The first option was to build an entirely new facility, expressly for the purpose of maintaining DMU trains. The new facility would be located so the fleet assigned to each of the three study corridors (Ventura, Antelope Valley, and San Bernardino) would have ready access to the shop. The second option would be to maintain the DMU fleet in Metrolink's existing maintenance facility (Central Maintenance Facility, or CMF) and planned Eastern Maintenance Facility (EMF). The study approach would be to perform the running maintenance and repair at the CMF, and heavy repair at the EMF. Both of these alternative approaches were studied in detail. Conceptual designs for each can be found in our report for Task 2.6, *DMU Maintenance Facility, Concepts, Costs and Criteria*.

A third alternative – fully maintaining a portion of the fleet at the CMF and the balance of the fleet at the EMF – was judged impractical and expensive and was not studied further.

6.2 Vehicle Configuration Assumptions

Before a conceptual shop design could be effected, a vehicle type had to be assumed. It has been noted previously that in the near term (say, next three to five years), the only realistic DMU technology for the study application would be a DMU compliant with present FRA requirements for passenger rolling stock operating on the "General Railway System", to which the three study corridors belong. The only production vehicle presently meeting these criteria is the Colorado Rail Manufacturing (CRM) DMU. Although it is possible that if Metro advertised for a fleet of 30 DMUs, other new designs would be proposed by the carbuilding community, we have no detailed prior knowledge of those designs. For the purpose of this exercise, we assumed the following:

- ☐ The vehicles to be maintained would be of a CRM design, both power and trailer cars.
- ☐ Based on our operational study, and SCRRA signaling system dictates (the 12 axle rule), we will need ten DMU/TMU/DMU trains (20 power cars and 10 trailers).
- ☐ The maintenance facility must have bays to accommodate from one to three MUs, both diesel and trailers.
- ☐ The vehicles do not have toilets; that is, the maintenance facilities need not be equipped for human waste disposal (this would be a significant complication)

6.3 Life Cycle Maintenance Program

Various philosophies can be applied when designing a vehicle maintenance program, including facility design. The philosophy we adopted for this study, consistent with Metrolink's maintenance approach, is referred to as a *Life Cycle Maintenance Program.* A Life Cycle Maintenance Program incorporates the following activities/events:

- ☐ Daily Service and Inspection
- ☐ Running Repair
- ☐ Heavy Repair
- ☐ Mid-life overhaul (outsourced)

Our design of a new maintenance facility and modification of existing facilities is based on the foregoing approach.

6.4 Industrial Engineering Principles

Our approach to the design of a new maintenance facility, and the modification of existing facilities, incorporated the use of certain industrial engineering principles. Use of those principles led us to the following additional assumptions regarding our designs:

- ☐ Control of DMU operations on the study network will be effected from Metrolink's present Operations Center, the MOC
- ☐ Wheel truing will remain a CMF task, regardless of the approach taken (utilization of new or existing facilities)
- ☐ Major diesel engine, transmission and generator work will be outsourced
- ☐ All approaches will include a Service and Inspection track. The track will be seven car lengths long; enough space for two three-car trainsets plus a single car length wash track.
- ☐ All approaches will have a six-car length (two trainsets) Running Repair track
- ☐ All approaches will have a Heavy Repair track three car lengths long, enough for a single trainset. This heavy repair track will require the following:
  - In-floor lift system
  - Heavy repair "back-ship" with a crane

6.5 Design of a New Maintenance Facility

Alternative No. 1 for the DMU fleet maintenance study was the provision of a new maintenance facility (and yard) dedicated *exclusively* to the DMU overlay fleet. Our approach assumes a 30 car service fleet, but the design was structured to accommodate up to 40 cars. The facility was also designed for a 50+ year lifetime requirement, a class of construction that is above typical retail or commercial projects.

6.5.1 New Facility: Major Features

A new maintenance facility, will require 47,500 ft.^{2} under roof. The entire facility property, including the accompanying yard, will require a lot size approximately 350' x 2650', or 21.3 acres.

The major features within our conceptual design for a new DMU facility include the following:

Daily Service and Inspection: Track No. 1

The underlying assumption for the Service and Inspection (S&I) track is that the entire fleet will be serviced each day as three-car trainsets. Services to be performed on each trainset include the following:

- ☐ Fueling (vehicles are assumed to carry sufficient fuel so as not to require mid-day fueling)
- ☐ Inspection, to comply with the Exterior Calendar Day Mechanical Inspection under the requirements of 49CFR 238.303 and the Interior Calendar Day Mechanical Inspection under the requirements of 49CFR 238.305.
- ☐ Interior cleaning

- ☐ Fluids check (engine oil, transmission oil and windshield washer fluid)
- ☐ Sand Tank refilling (DMUs carry sand to spray on the track to increase wheel-to-rail adhesion during rain, etc.)
- ☐ Exterior vehicle wash (located immediately outside the shop building)

Running Repair: Tracks No. 2 & 3

The two running repair tracks are separated from the S&I track by a Concrete Masonry Unit (CMU) corridor. Typically, the CMU contains several rooms. Included in our conceptual design are the following:

- ☐ Facility mechanical room (air compressor, etc.)
- ☐ Small parts store room
- ☐ Vehicle component repair room (electrical components, mechanical components, etc.)
- ☐ Facility electrical room (switchgear, motor controls for cranes and lifts, etc.)
- ☐ Supervisor's room

Tracks 2 and 3 within the new maintenance facility are dedicated to running repair; that is, those repairs which take less than one day. Track 2 has a pit for undercar work. It also has a top-of-car platform with access to the (reinforced) roof of the CMU corridor. HVAC units can be removed from the top of the car by an overhead monorail and hoist, and then placed on the utility corridor roof for minor repair or replacement. Track 3 is a flat track, suitably reinforced to allow portable vehicle lifts to be used.

Heavy Repair: Track 4

Generally speaking, our concept for heavy repair is the facilitation of removal and replacement ("R&R") of major components, such as, trucks, engines, transmissions air compressors, etc. This approach is adopted in order to put the vehicle back in service quickly. Most R&R exchanges can be effected in 3 to 4 days, whereas a complete engine rebuild would normally take two weeks, assuming all parts are immediately available. On our target car, the CRM DMU, the engines, trucks, transmissions and generator are removed by dropping them out from under the car. Consequently, installed on Track 4 is an in-floor lift system. With this system, the entire car can be raised and the discrepant component unbolted and lowered to the shop floor. Transfer rails are also provided to roll the failed unit into a major components storeroom located adjacent to Track 4.

Please refer to the report for Task 2.6, *DMU Maintenance Facility Concepts, Costs and Criteria, Appendix A* for shop layout and profile drawings.

6.5.2 Utilization of the CMF and EMF for DMU Overlay Fleet Maintenance

The second DMU fleet maintenance option considered viable is to maintain the DMU overlay fleet through a combination of the CMF and EMF shops. In this approach, the running maintenance and running repair would be effected at the CMF, and the heavy repair would be performed at the EMF. This approach takes into consideration the fact that the EMF is not in the best location for daily operations; hence, the EMF is proposed for heavy repairs, which are made at a much lower frequency.

Four assumptions were made in our investigation:

(1) DMUs will arrive at the CMF during the evening hours, and that adequate space for yard storage and maintenance will be available since a majority of the existing commuter trains spend late evening and nighttime hours at outlying layover facilities or the EMF

(2) DMUs will exit the CMF yard and shop prior to the ingress of Metrolink's locomotive-haul equipment

(3) A minimum 12 hours out-of-service time is available for the DMU fleet at the CMF

(4) Space for a 100 ft. x 300 ft. heavy repair building can be made available at the EMF

Our analysis of this approach, including conversations with SCRRA management, indicates that the above assumptions are reasonable at this stage of the study. We offer one caveat, however: The transition between the locomotive-haul rolling stock and the DMU fleet at the CMF can be managed – but with some difficulty. We also note that sharing of the CMF between the two fleets will dictate the need for some compromises. Chief among these compromises will be the apparent reduction in space on the shop floors, since both fleets would be sharing what was once dedicated to the locomotive-haul fleet only. The opening of the EMF will provide some relief, but coordination of key assets (shop equipment, personnel, parts, etc.) between the two fleets would require a major effort.

Analysis of the CMF for Use in Maintaining the Overlay DMU Fleet

Our analysis of the CMF's viability as a running maintenance and repair site for the DMU overlay fleet has resulted in the following conclusions:

☐ Service and Inspections (S&I) would be performed on the CMF's existing outdoor S&I tracks. Although we see no serious drawbacks to this concept, we note that fuel stop locations, and the logistical placement of select utilities, may not be ideal for our DMU choice. In this regard, we set aside $370,000 in our cost estimate (details provided in our report for Task 2.6, *DMU Maintenance Facility Concepts, Costs and Criteria*) for a general upgrade to the outdoor facilities to ensure compatibility with the DMU vehicle design.

☐ The eastern-most Progressive Maintenance Track (CMF Track P2) is 780 feet long, and could be used for the six-position DMU running repair track

☐ CMF spare parts storage is not ideal and would become acutely worse with the addition of the DMU fleet. We recommend the addition of a 48 ft. x 225 ft. parts storeroom which could also accommodate off-vehicle component repairs. See Figure 5.

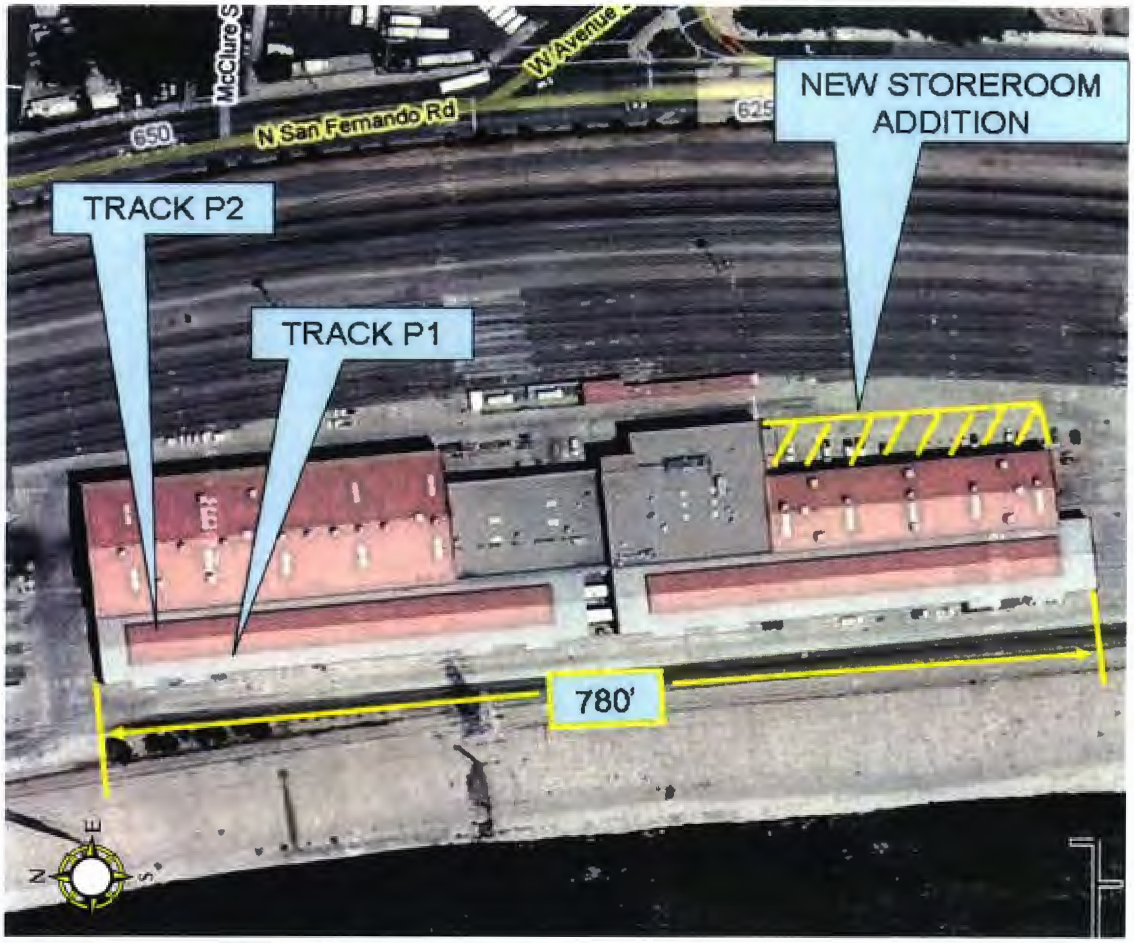

FIGURE 5: Aerial View of Central Maintenance Facility

There is very little property left to build any significant structures at the CMF. We looked at covering a portion of the yard tracks and "squeezing" another full bay on the west side of the facility, but each of these ideas seriously constrained overall facility flow of vehicles and material. Consequently, the previously discussed approach is considered optimal.

Analysis of the EMF for use in Maintaining the DMU Overlay Fleet

As previously noted, in the context of using existing Metrolink facilities for running maintenance and repair of the DMU overlay fleet, we have assigned heavy repair to the EMF, located in Colton near the San Bernardino station. In this regard, we recommend the construction of a 30,000 ft^2 (100' x 300') heavy repair facility. This facility would contain the following features:

- ☐ A single, full-length repair track with in-floor lifts for undercar component changeout
- ☐ An elevated work platform for HVAC unit replacement
- ☐ A 10- ton overhead bridge crane
- ☐ A 3000 ft^2 (30' x 100') parts storeroom
- ☐ Various machine shop equipment (drill press, lathe, welder, iron worker, etc)
- ☐ Offices for four individuals (shop manager, two shift supervisors, vehicle engineer)
- ☐ Lunch break room
- ☐ Rest rooms

7.0 COMMUNITY IMPACTS ASSOCIATED WITH A DMU OVERLAY SERVICE

The imposition of a DMU Overlay Service can have both positive and negative impacts on communities attendant to the target routes. The positive impacts include providing more availability of rail transportation and community development opportunities. Negative impacts could include increased noise, local traffic, and atmospheric contaminants, although a case could be made that the provision of a DMU overlay fleet enhances air quality, for the following reasons:

- We have demonstrated that with the exception of carbon monoxide (CO), the exhaust pipe emissions from a DMU train with the equivalent passenger-carrying capacity as a locomotive-haul train are significantly less than those emitted by the locomotive
- The energy consumed by a DMU train is about 9% less than that consumed by an equivalent locomotive-haul train on an identical route with an equivalent schedule

The scope of our work for this portion of the study included identification of those geographic locations subject to impact, positive or negative, and a ROM estimate of the number of affected locations.

7.1 Corridor Selection and Segmentation

The corridors examined in this survey included Metrolink's Ventura County Line, Antelope Valley Line, and San Bernardino Line. We identified communities (both planned and existing), major facilities, cultural and historic centers, parks and other areas of interest within one-half mile of the right-of-way (ROW) for each corridor. This resulted in a study area one mile wide along the entire Metro-owned length of each corridor.

Each corridor was broken into smaller segments for ease of identification of the affected areas. Each segment generally includes two Metrolink stations, but sometimes three. The average segment is from five to ten miles in length, yielding distinct impact zones from five square miles to ten square miles. These segments are defined graphically on the following three pages (Reference Figure 6 through Figure 8).

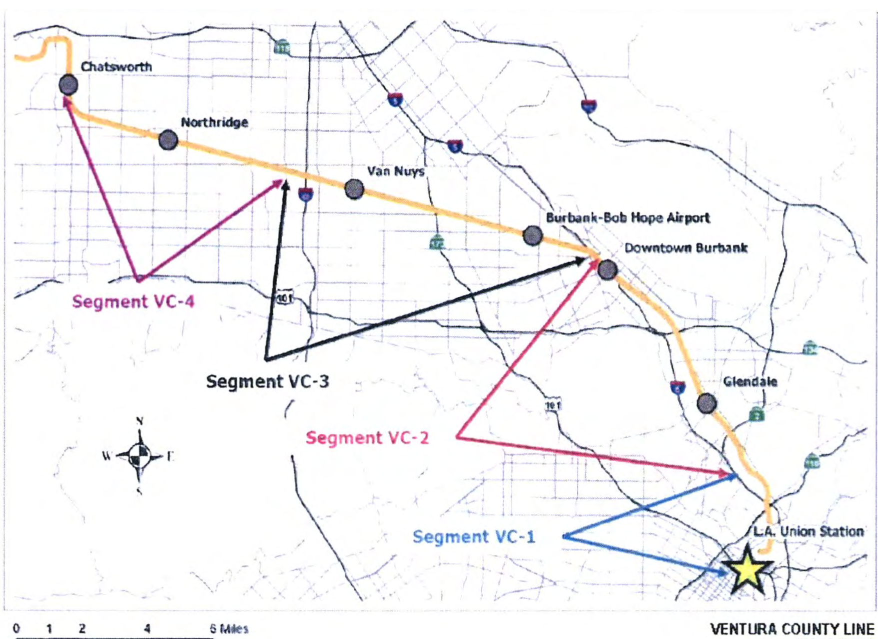

FIGURE 6: Ventura County Line Segment Map

LTK Engineering Services

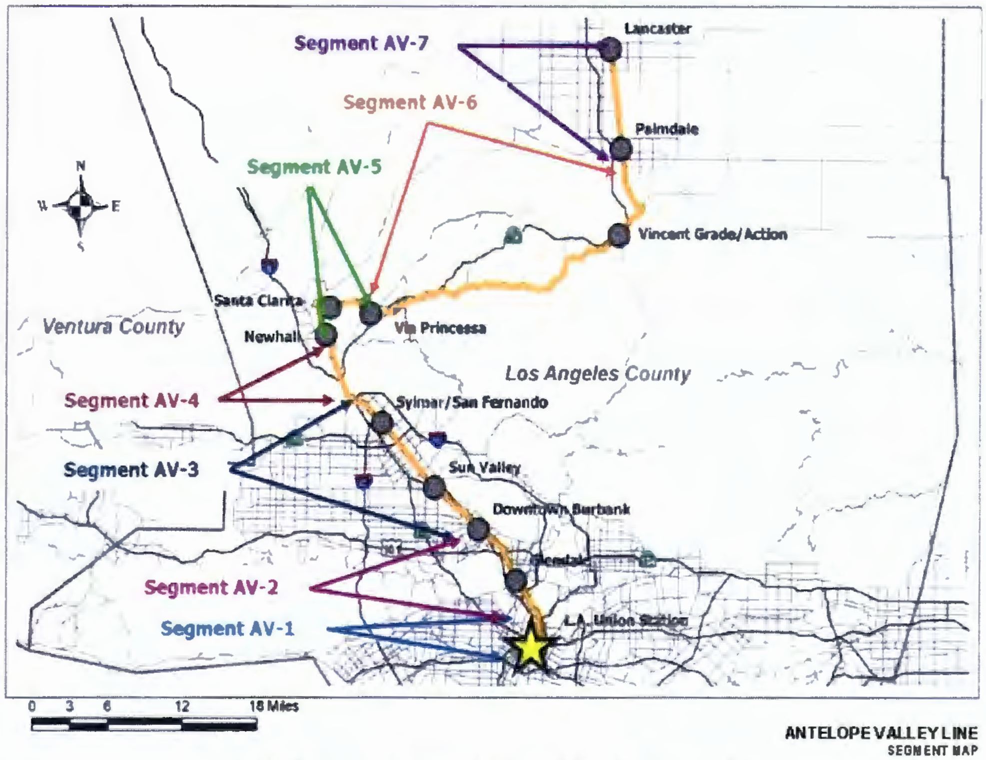

FIGURE 7: Antelope Valley Line Segment Map

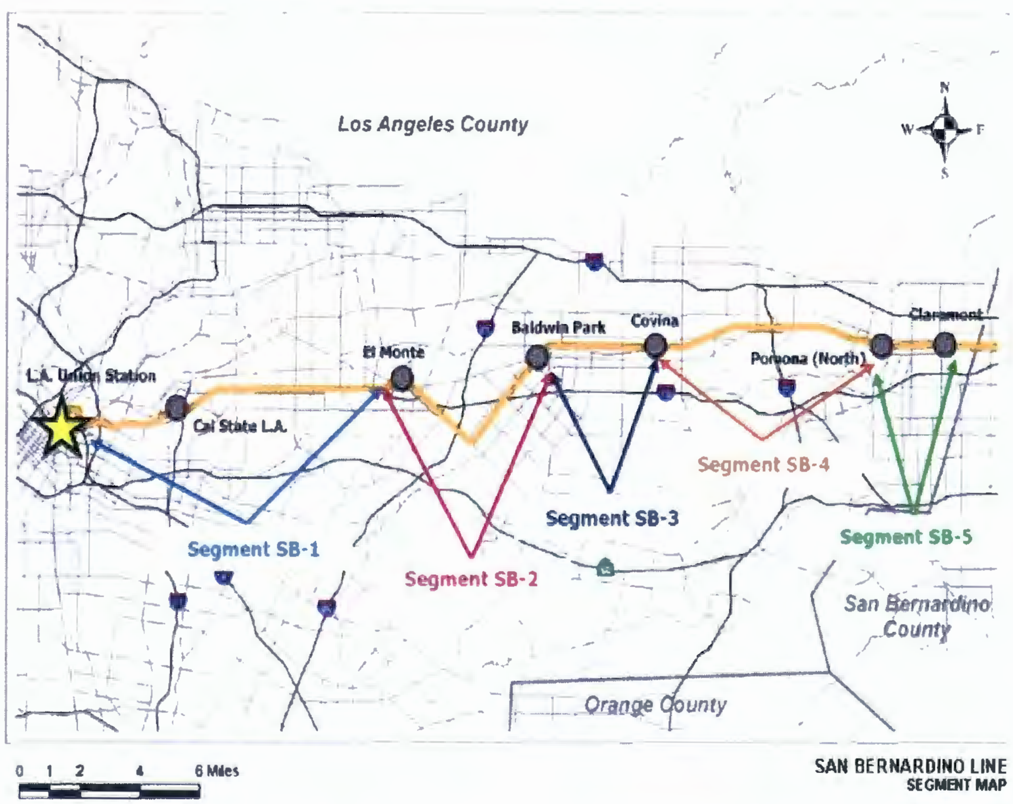

FIGURE 8: San Bernardino Line Segment Map

7.2 Impact Grouping Methodology

Population centers and other locations along the candidate corridors may realize benefits from DMU overlay service, or suffer potentially negative impacts due to the imposition of same. Since the benefits (increased transportation service, development opportunities) and negative impacts (noise; pollution) are fairly evenly distributed across the study area, the most meaningful approach to defining the overall impact of the DMU overlay service is to identify, by group, those *existing* entities most likely to benefit from the service; those *planned* entities most likely to benefit from the service; and those entities vulnerable to negative impacts and which may require mitigation measures. These three groupings are identified as follows:

7.2.1 Group 1: Existing Entities Likely to Benefit from a DMU Overlay Service

Existing entities which could benefit from the provision of a DMU overlay service have been identified as:

- ☐ Commercial centers
- ☐ Cultural and historic centers
- ☐ Public assembly sites
- ☐ Transportation centers
- ☐ Communities and neighborhoods

7.2.2 Group 2: Planned Entities Likely to Benefit from a DMU Overlay Service

Planned entities which might benefit from DMU service include:

- ☐ Planned major developments and other population centers (sports arenas, for example)

7.2.3 Group 3: Sensitive Areas Vulnerable to the Negative Impacts of a DMU Overlay Service

Those areas which could suffer potentially negative impacts resultant from a DMU overlay service, and which could require mitigation measures, include the following:

- ☐ Medical facilities
- ☐ Parks and other recreation areas
- ☐ Residential areas
- ☐ Schools

7.3 Segment Rating System

7.3.1 Rating System for Groups 1 & 2 (Positive Impacts)

The segment rating system for Groups 1 and 2 is as follows:

High: More than ten locations with opportunities for positive impacts per segment

Medium: Five to ten locations with opportunities for positive impacts within the segment

Low: Less than five locations with opportunities for positive impacts within the segment

7.3.2 Rating System for Group 3 (Negative Impacts)

The segment rating system for Group 3 is different than that of Groups 1 and 2, in that negative impact-sensitive areas are better identified by land use coverage than by numbers of specific sites, although the presence of a single impact-sensitive site is generally sufficient to warrant some level of mitigation effort.

The rating system for negative impact-sensitive areas is as follows:

High: Sensitive land use area is greater than 50% within the segment

Medium: Sensitive land use area is between 25% and 50% within the segment

Low: Sensitive land use area is less than 25% within the segment

7.4 Summary of Results by Corridor

The rating results by corridor are summarized in Tables 12 through 14 below.

		Ventura County			
		VC-1	VC-2	VC-3	VC-4
		UNION STATION TO TAYLOR YARD	TAYLOR YARD TO BURBANK JUNCTION	BURBANK JUNCTION TO CP RAYMER	CP RAYMER TO CHATSWORTH
GROUP 1	Existing Entities Likely to Benefit	HIGH	HIGH	MEDIUM	MEDIUM
GROUP 2	Planned Entities Likely to Benefit	HIGH	MEDIUM	LOW	LOW
GROUP 3	Sensitive Areas Vulnerable to Negative Impacts	LOW	LOW	LOW	LOW

TABLE 11: Ventura County Corridor Impact Assessment

		Antelope Valley						
		AV1	AV-2	AV-3	AV-4	AV-5	AV-6	AV-7
		UNION STATION TO TAYLOR YARD	TAYLOR YARD TO BURBANK JUNCTION	BURBANK JUNCTION TO CP BALBOA	CP BALBOA TO CP PORTAL	CP PORTAL TO VIA PRINCESSA	VIA PRINCESSA TO CP HAROLD	CP HAROLD TO LANCASTEI
GROUP 1	Existing Entities Likely to Benefit	HIGH	HIGH	MEDIUM	LOW	MEDIUM	HIGH	HIGH
GROUP 2	Planned Entities Likely to Benefit	HIGH	MEDIUM	LOW	MEDIUM	LOW	MEDIUM	LOW
GROUP 3	Sensitive Areas Vulnerable to Negative Impacts	LOW	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUI

TABLE 12: Antelope Valley Corridor Impact Assessment

		San Bernardino				
		SB-1	SB-2	SB-3	SB-4	SB-5
		UNION STATION TO EL MONTE	EL MONTE TO CP IRVIN	CP IRVIN TO CP BARRANCA	CP BARRANCA TO CP WHITE	CP WHITE TO CLAREMONT
GROUP 1	Existing Entities Likely to Benefit	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM
GROUP 2	Planned Entities Likely to Benefit	MEDIUM	LOW	LOW	LOW	LOW
GROUP 3	Sensitive Areas Vulnerable to Negative Impacts	LOW	LOW	MEDIUM	MEDIUM	LOW

TABLE 13: San Bernardino Corridor Impact Assessment

Ranking the corridors with regard to the positive impacts DMU overlay service will have, we assign a "3" to each "HIGH" score, a 2 to each "MEDIUM" score, and a 1 to each "LOW" score. Summing and averaging the rankings per corridor and per group results in the following scores:

Group 1 (Positive Impacts to Existing Entities)

Ventura County: 2.50
Antelope Valley: 1.75
San Bernardino: 2.20

This indicates that the Ventura County Line has the most opportunities for positive impacts resultant from the provision of DMU overlay service.

Group 2 (Positive Impacts to Planned Entities)

Ventura County: 1.75
Antelope Valley: 1.86
San Bernardino: 1.00

These results indicate that the Antelope Valley Line has slightly more opportunities for positive DMU service impacts for planned entities than the Ventura County Line, and significantly more than for the San Bernardino Line.

Ranking the corridors with regard to their vulnerability to potential negative impacts, we recognize that "LOW" is the best ranking, in that it indicates the least vulnerability. Consequently, for GROUP 3, a ranking of "LOW" is assigned a 3, a ranking of "MEDIUM" is assigned a 2 and a ranking of "HIGH" is assigned a 1.

Group 3 (Degree of Sensitive Land Usage)

Ventura County: 3.00
Antelope Valley: 2.14
San Bernardino: 2.60

This indicates that the Ventura County Line has the least sensitive land uses, followed by San Bernardino and then Antelope Valley.

In summary, the Ventura County Line scored the highest of the three corridors in regard to most opportunities for positive impacts to existing facilities; the Ventura County Line score second with regard to most opportunities for positive impacts to planned entities; and the Ventura County Line also scored highest in regard to least negative impacts to sensitive land uses. Consequently, it is concluded that, from a community impacts perspective, the Ventura County Line would be the strongest candidate for a DMU overlay service.

7.5 Comparison of Noise Produced by Locomotive-Haul Equipment and DMU Trains

The potential noise impacts of DMU operations were assessed by comparing them with comparable Metrolink operations. For the purpose of the analysis, a one-locomotive, four-passenger car Metrolink train with a seating capacity of 140 passengers[2] was assumed to run every 30 minutes (data was available for this train configuration, and it represents a worst-case scenario). Two configurations of FRA-compliant DMUs that are in service for U.S. transit agencies were used for the noise analysis.[3,4] These are shown in Table 14, *DMU Configurations*. The service schedules for the two DMU configurations were assumed in order to provide the same level of transportation capacity as the two Metrolink trains per hour.

An FTA methodology[5] was used to estimate noise exposures from typical Metrolink trains and DMUs at an equivalent distance of 50 feet from the tracks. The calculation used the FTA's suggested Sound Exposure Levels (SELs) for the commuter trains and DMU, and the assumed operational conditions.

Configuration	Service Configuration	Seating
DMU Single Level	Single DMU	160
DMU & Trailer (Double Deck)	DMU-trailer-DMU	188 (+200 trailer)

TABLE 14: DMU Configurations

The estimated L_{eq} ("Hourly Equivalent Sound Level"; a receiver's cumulative noise exposure from all events over a one hour period) for Metrolink trains and DMUs are presented in Table 15, *Projected Noise Exposures.* Note that the average traveling speeds of the Metrolink trains and DMUs were assumed to be 60 miles per hour.

Train Type	Numbers of Trains/ DMUs per Hour	Hourly Seating Capacity (Passengers)	Hourly L_{eq} at 50 ft (dBA)
Metrolink Trains	2	1,120	60.9
DMU Single Level	7	1,120	57.9
DMU & Trailer (Double Deck)	3	1,164	58.5

TABLE 15: Projected Noise Exposures

As shown in Table 15, with an assumed Metrolink schedule of two trains per hour, running DMUs with the same level of passenger seating capacity would generate lower noise emissions.

According to the aforementioned FTA noise impact criteria, the DMU noise exposure (per the assumed operational scenario) would have no impact on Category 1 (quiet is an essential

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2 Metrolink, 2007. Metrolink Factsheet. May 2007. Accessed at: http://www.metrolinktrains.com/documents/About/MetrolinkFactSheet.pdf.

3 LTK Engineering Services, 2008a. *Diesel Multiple Unit Technical Feasibility Analysis: Task 2.3.1.1: DMU Vehicle Market Survey*. May 14. Appendix A.

4 ______ 2008b. *Task 2.3.1.2: DMU Property Survey*. July 1.

5 FTA, 2006d. Chapter 5.

element, such as indoor concert halls or outside concert pavilions) and Category 2 (residences and buildings where people sleep) receptors at 50 feet in areas where ambient noise levels were greater than 62 dBA L_{eq}. In contrast, Metrolink trains in the same area would have a "moderate impact" when ambient noise levels were below 65 dBA L_{eq}, and would have no impact when ambient noise levels were above 65 dBA L_{eq}, for the same categories. In other words, the ambient noise levels would have to be higher (65 dBA L_{eq} vs. 62 dBA L_{eq} for the DMU) in order for the Metrolink train to be assessed as "no impact" to the existing environment.

8.0 PROJECT COSTS

8.1 Structure of the Cost Estimate

The cost to implement an overlay DMU service has two principle components; viz., capital costs and operating costs. Each of these principle costs has a number of components. It is important to keep in mind that the costs represented in this report are rough order-of-magnitude (ROM) only. The scope of this study was to determine the *feasibility* of a DMU overlay service. In order to produce cost estimates sufficiently robust to develop construction budgets, there are a number of tasks which will need to be accomplished.

The first task is to resolve certain policy issues. For example, we are presently bound by the "12 axle rule", which dictates that each train must have a minimum of 12 axles to ensure the integrity of the track circuits detecting block occupancy and grade crossing proximity. This rule necessitates three FRA-compliant type DMUs per train, since the only available FRA-compliant DMUs have four axles per car. In the wake of the recent Metrolink Chatsworth accident, however, there has been significant discussion of "Positive Train Control", also referred to as "Advanced Train Control", a technology prevalent in Europe. Some advanced train control technologies do not rely on axle shunting of track circuits. If one of these technologies were to be selected for the Metrolink corridors, in tandem with an advanced grade crossing warning system, it could relieve the system of the burden of the 12 axle rule and greatly enhance operational efficiency. For example, were the 12 axle rule to be lifted, we could meet the DMU overlay goals expressed in this report with one-third the fleet – ten DMUs instead of 20 DMUs and 10 trailers – at perhaps 40% of the fleet cost.

A second task that needs to be completed before a budget-level estimate can be generated is to advance the engineering design to the Preliminary Engineering level. The three major capital cost components are vehicles, maintenance facilities and infrastructure upgrades.

In some areas, within the scope of this study, we have come close to achieving a conceptual level of engineering, but we are nowhere near the 30% design level needed for construction budgeting purposes.

8.2 Capital Costs

As indicated above, the capital costs are broken down into three major components:

- ☐ Vehicles
- ☐ Maintenance Facilities
- ☐ Infrastructure Upgrades

The infrastructure costs can be assigned to specific corridors, but for this study they are provided as a lump sum cost. The vehicle fleet and the maintenance facility costs are system-wide expenses.

Insofar as the vehicle fleet costs are concerned, we assumed the current prevailing constraints in generating our estimate. These were:

i. That FRA-compliant vehicles would be required; and that

ii. DMU train consists would need to have a minimum of three cars each, this to satisfy the 12 axle rule. This equates to 10 x 3 = 30 cars. (In order to reduce both capital and operating costs, we elected to use two DMUs and a trailer for each trainset).

The maintenance facility costs are broken down into two categories. One cost is a complete new facility; the other is the upgrade of the CMF and EMF to accommodate a new DMU fleet. Again, these are system wide costs.

The final capital cost is that to implement alignment upgrades in order to increase network capacity.

We were also asked to give an ROM estimate of the cost to provide an EMU (Electric Multiple Unit) overlay service. This estimate has three components: EMUs, traction power substations, and overhead catenary system. A new maintenance facility would also be required in that it would not be practical to maintain EMUs and locomotive-haul equipment in the same shop: the maintenance and power (OCS) needs are too diverse.

Given the above, we have developed three alternative capital costing alternatives. These are:

Alternative 1: DMU/New Maintenance Facility

Alternative 2: DMU/Use of CMF and EMF

Alternative 3: EMU/New Maintenance Facility

A summary of these capital costs is presented in the following table:

Capital Construction and Engineering Costs

Cost Components (2008 Dollars)	**Alternative 1 DMU | New MF**	**Alternative 2 DMU | CMF & EMF**	**Alternative 3 EMU | New MF**
Vehicle Fleet (& catenary for EMU)	$150,000,000	$150,000,000	$273,000,000
Infrastructure Changes	$125,000,000	$125,000,000	$125,000,000
Maintenance Facility	$ 35,000,000	$ 20,000,000	$ 35,000,000
Land Acquisition	$ 20,000,000	--	20,000,000
TOTAL	**$330,000,000**	**$295,000,000**	**$453,000,000**

TABLE 16: Capital Costing Alternatives

8.3 Operating Costs

Our approach to operating costs is different than the approach we took in estimating capital costs. For capital costs, we used a "build up" methodology; that is, we priced each of the relevant components separately and summed them up to reach a total. Our approach to the operating costs, however, is more *comprehensive*. From our research, we were able to determine that Metrolink's full operating costs (fuel, maintenance, labor, etc.) were $80.75 per train mile for 2008. Assuming the non-fuel and non-maintenance components of this number are the same for locomotive-haul trains as DMU trains, since the same operating rules and overhead burdens apply to each train type, we can use that portion of the composite number for the DMU overlay fleet. We also know that of the composite $80.75 train-mile, $17.79 is projected for fuel and equipment maintenance. For our DMU propulsion technology studies, we determined that a three-car DMU train is about 29% more fuel efficient than an equivalent locomotive-haul train. We also estimate that DMU maintenance is about 20% less than for a locomotive haul-unit.

Using this data, we project with a fair amount of confidence that the per train mile operating costs of a DMU are $76.51.

Metrolink's costs for these components, in 2008 dollars, are as follows:

Agency costs:		\$62.96 per train-mile
Fuel costs:		\$8.57 per train-mile
Maintenance costs:		\$9.22 per train-mile
	Total	\$80.75 per train mile

Projected DMU costs for these components, in 2008 dollars, are as follows:

Agency costs:		\$62.96 per train-mile
Fuel costs:		\$6.17 per train-mile
Maintenance costs:		\$7.38 per train-mile
	Total	\$76.51 per train mile

Complete costing details can be found in our report to Task 2.7, *DMU Operations Implementation Cost Report*.

9.0 FUNDING

As with all projects, funding for the DMU overlay is an issue. Due to the fairly unique character of the DMU overlay service, however, there may be opportunities for non-traditional funding in addition to more conventional sources. In our review of potential funding sources, both conventional and innovative sources were considered within each category.

Potential revenue sources were categorized as follows:

- ☐ Revenue sources that could be initiated and controlled by Metro
- ☐ Revenue sources requiring local agency cooperation; specifically agencies with land use approval and developmental authority
- ☐ Possible non-traditional public sector revenue sources

9.1 Revenue Sources Controlled by Metro

The following potential revenue sources, within Metro's control, were identified:

- ☐ Station naming rights
- ☐ Station and vehicle advertising programs
- ☐ Employer-subsidized transit passes
- ☐ University-subsidized transit passes
- ☐ Joint development

Station naming rights allow the selling of the rights to name a public facility. This could include a transit station, stop, or transfer site. Since no new stations were identified for the service level proposed, this revenue stream is not likely, as the existing stations are owned by the cities within which they are located.

The selling of vehicle naming rights, however, is an interesting and potentially viable approach. A DMU fleet in the LA metropolitan area would be unique. DMUs look significantly different from locomotive-haul rolling stock, and have proven to be attractive to the ridership in Europe and on other continents. It is not at all difficult to imagine that local businesses, universities and perhaps transit advocacy groups would be willing to name a transit vehicle for a fee.

Advertising could be sold on either a station or a vehicle basis. Although the revenue stream from transit advertising is typically small (but stable), New Jersey Transit was recently able to increase revenues from advertising by competitively bidding various components of their advertising program rather than awarding same to a single entity.

A recent innovation in rail vehicle technology is a departure from print media (paper; cardboard) to electronic media, wherein digital passenger information signs provide upcoming station and other data to passengers enroute. These electronic messaging boards could easily be adapted to advertising purposes (separate from the passenger information display). In this manner, the same space could be sold to several advertisers.

Another revenue-generating approach entirely within Metro's control would be to partner with area employers through the use of subsidized transit passes for employees. Availability of subsidized rides encourages ridership and improves farebox cost recovery. As ridership increases, the overall system acquires increased "equity" in the form of reduced costs per rider and the ability to charge more for advertising. Similarly, Metro could partner with local universities to develop a subsidized transit pass program. Such an approach is planned for the new Tucson Modern Streetcar Project. In Tucson, the University of Arizona (UA) students will have the cost of a discounted annual pass added directly to their matriculation fee. This will be required of all students. Faculty will have the option of joining the program. Since UA is located at the northeast terminus of the line, and downtown Tucson is at the center of the line, this policy should contribute enormously to ridership.

With the increased ridership that a DMU overlay service would eventually bring, joint development might someday be possible. In this revenue-generating approach, land owned or purchased by Metro near a station is leased to a private developer under a contractual agreement specifying the design and/or type of development permitted. Revenue is generated through the lease proceeds in exchange for the developer's right to improve the site. Metro has used this approach at the Union Station Gateway, Universal City MCI and the Hollywood/ Highland Metro Rail Stations.

9.2 Potential Revenue Sources Requiring Local Agency Cooperation

Following is a list of potential revenue sources requiring local agency cooperation:

- ☐ Special Financing District
- ☐ Developmental Fees/Transportation Impact Fees
- ☐ Negotiated Agreements
- ☐ Transit Access Fee
- ☐ Infrastructure Financing District (tax increment financing)
- ☐ Business Improvement District (BID)
- ☐ Property-based Business Improvement District (PBID)
- ☐ County Service Area

Local jurisdictions can establish a *Special Financing District* to address the infrastructure needs associated with new land development. Transit stations and related fixed facilities may also be included in any financing plans developed for the defined district. Revenue sources would include development fees and Mello-Roos bonds. This type of program would apply to areas that are re-developing and new development along the DMU overlay service corridors. Local matches for federal grants are also possible.

With regard to *Development Fees* and *Transportation Impact Fees,* new developments can be assessed a one-time development charge to mitigate the financial burden imposed by providing transit services to the increase in ridership resultant from the new development. Typically, the jurisdiction in which the land development occurs must identify a list of improvements (including transit benefits) needed to mitigate the impact of the development. Fees to support these improvements (including transit service) can be made a part of a *Facility Financing Plan.*

Cities and counties may require developers to contribute to the provision of transit facilities beyond any legislated development fees through *Negotiated Agreements.* This would necessitate a high level of support for transit by the local jurisdictions.

An approach not yet used in California is the *Access Fee.* This is an annual fee charged to a commercial properties within a designated distance of stations, which properties benefit from their proximity to the stations. Such fees are used for both capital and operating expenses. The legal validity of such fees would have to be investigated for application in California.

Tax Increment Financing can be used to finance infrastructure improvements. This approach relies on the concept that enhanced property values and the corresponding increased amounts of property tax collected are a direct result of infrastructure improvements, such as those necessary to provide enhanced transit service. In order to use this methodology to collect revenue, the formation of an *Infrastructure Financing District* (*IFD*) is necessary. The creation of an IFD requires a two-thirds majority vote, however. Bonds can also be issued with the approval of the city council or county that created the IFD.

Business Improvement Districts (BID) allow business owners to organize their efforts within a district to provide needed services not provided by local agencies, including transportation improvements. In California, business-based BIDs are formed pursuant to the Parking and Business Improvement District Law. This law also allows for the creation of a Special Benefit Assessment District to raise funds within a specific geographic area. BIDs are designed, created and governed by those who will pay the assessments (e.g., businesses within a defined geographical area). Since BID taxes are self-imposed, revenues are typically low.

A similar concept is the *Property-based Business Improvement District (PBID)*. These organizations parallel the BID's noted earlier in structure; however, they can include property owners as well. A PBID can be a public-private partnership created for the improvement of a specific geographical area. Funds can be raised through a special assessment on real property. Property owners also determine the nature and extent of the district improvements. They also set the geographic boundaries of the district, and how much they are willing to spend for the improvements. The PBID is governed by a private non-profit corporation made up of a majority of property owners within the assessment district. Although valid in concept, the ability of a PBID to provide revenue to a regional rail project (such as a DMU overlay service) would require a legal opinion.

The State of California Government Code allows *counties* to provide for the financing of expanded public services within the county. These areas are identified as *County Service Areas or CSAs*. In concept, CSAs can be considered as a special type of Benefit Assessment District. A wide range of services can be provided under a CSA, including transit operating expenses as well as capital support if it can be shown that the service is extended beyond what is provided in other areas, and not provided on a countywide basis. CSAs have the power to levy property taxes to pay for the expanded service. With regard to funding the DMU overlay application via a CSA, Metro would need to request that the Board of Supervisors of the relevant counties initiate a CSA study to identify those specific areas in need of DMU service, conduct the necessary hearings, and pass the needed resolutions for a CSA to be formed. CSAs can generate small to large amounts of revenue. Amounts generated from projects in Sacramento have generated from $10,000 up to $1 million per year, dependent on the size of the county and the transit service needs.

9.3 Possible Non-Traditional Public Sector Revenues

The following new public sector revenue sources were identified as potential funding sources for a DMU overlay service:

- ☐ Carbon Emission Tax
- ☐ Congestion Pricing Plan for Los Angeles
- ☐ Project Delivery using Private-Public Partnership

As federal funding discussions evolve over the next year, opportunities for grant and discretionary programs which could help fund DMU programs may surface.

With increased attention to climate change and air quality issues, new funding mechanisms that tax vehicles according to carbon emissions ("carbon footprint") are being considered. These taxes could be used to fund the purchase of low-emission (per passenger) transit vehicles.

Since we have shown that DMUs are generally superior to locomotive-haul trains in this regard (*especially* if the 12 axle rule can ultimately be revoked and single DMUs are permitted on the network), they would almost certainly qualify for such programs.

A regional plan for *congestion pricing* that is technically feasible and acceptable to the public is presently being pursued by Metro. It will address various congestion pricing solutions that might be implemented with other approaches which would make the overall transit program more efficient, such as travel demand management and other improvements. Should congestion pricing be implemented on a permanent basis (Metro is only in the demonstration phase at this time), the possibility exists that funds derived from this new policy could be directed towards transit applications, including DMU technology.

Private Public Partnerships (PPP) are another possibility for ultimate funding of a DMU overlay project. PPPs come in many variations, but the fundamental structure typically involves a public agency partnering with a private entity to build and operate a new capital project, such as a transportation service. The private partner generally supplies the capital financing, and operates the system after construction. The private partner can be reimbursed for their efforts in a variety of ways, but the repayment structure usually involves the following elements:

- The private partner collects the revenues derived from the operation of the project; that is, the "farebox" receipts
- Payment for the gap between farebox receipts and the cost of operation is generally a function of the quality of service provided
- Payment related to capital financing is generally made post-construction and over a long period of time

It is noted that Bay Area Rapid Transit (BART) is considering the type of arrangement described above for its DMU-based eBART extension

10.0 CONCLUSIONS AND RECOMMENDATIONS

Various findings within the context of this study have led us to understand that DMU technology offers certain advantages (performance, energy conservation, emissions profile, operational flexibility) over locomotive-haul passenger trains. This is not to say, however, that the advantages and efficiencies of DMU technology can be meaningfully applied to the corridors and operations which were the subject of this study, or if it would be cost-effective to do so. There are significant factors which need to be evaluated before a realistic set of conclusions and recommendations for a DMU overlay service can be arrived at. We will attempt to reach justifiable conclusions and provide a recommended set of "next steps" in this section of the report. Our conclusions and recommendations are distributed amongst the following key areas of the study:

- ☐ Vehicle Technology Options
- ☐ Corridor Capacity and DMU Implementation Options
- ☐ Vehicle Maintenance Options
- ☐ Funding
- ☐ Community Impact

10.1 Vehicle Technology

As indicated in our report to Task 2.4, *Regulatory Issues*, any DMU fleet purchased for service on the three study corridors (Ventura County, Antelope Valley and San Bernardino) will be subject to 49CFR 238, since the study corridors are part of the "General Railroad System of Transportation". Such vehicles are known as FRA-complaint. Those subparts which define the requisite vehicle structure are 49CFR 238.203 (buff strength), 49CFR 238.205 (anti-climbers), 49CFR 238.211 (collision posts); and 49CFR 238.213 (corner posts). Metrolink and other Class 1 railcars conform to these requirements; however, there are presently no suppliers of FRA-compliant DMUs. There are, however, carbuilders who have yet to produce an FRA-compliant DMU, but which have either designs or preliminary concepts for such equipment. These carbuilders include Hyundai Rotem (Korea), who designed a DMU fleet for Triangle Transit, but which project failed to progress; Nippon Sharyo (Japan), who designed a DMU fleet for Chicago/Metra, but which project also stalled; Bombardier (Canada), who intends to use their FRA-complaint M-7 EMU as a platform for DMUs should the market dictate; and Siemens (USA), who has developed a conceptual design for an FRA-complaint DMU. With the 30 car fleet needed for the intended DMU service (see our report to Task 2.5.5, *Candidate Corridors Operational Capacity and DMU Implementation Plan Report*), however, Metro would likely attract bids from at least two of these carbuilders.

We also note that the 30 car fleet derived from the need to provide 9 DMU trainsets to make up the 46 DMU overlay trains that can be added to an upgraded study corridor network, plus one spare trainset. Each trainset has a three-car consist: two DMUs and one trailer. The reason for this is that Metrolink, BNSF and UP all require 12 axle trains when operating in their territory (necessitating that Amtrak comply with this requirement as well). These operators believe that 12 axles are required in order to ensure integrity of the block occupancy detection circuits and the grade crossing proximity detectors. This equates to three-car trainsets, in that each DMU has four axles. Very rough and preliminary ridership estimates for the off-peak DMU overlay service indicates that there is only a need to carry 60 passengers, on average resulting in a 75% excess seating capacity. This could certainly be accomplished with a single DMU, reducing the fleet need to ten DMUs for operational purposes alone. There is some possibility that the 12 axle rule could be relaxed. There has been significant public discussion regarding the implementation of Positive Train Control (PTC) on existing Metrolink corridors. Positive Train Control is not a unique signal technology, per se, but a generic term applied to Advanced Train Control, as found in Europe. Many of these systems do not rely on railcar wheelset shunting (shorting the track circuit from running rail to running rail) to detect train presence. If such a technology were to be adapted by Metrolink, it would obviate the need for 12 axles per train and single car DMUs could be run throughout the system, as is done on other railroads, such as Tri-Met's Westside Express Service (WES) DMU service. Consequently, one recommendation would be to query each of the potential FRA-compliant DMU builders and assess their interest in both 10 and 30 car DMU fleets. We suggest the following four recommendations could be pursued by SCRRA if/when the opportunity arises in the future:

Recommendation No. 1: Perform a carbuilder outreach to determine the level of interest in various size DMU fleets.

Recommendation No. 2: Perform a simulation for a single FRA-compliant DMU over the same route as the three-car DMU train was run to determine the energy consumption and emissions profile in the event that the ultimate incorporation of PTC and advanced grade crossing technology obviates the need for 12 axle trains.

Recommendation No. 3: Investigate various European DMU technologies and determine how compliant they are with 49CFR 229.

Recommendation No. 4: Open up a dialogue with the FRA to determine how receptive they would be to allowing 49CFR 229 to govern DMU operations on the study corridors.

10.2 Corridor Capacity and DMU Implementation

As indicated in our report to Task 2.5.5, *Candidate Corridors Operational Capacity and DMU Implementation Plan Report* of this Study, it will be possible to add DMU trains to the existing network. We have identified 46 (daily) DMU trains which could be added to the Metrolink schedule. We established a goal of providing one DMU train per hour in each direction—during off-peak hours. We also identified a number of infrastructure modifications designed to facilitate the addition of the extra trains. These modifications can be partitioned into two groups. The first group included only those changes absolutely necessary to accept the additional trains; essentially, layover tracks at each of the terminals for each of the three study corridors. These are essential so that the DMU trains don't "foul" the main tracks while awaiting a network opening for a return to Union Station. The second group of infrastructure changes included those which would add to the network capacity, but were small enough to be considered reasonable.

We ran three simulations, as follows:

The first simulation was our baseline model, and contained only Metrolink, Amtrak and freight trains. We constructed the baseline for two reasons. First, to verify our model—once the baseline was completed, we compared the results to the published rail traffic schedules to ensure the validity of the simulation. The second reason the baseline was constructed was to provide a basis for comparison with later network models with the overlay service included. The baseline model would yield present average speeds and percent delay for all trains. We would need to know the impact that our proposed DMU overlay service would have on these network parameters. Our goal here was to provide a true "overlay" service; that is, a DMU traffic network superposed onto the baseline network with little or no impact to baseline service.

The second simulation, "DMU 1", contained only the Group 1 infrastructure changes; i.e., the essential layover tracks at the three corridor terminals. The following trains were added to the baseline model:

- ☐ 16 DMU runs between Union Station and Chatsworth (Ventura County Line)
- ☐ 6 DMU runs between Burbank Bob Hope Airport and Chatsworth (Ventura County Line)
- ☐ 16 DMU runs between Union station and Via Princessa. Extending these trips to Palmdale was considered not feasible due the lack of population density in tandem with the need to double track the alignment. (Antelope Valley Line)
- ☐ 8 DMU runs between Union Station and Claremont (San Bernardino Line)

All of the 46 above trains were able to be incorporated within the network, but the average speed and percent delay impact to the baseline model was significant. This violated our premise for an overlay service; that is, that the impact of the overlay should be either non-existent or minimal.

The third simulation, "DMU 2", included all the above runs, but also incorporated all the recommended infrastructure changes. Results from this simulation were much improved over the DMU 1 runs. In fact, many of the runs were improved over the baseline model. This simulation was deemed acceptable, and was the basis for our cost estimate. It is recommended that the infrastructure improvement analyses be provided to SCRRA for their further consideration and possible incorporation into their capital infrastructure program.

Recommendation No.5: As we noted, our goal for this study was to provide 60 minute service in each direction. The fleet sizing, infrastructure changes and ROM ridership projections given in this report were resultant from this initial assumption. It may be possible that with enhanced service, ridership levels would increase to the point where the placement of one or two additional stations might be justified. As an ancillary recommendation, if shorter headway services were to be modeled, a more robust ridership projection may result.

Recommendation No.6: It may be that the DMU overlay service designed for this study could be implemented by using Metrolink's existing locomotive-haul rolling stock, or the locomotive-haul equipment presently being constructed by Motive Power (locomotives) and Rotem (passenger cars). If so, it would save a significant amount of money as opposed to procuring a new DMU fleet to serve off-peak hours, although the energy conservation and emissions benefits of DMU technology would have to be sacrificed. It is recommended that this option be explored with SCRRA.

10.3 Maintenance Facility

After a significant amount of study, it was determined that there were only two realistic options for the maintenance of the DMU overlay fleet in our DMU 2 simulation model. These two options were to either build a new maintenance facility in a location accessible to all three of the study corridors, or to use Metrolink's existing CMF and planned EMF facilities in combination to maintain the DMU fleet. Each option was studied extensively, and costed.

From an efficiency perspective, a new maintenance facility, accessible to all three corridors, and dedicated to the DMU fleet, would be the optimal solution. It was costed at $54.6 million (ROM, including real estate costs). Although seemingly expensive, it represents only 11% of the total cost for the DMU overlay service, not including real estate costs (Reference our report to Task 2.7, *DMU Operations Implementation Cost Report*). The other alternative would be to perform running maintenance and repair of the DMU fleet at the CMF, and heavy repair at the EMF. This could not be accomplished within the existing shop infrastructures, however; upgrades would be required. These upgrades were costed at about $20 million, or about 7% of the total. It was also noted that although it would be possible to maintain the DMU fleet in the CMF and EMF, it would be awkward, at best, from a logistical perspective. Operational conflicts will be bound to occur, when the DMU fleet leaves the CMF for off-peak service while the locomotive-haul fleet is coming in for daytime servicing. All things considered, the use of a new facility dedicated to the maintenance of a DMU fleet is recommended.

Recommendation No.8: A new facility, dedicated to the DMU fleet, and accessible to all three corridors, is recommended for DMU fleet maintenance.

We note that this recommendation is predicated on a 30 car DMU fleet. We also raised the possibility of a relaxation of the 12 axle rule if a new signal technology is adapted for the network, which would permit the running of single DMUs. In such a case, the necessary fleet size would drop dramatically to ten. It would not be recommended to build a new shop facility for such a small pool of cars.

Recommendation No. 9: In the event that the 12 axle rule is relaxed, and operation of single DMUs is permitted, the necessary fleet size would drop to ten DMUs (no trailers), and it is recommended that this fleet be maintained in Metrolink's existing facilities.

10.4 Funding

A number of new local revenue sources have been identified that can generate additional funding to support either capital or operating needs of the DMU service. Station naming rights, enhanced advertising, new parking fees and fines are funding mechanisms that are either under the control of Metro or would require negotiation with the DMU operator. Individually, none of these new potential funding sources would generate sufficient funds to cover all DMU development and on-going operating and maintenance costs.

Funding mechanisms that are under the control of Metro offer more flexibility and control than the property based measures that require the coordination and approval of local governments; however, property based revenues to support rail service is an underutilized funding tool in the Metro area. Joint development opportunities near stations and developer or property fees need additional site specific analysis to more accurately project revenues. (*Note*: Stations to be served by the DMU Overlay Service are Metrolink stations owned by the various cities in which they are located.)

The opportunity for acquiring additional federal funding for rail service improvements and vehicle acquisition is greater with the new federal administration's focus on infrastructure improvements. Positioning the DMU project on the appropriate lists to receive federal funds will enhance timely funding.

The use of a Public Private Partnership (PPP) delivery strategy for the construction a new maintenance facility offers the opportunity to bring in either a design build or other PPP mechanism to assist with construction and operation. This strategy should be further analyzed should the project development progress.

10.5 Community Impacts

As indicated previously, the implementation of a DMU overlay service can have both positive and negative effects on the corridors in which it operates. In our study, potential impacts were divided into three groups. Groups 1 and 2 identified areas which would be positively impacted by the service; Group 3 was comprised of those entities which could suffer negative impacts (principally noise) from the implementation of an overlay service. Results (numbers of affected properties from each corridor sector) were given earlier in this report (Reference Section 7.4). This data has been further conditioned for summarization purposes and is given in Table 17 below. Using a similar methodology, an overall score for each alignment is generated below based on the rank of each alignment for each positive/negative impact criteria, and the rank of each alignment based on the areas of likely community concern (parking capacity and at-grade crossings). For each criteria, the alignment with the highest ranking received a three (3), the alignment with the second highest ranking received a two (2), and the alignment with the lowest ranking received a one (1).

Alignment	Key Destinations/ Significant Features	Noise and Other Sensitive Adjacent Land Uses	Major Development Projects or Land Use Changes	Parking Requirement Projections (2030)	At-Grade Crossings*	Total Overall Score
Ventura County Line (VCL)	3	3	2	3	3	14
Antelope Valley Line (AVL)	2	1	3	1	1	8
San Bernardino Line (SBL)	1	2	1	2	2	8

*Based on the least number of grade crossings

Highest Rank = 3
Middle Rank = 2
Lowest Rank = 1

TABLE 17: Overall Score for Each Alignment

Table 17 indicates that the Ventura County Line ranked highest for implementation of additional DMU service in terms of overall community impacts, since it had the highest total score when comparing the rankings for each criteria. The Ventura County Line ranked highest in four (4) out of the five (5) criteria included in Table 17, including:

- The highest percentage of Key Destinations/Significant Features;
- The lowest land use coverage of Noise or Other Sensitive Adjacent Land Uses;
- The lowest projected station parking deficit; and
- The lowest number of at-grade crossings.

10.6 Closing Remarks

DMU technology offers a number of benefits to a service region such as the three corridors which were the focus of this study. These benefits account for the rise in popularity of DMU service to a very large extent in Europe, and to a smaller, but still significant extent in Asia. The major benefits which the utilization of DMUs offer include:

- The ability to provide regional commuter service to areas without the attendant cost of electrification
- The ability to provide a more cost-effective vehicle technology solution than an equivalent locomotive-haul consist for small trains, both from a capital and an operations cost perspective
- The ability to run single cars should ridership levels warrant same

- ☐ More energy-efficient operation than for equivalent locomotive-haul trains
- ☐ A more environmentally-friendly emissions profile than for equivalent locomotive-haul trains

In our study, we have also discovered that a DMU overlay based on hourly service could be achieved with ten trainsets. 46 daily trains would be added to the existing rail network in the corridors to achieve this level of service.

Although we have demonstrated that the service as described could be implemented, the study also revealed several obstacles which might either preclude or postpone implementation. These include:

- ☐ The requirement for an FRA-compliant DMU. The only company which manufactures FRA-complaint DMUs, Colorado Rail Manufacturing, has stopped manufacturing railcars, even on existing orders. Other manufacturers may be interested, but only in orders of approximately 25 DMUs or more.
- ☐ The 12 axle rule. This rule, enforced by the current corridor operators, dictates that each train must have a minimum of 12 axles to ensure adequate train detection by the signal system. ROM ridership estimates, however, indicate an average car loading of 60 passengers for the proposed overlay service, well below single DMU passenger-carrying capacity (75 seated plus 90 standees). This requirement forces the utilization of two un-needed DMUs on each train, vastly increasing capital outlay and operations costs, and obviates one major advantage of DMU technology—the flexibility to run single cars, and the savings in cost, energy and emissions generation associated with same.
- ☐ The cost for the DMU Implementation plan described in this report ranges from $295 million to $330 million. It would be difficult to justify this level of expenditure given the present ridership projections.

Given the above, it would not be possible to make a case at this time for the cost-effectiveness of the DMU overlay service as described in this report, although some recommendations could be considered in the near-term. The above recommendations spell out a path forward that may eventually allow utilization of the many benefits that European and Asian transit properties now realize from DMU service. As many transit agencies worldwide have learned, these benefits are real. Effort expended in achieving a regulatory and technical framework which would allow Metro to take advantage of the emerging DMU technology could eventually result in a large return.

Los Angeles County
Metropolitan Transportation Authority

Item 8

Diesel Multiple Unit (DMU) Technical Feasibility Analysis

Planning & Programming Committee
March 18, 2009

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Diesel Multiple Unit (DMU)

- DMUs for application on existing Metrolink corridors must be Federal Railroad Administration (FRA)-compliant (Colorado Railcar Manufacturing vehicle shown)
- Non-compliant DMUs have been in use in Europe and the U.S. for several years. Examples include North County Transit District's Sprinter and New Jersey Transit's River Line (shown)

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Background

DMU technology considered for our portions of Metrolink-operated lines: Ventura County, Antelope Valley and San Bernardino. Issues examined included:

- DMU technology and market availability
- Fuel options, including clean fuel alternatives
- Vehicle performance, including fuel efficiency and emissions profile
- Operational capacity
- Potential infrastructure improvements
- Fleet maintenance options
- Community impacts
- Potential non-traditional funding sources
- Costs

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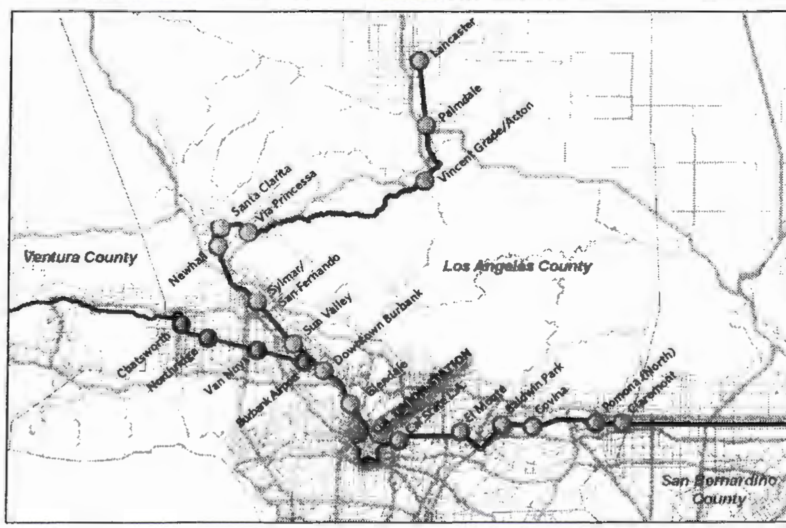
Three Candidate Corridors

N



Ventura County Line
Antelope Valley Line
San Bernardino Line
Major Highways

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Analysis Assumptions

- DMU service must be a true overlay service – it must not negatively impact any existing rail operations
- Service to be at least hourly off-peak
- Service to be considered during peak hours only if no impact to existing commuter operations

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General Conclusions

- Not cost effective to implement DMU service on three Metrolink corridors at this time:
  - 12 axle rule requires use of 3-car consist, but only one-car train needed to meet demand
  - 30 cars needed for ten 3-car consists likely requires new maintenance facility
  - No FRA-compliant DMU vehicles on market
- Future implementation of Positive Train Control and improved grade crossing technologies may eliminate need for 12 axles, could provide future opportunity for development of DMU service on Metrolink corridors
- DMU trains preferable for overlay service to locomotive-haul trains from operations cost, fuel economy and emissions perspectives

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Findings

1) With the proposed infrastructure improvements, it would be possible to provide hourly off-peak commuter service on all three corridors
2) 46 weekday DMU runs could be accommodated on the three corridors with no impact to any existing service
3) Estimated 60 riders per three-car train; average weekday ridership of 2,800 passengers
4) "Clean Diesel" (Ultra Low Sulfur Diesel (ULSD) + exhaust after-treatments to meet Tier 4 standards) would be required for the DMU fleet; Electric Multiple Unit solution analyzed, but total capital cost to implement was significantly higher

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DMU and Metrolink Comparison Table

	DMU	Metrolink	Comments
Capital Costs			
	$330 M (New Maintenance Facility) $295 M (Central Maintenance Facility & Eastern Maintenance Facility)	$274 M (CMF & EMF)	7% cheaper to implement using Metrolink vehicles
Operating Costs			
	$76.51 per train mile	$80.75 per train mile	5% cheaper to operate DMU because of lower fuel and maintenance costs
Cost per new rider	$105,000	$98,000	7% cheaper to add more Metrolink midday serivce (due to lower capital costs)
Fuel Economy			
Fuel consumption	81 gallons	113 gallons	DMU 29% more fuel efficient
Emissions*			
Carbon Monoxide (CO)		-38%	38% higher CO emissions for DMU
Particulate Matter (PM10)	-26%		26% less PM 10 emissions for DMU
Nitrous Oxide & Non-Methane Hydrocarbons (NOx + NMHC)	-51%		51% less NOx + NMHC emissions for DMU
Carbon Dioxide (CO_2)	-12%		12% less CO_2 emissions for DMU

*Based on simulated runs comparing DMU and locomotive.

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Next Steps

- Forward report to Metrolink for future consideration
- Monitor the progress of:
  - FRA-compliant DMU vehicle manufacture;
  - DMU propulsion and fuel technologies;
  - Development of improved rail signal technologies; and
  - FRA's evolving requirements for rolling stock compliance
- Continue to consider DMU as part of alternatives analyses in corridor studies

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