3.0 DIESEL MULTIPLE UNIT ASSESSMENT

3.1 SUMMARY

The second goal of the Around the Bay Rail Study is to examine the opportunity to achieve mutual benefits from using new passenger rail vehicle technology. Nationwide, Diesel Multiple Unit (DMU) rail vehicles are an emerging opportunity to use self-propelled passenger train vehicles in corridors that extend from heavily used passenger lines to less densely populated regions.

The third goal of the Around the Bay Rail Study is to examine the opportunity to use DMU vehicles in daily rail transit service on the 47-mile route between Santa Cruz and Monterey.

This section provides background to the emerging use of Diesel Multiple Units to provide passenger rail service at lower costs and at a smaller scale than conventional passenger rail trains. DMUs are single level, self propelled passenger rail vehicles. The passenger cars can operate as single vehicles or in trains (or, in "multiple units") without a separate locomotive for power. Electric Multiple Vehicles or EMUs, using overhead or third rail contact for power, operate as single units or in multiple unit trains in many parts of the midwest and eastern United States. Diesel Multiple Units began to see increasing use throughout North America until the concurrent decline of U.S. rail car manufactures and U.S. public investment prior to the 1970's. A small number of original DMUs remain in use today. However, all DMUs in use today (Dallas beginning in 1997, Vermont beginning in 1999) have been extensively rebuilt and approved for use by the Federal Railroad Administration for safety performance and crashworthiness.

A resurgence of DMU design and production in Europe and Japan over several years has raised the prospect for the expansion of modern DMU use once again in the US. A wide range of design, performance and costs exist in the new vehicles. Several European vehicles have capacities and features that equal or exceed the highest quality commuter and intercity trains found in the U.S.

The IC 3 *Flexliner*, which toured Northern California in 1997, is an example of train amenities equal to commercial airline business class service. The IC 3s seating capacity is approximately 140 passengers and has a top speed of more than 80 mph. Like many high-end DMUs, the IC 3 vehicle is made of 2-3 units (hence the name Intercity City car with 3 connected units) that are permanently joined as "married pairs or triplets." Passengers may walk between the married pair units without having to open or pass through doors. These vehicles are in service in Scandinavia and Israel and a purchase is currently being negotiated in Pennsylvania.

To date, all European or Japanese DMUs have not yet achieved FRA approval for operating on the U.S. freight and public railroad track network. One category of these vehicles in particular is referred to as Diesel Light Rail Vehicles (DLRVs) because their size and weight resemble a light rail vehicle more than a commuter or intercity rail car. The Siemens Regio Sprinter, which also toured the local branch lines with special permission from the UPRR and State Public Utilities Commission, is a good example of a DLRV. It has a top speed of approximately 65 mph and can carry 75 passengers.

In short, all new DMUs, like other forms of new technology, pose institutional and operating issues that must be addressed to achieve acceptance. These issues are now the subject of national interest within the public transit industry in order to introduce the vehicles in "new start" passenger rail programs.

The purpose of Section 3 is to collect and analyze general data about the institutional/regulatory issues, operational issues, relative capacities, operating and maintenance (O&M) costs and capital costs of Diesel Multiple Unit (DMU) and Diesel Light Rail Vehicle (DLRV) equipment, so that the feasibility of such equipment for proposed passenger service in the Santa Cruz/Monterey-San Jose corridors can be assessed. Institutional issues that will require federal regulatory approval and private freight railroad acceptance are outlined.

Key Findings – Regulatory/Institutional Issues

Regulatory and institutional barriers to the operation of DMU and DLRV equipment in the United States is reviewed below. As a result of this review, the following issues were identified. These issues are discussed in greater detail in the balance of Sections.

DMUs:

- No new DMU equipment compliant with Federal Railroad Administration regulations (crashworthiness, etc.) is yet available for sale in North America.

- The FRA's proposed passenger rail safety standards which are expected to take effect in 1998, will make the requirements for new DMU equipment more stringent in the North American market.
- There are two potential strategies for developing new FRA-compliant DMU equipment; the conversion of European DMU equipment or the redesign of North American Electrical Multiple Unit (EMU) equipment to diesel operation.
- Some of the operating advantages suggested for DMU equipment are unproven in the North American market and may not be permitted under existing FRA rules.

DLRVs:

- DLRV equipment does not comply with FRA regulations and, therefore, can operate only on dedicated rights-of-way and on freight tracks with freight windows, where there is complete time separation between railroad and DLRV activities. This restriction makes it virtually impossible to use DLRVs for service from Monterey or Santa Cruz to San Jose.
- Even if the Union Pacific Rail Road were to agree to a strict time separation of freight traffic and DLRVs for Around the Bay daily service on the track between Pajaro and Castroville, the presence of Amtrak and Santa Cruz-Monterey intercity service on this same track would prohibit mixing DLRV and conventional passenger rail service.
- Acceptance of DMU or DLRV operation by the UPRR will be a function of the railroad's corporate attitude about risk and willingness to accept new practices as much as public regulatory approval.
- California Public Utility Commission regulations for LRV equipment may restrict the use of existing European DLRV models in California.

Key Findings – O&M Costs

After analyzing available O&M cost data for both DMU and locomotive-hauled equipment, the following general premises were found:

- In short consists, DMUs are more efficient to operate and maintain than locomotive-hauled equipment of similar capacity.
- The O&M cost advantage of DMU equipment is highest for train consists with a capacity of less than 400-500 passengers such as a four car *IC 3 Flexliner* consist.

- A major cost advantage of DMU train equipment in the Around the Bay Rail study is that a single train set can be used in a service plan where a train travels on a common trunk line and then splits to serve two destinations.

Comparisons of DMU and Caltrain equipment are further explored in the Service Plans, Section 4, in the context of operating plans developed for the different rail services envisioned for the Santa Cruz/Monterey to San Jose corridor.

3.2 INTRODUCTION

The purpose of this section is to collect and analyze general data about the institutional/regulatory issues, operational issues, relative capacities, operating and maintenance (O&M) costs and capital costs of Diesel Multiple Unit (DMU) and Diesel Light Rail (DLRV) equipment, so that the feasibility of such equipment for proposed passenger service in the Santa Cruz/Monterey-San Jose corridors can be assessed. Obtaining applicable O&M costs for such equipment presents some special challenges. Total O&M costs for rail vehicles include the following factors:

- Crew Costs
- Fuel Consumption/Costs
- Vehicle Maintenance Costs

Crew costs are generally driven by agency practices and are not directly driven by the type of equipment operated. Crew costs for Caltrain rail operations were used because the labor market is close to the Santa Cruz/Monterey study and Caltrain costs are benchmarks for this study. Amtrak operates Caltrain services under contract to the JPB, so these crew costs also represent Amtrak crew costs. A future option to explore is the use of local transit system labor forces to maintain DMU passenger rail equipment.

Fuel consumption is driven by the type of vehicle operated. Standard rates of fuel consumption for different DMU vehicles were obtained from manufacturers. **Fuel costs** may vary by agency contracts and regional differences. However, fuel costs were determined by combining rates of fuel consumption with standardized fuel costs.

While crew and fuel costs can be easily quantified and compared across different vehicle types, **maintenance costs** for vehicles vary by operating agency, region, country, labor rates, regulatory practice and accounting methods. Different U.S.

commuter rail agencies with similar equipment assign different maintenance costs to the operation of their equipment.

Although historically DMUs have operated in North America, two of the most common, Budd RDCs and SPV 2000s, have been retired from most passenger services. No new Budd RDCs have been built since the mid-1950s and surplus RDC fleets available for rebuilding are becoming increasingly scarce. For this reason rehabilitated Budd RDCs were not considered for this project. Moreover, the Budd vehicles are vastly different from the modern DMU equipment which is widely available in Europe and Asia today and is presently being promoted in the North American market. However, none of these modern DMU vehicles have been operated in the United States or Canada for anything other than brief demonstration services.

For the comparison between DMU and locomotive powered equipment required for this framework, four general classes of rolling stock will be analyzed. These four classes are listed as follows:

- Locomotive-hauled
- Conceptual European Diesel Multiple Units (DMUs built FRA approved)
- Conceptual U.S. Diesel Multiple Units (DMUs proposed, not built)
- European Diesel Light Rail Vehicles (DLRV)

The statistics and information for each class will be based on the performance, capabilities and experience of actual vehicles obtained from various sources. In the case of the locomotive-hauled class, Caltrain operations and costs for their diesel locomotive-hauled gallery car fleet will be used to establish a baseline against which the other classes will be compared. The comparison of more general "classifications" of equipment, instead of actual manufacturers, will be done for two reasons:

- DMU equipment is highly customizable with a wide variety of engine, transmission, coupler systems, and car lengths which affect O&M costs, so different configurations of a specific model can have different performance.
- Equipment manufacturers are often reluctant to share performance data, if they feel as if they are being assessed in "consumer reports" style environment.

The purpose of this analysis is to determine what general class of equipment is best suited to passenger service in the different study scenarios, not to determine which specific *manufacturer's* equipment should be used for the Around the Bay rail services.

Amtrak has operated a number of demonstration services with DMU equipment, including the ADtranz IC 3 Flexliner and the Siemens Regio-Sprinter. At present, no O&M cost estimates have been derived from demonstration services conducted in the United States, however, Amtrak is hoping to develop such estimates if it can arrange a long-term demonstration for the equipment.

Another difficulty in comparing O&M costs for locomotive-hauled and DMU equipment results from the unique and very different capabilities of the different types of equipment. The expense of locomotive operations can be spread to the costs of operating a "consist" of the locomotive and the coaches it pulls (or pushes). A single DMU is less expensive to operate than a single locomotive because the engine and mechanical parts are more simple, but the longer the DMU train, the more expensive the mechanical equipment contained since each DMU is self-powered. A "typical" locomotive-hauled train cannot be fairly compared to a "typical" DMU train. There is no such thing as a typical consist. The problem is multivariate and therefore trains of DMUs and locomotive-hauled trains with *equivalent* passenger capacities must be compared to one another in order for there to be a fair comparison. A special framework has been developed for better comparing multiple operating and maintenance cost variables and this framework is presented in this report.

Peer Review of Issues

In an effort to collect the greatest amount of information about DMU operations, several specialists were contacted in the railroad and transit industries regarding the use of DMU technology to build on the knowledge of the consulting team. The names of contacts and issues discussed are summarized at the end of this section.

There are at present no available estimates of O&M costs for DMU equipment in operation in the United States. The Calgary Commuter Rail Task Force has developed O&M costs for the Regio-Sprinter based on Calgary Transit's demonstration service early in 1996, but those estimates are based on limited Canadian experience. Of the two other areas considering DMU equipment, neither North County Transit District (NCTD) nor Triangle Transit Authority (TTA) used actual DMU O&M cost estimates as part of their preliminary planning for service. The TTA, for instance, averaged O&M costs for light rail and commuter rail in order to create an "order-of-magnitude" estimate for planning purposes. However, European O&M cost estimates are available for both DMU and Diesel Light Rail Vehicles and these can be used for comparison to the JPB Caltrain's existing locomotive-hauled services.

3.3 INSTITUTIONAL/REGULATORY ISSUES

There are a number of issues that affect the feasibility of using DMUs and DLRVs in passenger rail service in the United States. These issues will need to be monitored and resolved before DMU or DLRV equipment can be placed in regular revenue service.

The most important of these issues concerns the FRA's buff strength requirements for multiple-unit equipment and cab cars. Buff strength governs the force applied to the end of the vehicle which could be withstood by its structure. FRA regulations[1] (footnotes are at the end of the section) require a 400,000 lb. buff strength for multiple unit passenger equipment operating in trains with a gross weight under 600,000 lbs. and an 800,000 lb. buff strength for multiple unit passenger equipment operating in trains with a gross weight over 600,000 lb. No European or Japanese rail vehicle manufacturer presently produces a compliant DMU for the American market. No DMU equipment sold overseas presently meets these requirements. Any rail equipment that will operate in mixed traffic over the same tracks used by passenger or freight trains is governed by these FRA standards.

Only transit operations that operate either on an isolated rail network (like BART) or operate on tracks that are segregated from railroad traffic by time of day (like San Diego Trolley) are exempt from FRA regulation. This last strategy involves the provision of "freight windows" in which freight trains have complete control of tracks that are otherwise used by non-compliant passenger equipment, like light rail vehicles. The FRA has not actually ruled about the legality of using freight windows with non-compliant equipment, but it has taken no formal position in regards to light rail operations using such a strategy. San Diego Trolley and Maryland MTA Light Rail presently use freight windows and Salt Lake City and Oceanside, California are developing light rail systems that rely on them.

Another issue of concern to any passenger rail operator is side-impact strength. Buff strength is not the only measure of protection in the event of a collision. Rail vehicles operating on lines with roadway grade crossings can also collide with roadway vehicles which ignore the grade crossing protection. For this reason, compliance with existing FRA buff-strength requirements is not enough to assure passenger safety on lines with frequent grade crossings, since rail vehicles can also receive side and corner impacts from motor vehicles. New FRA regulations currently under review may set strength requirements for side and corner impacts.

3.4 COMPARISON OF DMU VEHICLE TYPES

Conceptual European Diesel Multiple Units

Manufacturers such as Siemens, GEC Alsthom and ADtranz have DMU equipment operating in passenger service on European railroads. There are several reasons why such vehicles may soon operates in the United States. All three manufacturers claim that the equipment can be upgraded to meet U.S. FRA standards. The manufacturers claim that FRA-compliant equipment can be delivered within twenty-four months of the first order. The ADtranz DMU has operated in demonstration service in the United States without meeting the FRA standards under a special arrangement with the FRA. Pennsylvania DOT is negotiating with ADtranz for several DMUs for their Harrisburg service. It is believed that both GEC Alsthom (in association with Bombardier) and ADtranz responded to the RFP with proposals for FRA-compliant versions of their European equipment. Pennsylvania DOT has yet to select a winning bidder (April 1998), but it may be possible to “add-on” to the Pennsylvania DOT order once a contract is awarded.

The DMU capital and operating cost estimates in Section 4.0 are based on an average of data from two European DMU vehicle manufacturers, a Siemens VT628 and the ADtranz IC 3 Flexliner. Both vehicles have similar seating capacity. The Siemens vehicle has been in production for over four years, and the IC 3 has been in production for less time. The use of this average approach results in the designation of *Conceptual* European DMU.

Conceptual U.S. Diesel Multiple Units

Nippon-Sharyo and Bombardier have both been marketing DMU model designs for the North American market. Bombardier has since withdrawn their DMU model in favor of an Americanized version of a DMU produced by GEC Alsthom in France. Figure 3.1 is from a promotional brochure for the GEC Alsthom DMU. These conceptual carbody designs are based on electric multiple unit (EMU) models produced by these companies for other North American transit properties. The Bombardier design was based on an EMU produced for the Deaux Montagnes Line in Montreal. The Nippon-Sharyo design is based on an EMU produced for South Shore Line in Northern Indiana. Nippon-Sharyo claims that its DMU is FRA compliant and could be assembled in the United States with an eighteen (18) month lead time, but they are not clear whether their vehicles meet the 400,000 lbs. or 800,000 lbs. standard. Neither of these DMU models has ever been in production overseas, nor have any domestic orders been received, so there is no assurance that these models meet the claimed design standards or can pass FRA requirements.

Each car Nippon-Sharyo car has an 87-person seating capacity. This is a shorter vehicle than the European married-pair models and therefore could be expected to cost less per unit. However, to carry the maximum number of passengers estimated for peak season Santa Cruz and Monterey intercity service the total capital cost of total vehicles required would be nearly the same. Figure 3.2 is a conceptual layout from promotional brochure for the Nippon-Sharyo vehicle.

European Diesel Light Rail Vehicles (DLRVs)

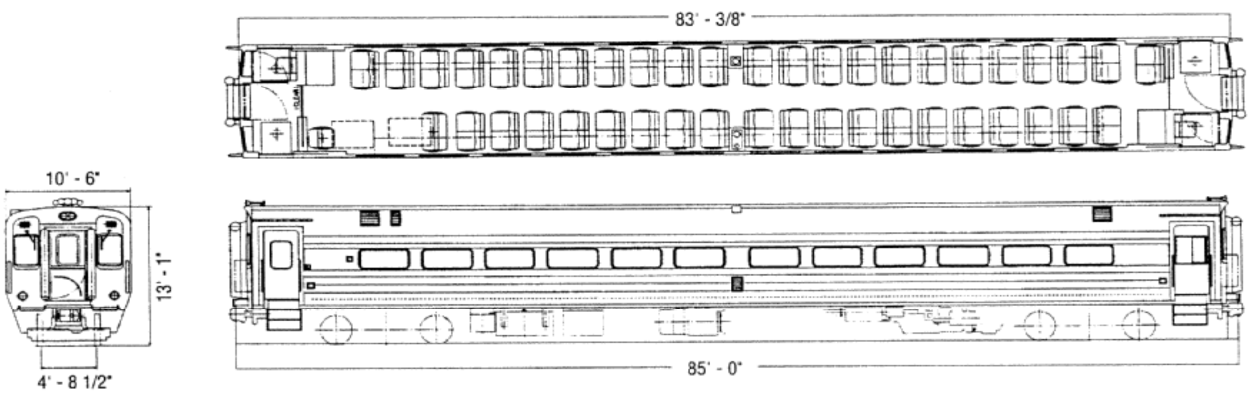
The Siemens-Duewag "Regio-Sprinter" has recently been demonstrated in various North American cities including Santa Cruz and Monterey counties. Other similar vehicles are being offered by ADtranz (Regio Shuttle) and Bombardier (Talent). Unlike the other European DMUs, which resemble standard railroad passenger coaches, the Regio-Sprinter is best characterized as a diesel powered light rail vehicle (DLRV) in terms of its construction and operating performance. Its buff strength is even lower than the European DMUs (between 125,000 and 135,000 lbs.) discussed above, and hence is even further from compliance with FRA regulations.

Figure 3.1

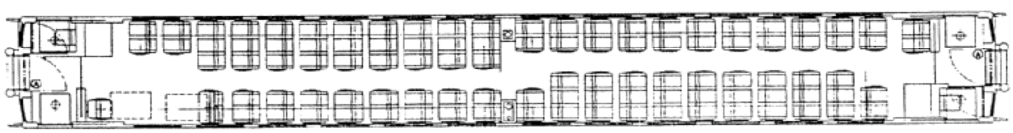
DESIGN VARIATION OF NIPPON SHARYO DIESEL RAIL CARS

- **Offers compliance with all existing FRA and ADA requirements. Provides complete flexibility and versatility in all Commuter operations.**
- **May be operated in single car or multiple car (up to 10) consists allowing efficient peak and off-peak services.**
- **Can be supplied in various configuration, seating arrangements, cab configurations, with ADA compliant Toilet facilities.**

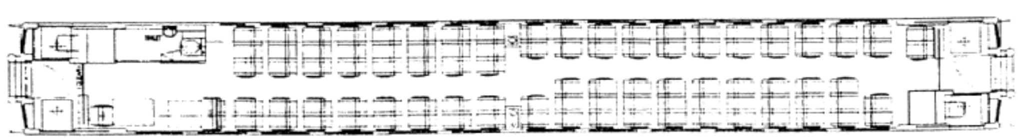
Base Car layout (2x2 Seating, 87 passengers)



Alternative Seat Configuration (3x2 Seating, 105 passengers)



Alternative Seat Configuration (3x2 Seating with ADA Compliant Toilet Facility, 98 passengers)



Nippon Sharyo U.S.A., Inc. 375 Park Avenue, Suite 2806, New York, NY 10152 Tel : 212-755-2150 / Fax : 212-755-2257

Figure 3.2

ALICE Diesel Multiple Unit

ALICE 405 - 406

GENERAL DATA

Type of trainset: Diesel Multiple Unit (DMU)

Train composition: power car + motorized-trailer + trailer + power car

SYSTEM DESCRIPTION

Propulsion system: one or two diesel engines per power car or motorized-trailer 400 hp (300 kW) per engine

Transmission: hydraulic - two stage driving inboard axles

Cooling system: roof-mounted coolant radiators with hydraulic fan motor

Fuel tank capacity: 670 US gal. / 2500 approx. litres per car

Truck type: outboard bearing, fabricated frame

Primary suspension: helicoil springs

Secondary suspension: air springs

Brakes: friction tread brakes on all wheels, two disc brakes on each unpowered axle and dynamic retarder within transmission.

Heating: floor

Air conditioning: two 6,5 ton roof-mounted self-contained units

Carbody: stainless Steel (ferritic and austenitic)

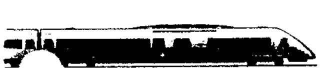
ELECTRICAL SYSTEM

Auxiliary power: one diesel engine powered APU per power car or motorized-trailer

Auxiliary voltage:
480 Vac /3 ph /60 Hz
120 Vac /1 ph /60 Hz

Low voltage: 24 Vdc or 72 Vdc

Lighting (passenger area): fluorescent



ALICE 405

PERFORMANCE		Metric	Imperial
Maximum operating speed on level tangent track		160 kph	100 mph
Minimum horizontal curve radius		80 m	3149"
Minimum vertical curve radius		500 m	19685"

DIMENSIONS		Metric	Imperial
Length (over coupler)		105528 mm	4154"
Width (over side sheets)		3119 mm	122"1/32
Width (over threshold)		3024 mm	119"
Height (rail to roof)		4001 mm	157"1/2
Doorway width	(center side door)	1350 mm	53"1/64
	(end side door)	750 mm	29"1/64
Coupler height above rail		876 mm	34"1/64
Wheel diameter (new)		920 mm	36"1/64
Nomber of Axle motors		5	
Truck wheel base		2600 mm	8'6"1/2
Truck centers		18135 mm	713"1/32
Track gauge		1435 mm	56"1/64
Floor height above rail		1300 mm	51"1/64
Minimum height - floor to ceiling		2200 mm	86"1/32

WEIGTH AND CAPACITY	Metric	Imperial
Car weight trailer car	46000 kg	101 000 lb
Car weight power car	59000 kg	130 000 lb
Seat Capacity	260 to 340 seats	

ALICE 406

PERFORMANCE		Metric	Imperial
Maximum operating speed on level tangent track		200 kph	125 mph
Minimum horizontal curve radius		80 m	3149"
Minimum vertical curve radius		500 m	19685"

DIMENSIONS		Metric	Imperial
Length (over coupler)		105528 mm	4154"
Width (over side sheets)		3119 mm	122"1/32
Width (over threshold)		3024 mm	119"
Height (rail to roof)		4001 mm	157"1/2
Doorway width	(center side door)	1350 mm	53"1/64
	(end side door)	750 mm	29"1/64
Coupler height above rail		876 mm	34"1/64
Wheel diameter (new)		920 mm	36"1/64
Nomber of Axle motors		6	
Truck wheel base		2600 mm	8'6"1/2
Truck centers		18135 mm	713"1/32
Track gauge		1435 mm	56"1/64
Floor height above rail		1300 mm	51"1/64
Minimum height - floor to ceiling		2200 mm	86"1/32

WEIGTH AND CAPACITY	Metric	Imperial
Car weight (trailer car)	46000 kg	101 000 lb
Car weight (power car)	59000 kg	130 000 lb
Seat Capacity	260 to 340 seats	

* The technical data are given for information purposes only and may be modified without previous notice.

GEC ALSTHOM

Under existing FRA regulations, DLRV equipment cannot operate on active railroad tracks. This includes tracks used by freight trains, locomotive-hauled passenger trains, and even FRA-compliant DMU trains. The previously mentioned demonstrations have all taken place on trackage which is segregated in time from regular rail freight operations. The freight trains can only operate during the time periods when the Regio-Sprinter does not operate, similar to the San Diego Trolley. For these reasons, DLRVs are generally not appropriate for operation on mainline railroad tracks, where it is not possible to create “freight windows”.

The Public Utilities Commission (PUC) of the State of California regulates the buff-strength of light rail equipment, but not railroad equipment which is under the jurisdiction of the FRA. The PUC would probably claim jurisdiction over DLRV equipment operating in light rail service. PUC General Order 143A. Section 6.03 stipulates the LRV compression loads (buff strength) should be “equal to twice the unladen car body weight applied longitudinally at the end car sills.” Much of the European DLRV equipment being offered in this country falls short of meeting this standard. A Regio-Sprinter weighs approximately 31 metric tons (68,343 lbs.) and has a buff strength of only 125-135,000 lbs. For this reason, some changes in the DLRV models may be necessary to allow operation in California.

There are a number of other institutional and regulatory issues regarding the use of DMU or DLRV equipment for passenger service in the United States. These issues include:

- Recent FRA Notice of Proposed Rule Making (NPRM) on Passenger Railroad Standards,
- FRA Regulations Regarding Locomotive Inspections,
- Maintenance Crew Familiarity, and
- Signal Shunting Capabilities.

Recent FRA Notice of Proposed Rule Making (NPRM)

The Federal Railroad Administration has recently issued (September 23, 1997) proposed passenger equipment safety standards and regulations for passenger railroad equipment operating in the United States. These proposed standards and regulations tighten the regulatory requirements for DMU equipment. For instance, under the proposed Rule 238.203 all passenger equipment will have to meet an 800,000-lbs. buff strength requirement. In addition, the proposed rules introduce an array of requirements for collision posts, corner posts, rollover strength and side impact strength which are not mentioned in the existing FRA requirements for MU equipment. It is unclear whether the DMU equipment proposed for the North American market by equipment manufacturers can meet the proposed standards.

FRA Regulations Regarding Locomotive Inspections, Coupling

The Federal Railroad Administration has historically defined DMUs and cab cars as locomotives (because they have cab controls), which means that they require inspection every 93 days, raising operating and maintenance costs. This requirement will be maintained under the new FRA NPRM.

Some DMUs, like the IC 3 Flexliner, can couple and uncouple automatically. This can allow a single train to serve two branches, with the train splitting up at the junction of the two lines. The automatic coupling can also allow a service provider to easily tailor train length to the passenger demand at different times of day, reducing unnecessary car miles. Finally automatic coupling can make yard sorting and consist make-up much easier than with locomotive-hauled equipment. However, it should be noted that the use of automatic coupling has not been approved by the FRA and the use of automatic coupling does not eliminate the existing FRA requirements for air brake tests[2], etc. Indeed the new proposed FRA rules require that a Class II brake test be conducted "whenever previously tested units are added to or removed from the train . . ."[3] These restrictions on the use of automatic coupling will need to be resolved to achieve the operational flexibility that has been suggested for IC 3 DMU equipment.

Maintenance Crew Familiarity

Maintenance crews will require training in order to properly maintain DMU equipment because it is significantly different than the equipment presently operated by Amtrak for the JPB or operated anywhere else in the United States. For these reasons, maintenance staff will need to receive special training in order to conduct regular inspections and maintenance and cannot be hired from other commuter railroad properties.

Signal Shunting Capabilities

DMUs operating singly have had inconsistent signal shunting capabilities which means that normal railroad signal systems have trouble "detecting" the presence of the vehicle. This is due to the fact that individual DMUs operating alone are light in weight and have only two trucks in contact with the rails. European DMU equipment usually consists of a married pair or triplet, which places at least three trucks in contact with the rails. This signal shunting problem can be rectified by operating two-car trains. Other technological solutions, however, are also available, and this problem is now considered solved.

3.5 O&M COST DATA

O&M Cost Data Structure

In developing the O&M cost comparison for locomotive-hauled and DMU equipment, this section of the report addresses three goals:

- The expense classes and sub-classes used to create DMU and Diesel Light Rail O&M cost estimates should be similar in structure to those used for JPB Caltrain locomotive-hauled services.
- The O&M cost estimates should only include expense classes and sub-classes that pertain to *vehicle* operations and not the maintenance of track and structures or administration.
- All expense classes and sub-classes should be defined so that they can be compared across vehicle types (that is, cost/train hours, cost/train miles, gallons/mile, etc.)

In order to accomplish these goals, a cost comparison effort was put in place which included analyzing the O&M cost estimates for locomotive-hauled equipment produced for analysis of extensions for the Caltrain system.[4] Those estimates had several expense classes. Only two of these expense classes were determined to directly relate to the operation and maintenance of trains:

- Train Operations
- Maintenance of Equipment

These expense classes were taken from an O&M cost model for JPB commuter rail operations. In this analysis, the costs for the Maintenance of Equipment were taken directly from the cost model and should directly mirror actual JPB costs. The train operations expense class in the JPB model included the cost for overtime wages, which was outside this analysis. For this reason, Caltrain wages and a wage-benefit ratio were obtained directly from Caltrain.[5] Fuel was an important expense subclass and the cost of fuel was also obtained directly from Caltrain.[6]

Of the classes, Train Operations was the most important, consuming around 21% of the combined Amtrak/JPB O&M costs. Maintenance of Equipment was the next most important, consuming around 14% of the combined Amtrak/JPB O&M costs. Maintenance of Way and Fuel were much smaller, consuming around 8% and 5%, respectively.

The Maintenance of Way, General Administrative and other Contract Management expense classes were not included in this analysis because those expense classes do not directly impact *vehicle* operations. Moreover, those expense classes should not differ much based on the relative efficiencies of operating DMU and locomotive-hauled equipment. It has been suggested that DMU equipment is lighter than the F40's presently used by Caltrain and might therefore result in fewer broken rails and less track maintenance. However, capturing the differential in maintenance of way costs that would result from using lighter vehicles would be difficult and is beyond the scope of this analysis.

3.6 O&M COST DATA SOURCES

Operator Wages and Fringes

All O&M cost estimates in this report assume the same labor costs for all types of vehicle consists, based on Caltrain crewing rules. Caltrain labor costs per train are based on the size of the consist used, as longer trains require more assistant conductors. Of course, real trains may require more staff in order to insure complete fare collection on a full train. For comparison purposes, only the minimal staff customarily required on Caltrain trains were included in this analysis. Any additional fare collection staff required would be equivalent for locomotive-hauled and DMU consists.

Labor costs were based on revenue train hours. Of course, every revenue train hour has additional non-revenue hours associated with it that cover yard and deadhead moves. The cost of these non-revenue hours was assumed to be directly related to the cost of revenue hours regardless of the type of equipment used. For this reason, non-revenue operating labor costs for all of the equipment types were not included in this analysis. The cost of non-revenue hours will be included in the operating plans developed in Section 4. The cost of labor benefits were assumed for this analysis to be a percentage of the wages listed below and were estimated to cost .55 times[7] (including 8% for FELA) the cost of the actual wages. FELA refers to the Federal Employees Liability Act of 1908, which established a national workman's compensation system for all railroad employees that is funded by railroads, both public and private.

Every train, regardless of size was assumed to require an engineer. According to Caltrain rules, a train operating with up to four revenue passenger cars can be operated with only a conductor.[8] Trains operating with four to six revenue passenger cars can be operated with a conductor and an assistant conductor. Trains operating with seven or more revenue passenger cars can be operated with a conductor, an assistant conductor, and a conductor's helper. For the purposes of this report, a DMU vehicle was assumed to be defined as the same as a bi-level passenger coach, so a DMU train with four to six vehicles was assumed to require a conductor and an assistant conductor, just like a locomotive-hauled train.

Some DMU equipment manufacturers have indicated that their equipment is especially labor efficient, allowing one operator to both operate the train and the doors or allowing a train to be broken up into pieces to serve two lines, etc. Labor "savings" such as these were not included in these estimates because they have not been substantiated in the North American market. For this reason, it was decided that any O&M efficiencies revealed by operation of DMUs would have to result from the equipment itself and not related labor efficiencies. The following approximate direct labor rates were provided by Caltrain:

Data Summary - Labor (Operator Wages and Fringes)

- Engineer $24.00 per hour
- Conductor - $20.00 per hour
- Ass't Conductor - $18.50 per hour
- Conductor Helper - $17.00 per hour
- Crew costs assigned based on the minimum required under Caltrain rules

Fuel and Lube

The Fuel and Lube expenses for rail vehicles generally include three main cost areas:

- fuel consumption for revenue operations
- fuel costs
- cost of equipment lubrication

<u>Fuel Consumption for Revenue Operations</u>

Fuel consumption was calculated for revenue operations based on the number of train miles traveled. For the locomotive-hauled equipment, a fuel consumption rate of 2.23 gallons of fuel per revenue train mile for F-40 locomotive-hauled was assumed. The JPB O&M cost model assumed that fuel costs increased by car-miles traveled. In fact, the fuel consumption of locomotive-hauled consists should increase slightly as consist size rises, but not as steeply as would be implied by a per car-mile cost basis. For this reason, a method was adopted for estimating fuel costs different than those used in the JPB model.

Fuel consumption rates were obtained from Siemens, ADtranz and Nippon-Sharyo for their DMU and DLRV equipment. These fuel consumption rates were averaged to produce fuel consumption rates for each class of equipment:

- Production European Diesel Multiple Units -0.33 gallons per vehicle mile
- Conceptual U.S. Diesel Multiple Units - 0.42 gallons per vehicle mile[9]
- Conceptual European Diesel LRVs - 0.28 gallons per vehicle mile[10]

It should be noted that for the DMU equipment, these fuel consumption rates are listed for an individual self-contained unit or married-unit. If a train contains three DMU units, then the fuel consumption rate for that train would be three times the rates listed above. It should also be noted that DMU manufacturers offer a wide range of performance levels for their DMU equipment. Some high-performance levels are equipped with more engines or more powerful engines and in such cases fuel consumption would increase accordingly. In each case, the most standard version of the rail equipment was selected as a basis for comparison.

<u>Cost Of Fuel</u>

All of the equipment analyzed in this study is diesel powered. The cost of diesel fuel can vary widely over time and by region of the country. As already seen, DMU and DLRV equipment, when operated in small consists, is much more efficient in terms of fuel consumption than an equivalent diesel-hauled train. The cost impact of this relative fuel efficiency is based on the cost of diesel fuel. The cost of diesel fuel for Caltrain has varied over the past year between $0.68 and $0.80 per gallon and was at the time of his report $0.75.[11] This price is well within range for past experience with other commuter rail carriers throughout the country and is used for this study.

Cost Of Equipment Lubrication

One cost factor not directly addressed in the JPB O&M cost model is the cost of lubrication. Many proponents of DMU and DLRV equipment suggest that one of the primary advantages of such equipment is the reduced lubrication requirements. While this advantage is true, lubrication is not a significant cost factor. Vehicles and Equipment Department suggested that diesel locomotives consume more lubrication than DMUs do because in large locomotive engines the lubrication ends up in the combustion chamber. This is much less of a problem for the much smaller bus or truck-type diesel engines found on DMUs. Previous experience indicates that an F-40-locomotive engine consumes 5-10 gallons of lubrication a day.[12] The locomotive's entire 243 gallons are changed out once a year. Most modern locomotives provide Head-End Power (or HEP) which provides electric power for the train's lights, heating and air-conditioning. This HEP is often supplied via a small diesel engine or auxiliary power unit (APU). The APU has its 25 gallons changed every 45 days. Diesel engine lubricant, when purchased in bulk, costs around $2.50 a gallon. Even if DMUs consumed ZERO lubrication, the total daily cost differential between the two kinds of equipment would total only $20 (eight gallons @ $2.50 per gallon). In fact, a Vehicles and Equipment Department estimated that the types of engines used on DMUs would consume around two quarts of oil for every 1000 miles. Because actual lubrication consumption figures for the DMU equipment were not easily available and because the total possible cost differential is so small, lubrication costs were not included in this analysis.

Data Summary - Fuel Consumption

- Locomotive-hauled – 4 car consist 2.23 gallons per train mile
- Conceptual European Diesel Multiple Units - .33 gallons per vehicle mile
- Conceptual U.S. Diesel Multiple Units - .42 gallons per vehicle mile
- Production European Diesel LRVs- .28 gallons per vehicle mile
- Lubrication costs were not included in this analysis

Inspection, Maintenance and Repairs of Revenue Vehicles

The final expense class in the JPB O&M cost model used for this report was the Maintenance of Equipment. In the JPB O&M cost model for locomotive-hauled equipment, this expense class is made up of a large number of labor, supervisory and material costs which vary in terms of train miles, car miles, and number of employees. Costs which were derived from train miles were attributed to locomotive maintenance and those which were derived from car miles were attributed to coach maintenance. Those costs which could not be attributed to either train or car miles, were converted into a percentage "tax" on those costs which could be attributed. The derived cost elements for this expense class worked out to $2.01 per train mile and $0.63 per car mile, which is slightly high for our experience for such costs with other commuter rail providers.

Siemens, ADtranz, Bombardier and Nippon-Sharyo were consulted with to obtain per vehicle mile maintenance costs for their DMU and DLRV equipment. Also analyzed was the results of a 1993 Deutsche Bahn (German National Railways) study of the maintenance costs for the 628/928 train set that was cited in Economics of Diesel Multiple Unit Operations. It should be noted that the maintenance costs for the European equipment is based on actual European railroad experience, while the maintenance costs for the conceptual U.S. equipment are derived from manufacturer estimates. These per-vehicle mile maintenance costs were averaged to produce fuel consumption rates for each class of equipment:

- Conceptual European Diesel Multiple Units - $1.18 per vehicle mile
- Conceptual U.S. Diesel Multiple Units - Not available at this time
- Production European Diesel LRVs- $0.84 per vehicle mile[13]

Since a train can be composed of several units or married-units, each with its own motive power, maintenance costs rises with the lengthening of the train, so a train of three European DMUs would cost $3.54 per train mile to maintain.

Data Summary - Vehicle Maintenance

- Locomotive-hauled – 4 car consist $2.01 per train mile
  $0.63 per car mile
- Conceptual European Diesel Multiple Units - $1.18 per vehicle mile
- Conceptual U.S. Diesel Multiple Units - Not available at this time
- Production European Diesel LRVs- $0.84 per vehicle mile

3.7 PASSENGER CAPACITY

The information provided by European manufacturers about their DMU equipment was usually about intercity configurations of equipment. Intercity equipment in Europe has amenities such as first class seating sections, telephones and bathrooms, all of which take up usable passenger space. For longer commuter trip like the trip to the San Francisco Bay area, some of these amenities may be very attractive. However, first class seating is very uncommon in the U.S. European equipment generally consists of married-pairs or married triplets which are semi-permanently coupled and operate as a single unit. For this reason, the seating capacities of the European DMU equipment were increased slightly to assume that space used for first class seating was converted to standard passenger seating. Every first class seat was assumed to be replaced by two standard seats. It is always possible to alter the passenger capacity of railroad equipment by altering the pitch and density of the seating, but the manufacturers representatives did not feel that the estimates used were unreasonable. It should be noted that all of the passenger capacities listed for each class represent averages and that these averages represent vehicles of very different sizes.

Data Summary - Passenger Capacity, By Vehicle Class (Average)

- Locomotive-hauled - Gallery Coach -140 passengers
- Conceptual European Diesel Multiple Units -144 passengers per unit
- Conceptual U.S. Diesel Multiple Units - - 82 passengers with bikes
- Production European Diesel LRVs- - 74 seated passengers per unit

Figure 3.3 compares the capacity and costs of two categories of DMUs with a conventional passenger train such as Caltrain. The DMU costs range from $2.5 million to $3.7 million for each unit. Capital costs are further discussed in Section 3.9.

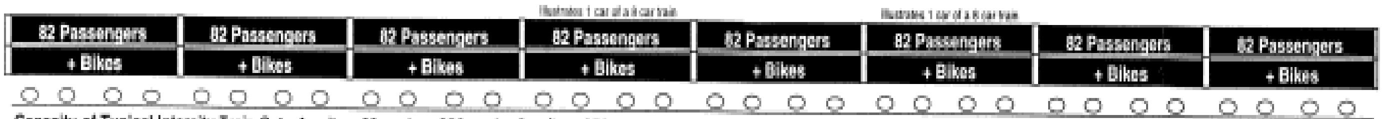
Around the Bay Rail Study

Figure 3.3 Comparison of Capacity and Costs For Conventional Intercity Train and DMU Consists

Vehicles Not To Scale

A. US Conceptual DMU - Example: This vehicle is curretly electric powered only; now operating at Indiana & Maryland Commuter Rail Agencies

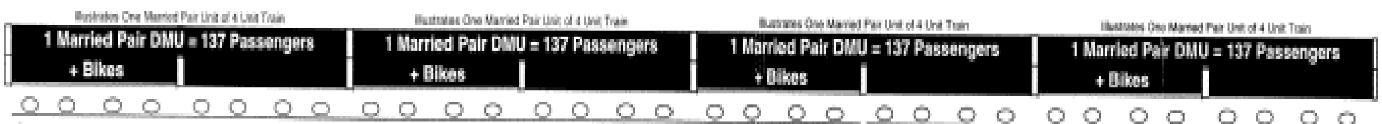
Single Car Unit - Double End - 85 Feet Long
Example of potential suppliers: Nippon Sharyo, Bombardier
FRA Compliant: Based on existing electrical EMU that is compliant
Prototype tested in US? No - see above.



Capacity of Typical Intercity Train Set: 4 units x 82 seats = 328 seats; 8 units = 656 seats
Cost for 1 DMU unit @ $ 2.5 million*. Cost for 4 Car Train Set = $10 million

B. European Conceptual DMU - Example: IC3 Flexliner

Married Pair or Triple Married Units Available - Double End - 160 to 190 Feet Long
Example of potential suppliers: Siemens, AD Tranz
FRA Compliant? TBD Prototypes tested in US? Yes.



Capacity of Typical Intercity Train Set: 4 units x 137 seats = 548 seats
Cost of 1 DMU unit @ $ 2.5 - $5.0 M. Cost of 4 Car (married pair) DMU Train Set = $10 - $20 million

C. Diesel Hauled Passenger Train - Example: Caltrain, ACE

Four car train + locomotive - Each Passenger Coach 85 Feet Long. Locomotive 60 Feet Long, Total = 400'.
Example of potential coach suppliers: Bombardier, Nippon Sharyo, ABB, others
Example of potential locomotive suppliers: GE, EMD, Boise Locomotive
FRA Compliant? Yes

Capacity of Typical Intercity Train Set: 4 coaches x 140 seats = 560 seats
Cost for 1 Loco @ $ 2.1 to 2.5 million. Passenger cars/cab coaches @ $ 1.7 M each. Cost for 4 Car Train Set = $10 million

* DMU capital cost estimates are based on preliminary; no actual orders have been placed.
US Conceptual DMU is shown as an 8-car consist. Actual operations would be limited to 4-6 vehicles due to train length and O costs.

3.8 MAINTENANCE FACILITY

The expense class of Maintenance of Equipment includes the cost of both labor and materials for maintaining the locomotive-hauled and DMU equipment. Existing Caltrain equipment is serviced and maintained at facilities in San Francisco, San Jose and Gilroy. Because Caltrain is already considering an expansion of its maintenance and servicing facilities based on its present and expected future requirements, it is quite likely that the addition of extra cars and locomotives to serve the Santa Cruz/Monterey area would also require expansions of the existing facilities or entirely new facilities. Therefore no cost is included in the discussion of capital costs in Section 4.

DMUs would require a completely different kind of maintenance facility than the facility used to maintain Caltrain locomotive-hauled equipment today and would therefore require a completely new dedicated DMU maintenance facility. It would be possible, however, to design any new Caltrain maintenance facility so that it could accommodate both locomotive-hauled and DMU equipment. The different facility requirements result from the fact that DMU engines are very often truck or bus engines and every vehicle is equipped with at least one engine. For this reason, it is assumed that the SCCRTC/TAMC would require a new maintenance facility dedicated to the servicing of its DMU fleet, if DMU equipment were utilized. The capital cost of building such a facility is included in the capital costs (see next section) for the different kinds of equipment.

In late 1996, Dallas Area Rapid Transit Authority (DART) began commuter rail service with refurbished Budd RDCs. DART has constructed a 125,000 square foot maintenance facility with two bays and room for two cars in each bay. It is the only DMU maintenance facility recently constructed in the United States. This facility had a total capital cost of $7.5 million dollars[14] and this figure was used to produce a conservative estimate of the future cost of a new DMU maintenance facility to be $10 million.

3.9 CAPITAL COSTS

Because the capital cost of DMU equipment is often substantially more than that of unpowered coaches and because DMU equipment would very likely require a new specialized maintenance facility, it is important to detail the capital costs of

the different kinds of equipment in this analysis. The capital costs for the locomotive-hauled equipment was taken from a discussion with Walter Stringer, Manager of Operations at Caltrain based on recent bids for new Gallery Cars (non-powered passenger coaches).[15]

The capital costs for the DMU equipment represents only manufacturer estimates or previous bids and may not represent the actual cost of purchase for a fleet of vehicles the size of a fleet required for a typical SCCRTC/TAMC passenger rail service. Capital costs for Conceptual U.S. DMUs are not available at this time as no orders for such equipment has been placed up to this time. An overall sense of the cost of Conceptual U.S. DMU equipment may soon become available as a result of the Pennsylvania DOT procurement of DMUs for their Harrisburg service. At this time, Pennsylvania DOT has yet to award a contract in that procurement process. Initial costs for such equipment can be expected to be high, as the first production vehicles would have to bear the cost of re-designing and re-engineering the equipment for diesel operation. A preliminary estimate of the cost based on discussions with vehicle manufacturers indicate that Conceptual U.S. DMU equipment would cost between $2.5 and $3.0 million per unit. The per vehicle additional maintenance facility capital cost was derived from the DART experience as described in the previous section.

Data Summary - Vehicle Capital Costs

- Locomotive - $2.1 million per F-40 locomotive (HEP power)
- Gallery Coach - $1.6 million per Coach
- Gallery Cab Car - $1.75 million per Cab Car
- Conceptual European DMUs - $3.7 million per married-unit[16]
- Conceptual U.S. DMUs - $2.5-$3.0 million per unit (estimate)
- Production European DLRVs- $1.8 million per vehicle[17]
- DMU Maintenance Facility - $576,923 per DMU vehicle

Table 3.1 Summary of DMU Equipment Data

	Caltrain Conventional Passenger Train	Conceptual European DMUs	Conceptual U.S. DMUs	European DLRV's
Labor (Train Operations)	Engineer $24.00/hour Conductor $20.00/hour Assn't Conductor $18.50/hour Conductor Helper $17.00/hour	Same Same Same Same	Same Same Same Same	Same Same
Benefits Multiplier	55%	Same	Same	Same
Operating Fuel Consumption	2.23 gallons/train mile	0.33 gallons/vehicle mile	0.42 gallons/train mile	0.28 gallons/train mile
Cost of Fuel	$0.75 per gallon	$0.75 per gallon	$0.75 per gallon	$0.75 per gallon
Vehicle Maintenance	$2.01 per train mile $0.63 per car mile	$1.18 per vehicle mile	NA	$0.84 per vehicle mile
Passenger Capacity (seated)	140 per gallery car	174 per multiple unit	82 per multiple unit	74 per car (unit)
Capital Cost	$2.1 million per locomotive $1.6 million per gallery coach $1.75 million per gallery cab	$3.7 million per multiple unit	$25.-$3.0 million per unit (Estimate)	$1.8 million per DLRV

Figure 3.1 summarizes DMU and diesel-hauled equipment costs. Table 3.1 presents a summary of DMU equipment data so that such equipment can be compared to the diesel-hauled equipment common in the North American market for proposed passenger service in the Santa Cruz/Monterey to San Jose corridors.
This data collected has included:

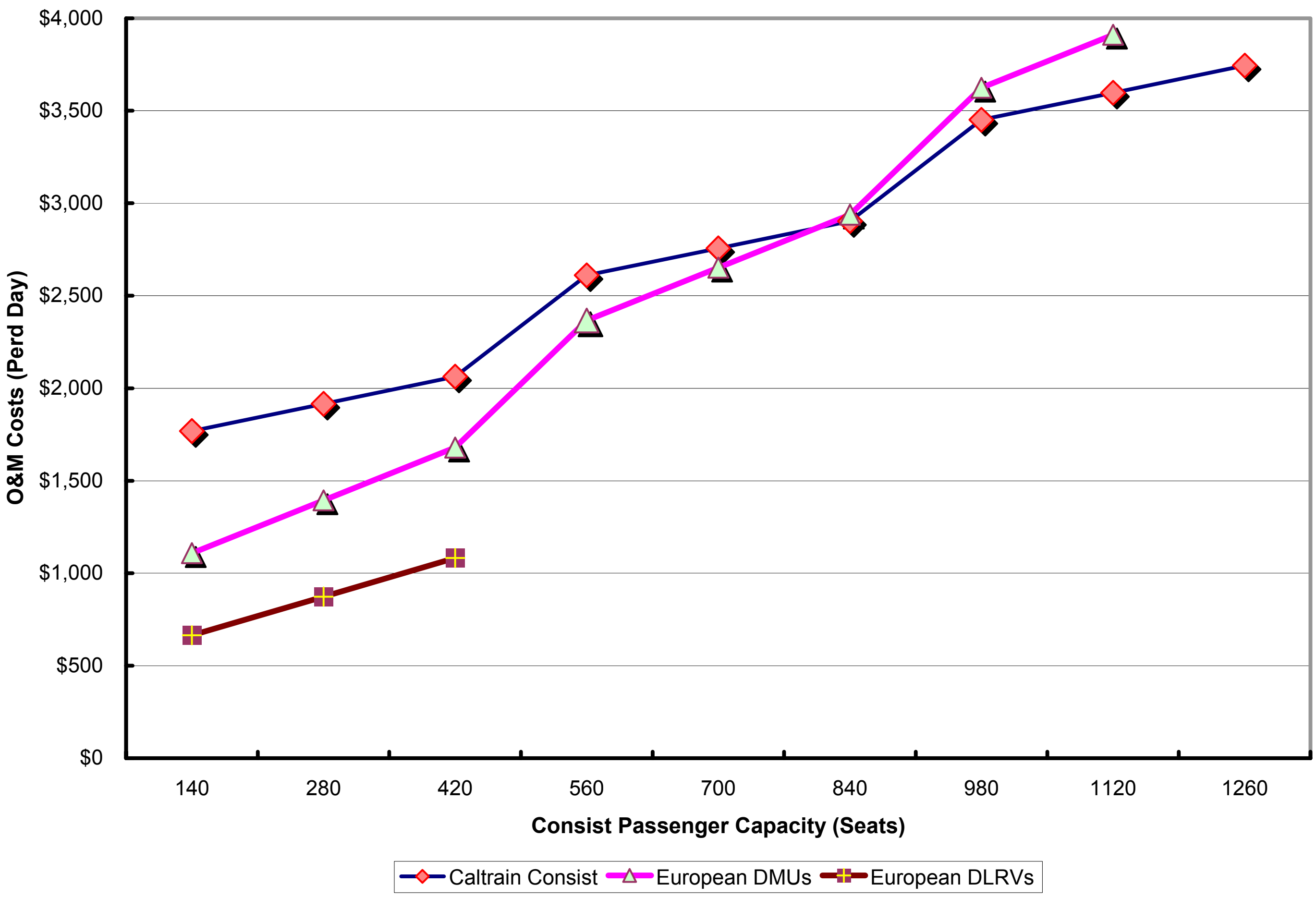
- Institutional/regulatory issues,
- Operating and maintenance (O&M) costs, and
- Capital costs.

The data included in this section was used as background information for the evaluation of equipment appropriate to the intercity and daily service under consideration for Santa Cruz and Monterey counties. The decision as to which equipment is a "best fit" between the equipment types available, the different types of service proposed and the different corridors is based on the analysis of operating plans presented in Section 4.

This information is useful when it is possible to compare the different types of equipment against one another based on their passenger capacities. Figure 3.4 compares the operating and maintenance costs of different types of equipment operating over 500 miles for 5 train hours. Please note that Conceptual U.S. DMU equipment is not included because it lacks any operating history.

From a glance, it is clear that the DLRV equipment is not appropriate for anything more than short haul or light density services, because of its low seating capacity (standing room is more extensive). It is also clear that DMU equipment is less expensive to operate than locomotive equipment, when the trains are operating with short consists: less than 700-800 passenger capacity.

Figure 3.4 Vehicle Operating and Maintenance Costs For Different Types of Rail Equipment by Capacity



3.10 INFORMATIONAL CONTACTS AND RESEARCH

In an effort to collect the greatest amount of information about DMU operations, several specialists in the railroad and transit industries were contacted regarding the use of DMU technology in addition to our own expertise. Many of these specialists were originally contacted as part of a study of DMU equipment conducted for the Massachusetts Bay Transportation Authority (MBTA) which was updated as part of this analysis for SCCRTC/TAMC. These specialists fall into three basic categories:

- Industry Watchers/Consultants,
- Agency planners considering DMU technology, and
- DMU manufacturer representatives.

The Appendix contains a list of the informational contacts regarding DMU Operating and Maintenance (O&M) costs.

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[1] Code of Federal Regulations, Title 49, Section 229.141 (a) and (b)

[2] Existing FRA regulations regarding brake tests can be found in 49 CFR 232.12. There are several different types of brake tests, but a test conducted when a train is combined or broken up takes approximately 2-3 minutes. The train must be stopped and the engineer must apply and release the brake air pressure. At the same time, the conductor or assistant conductor must get off the train and watch to see that the brakes physically being applied and released.

[3] USDOT, "Passenger Equipment Safety Standards; Proposed Rule", Federal Register, September 23, 1997, p. 49811 proposed rule 238.317.

[4] Manuel Padron & Associates, San Francisco Downtown Station Relocation EIS/EIR, Operations and Maintenance Cost Methodology Report, JPB, August 30, 1995. The $13.02 costs per car mile used in this study were also used in the SCCRTC Intercity Recreational Rail Study, 1996.

[5] Caltrain staff interviewed over the phone on 10/27/97.

[6] Caltrain staff interview, 10/27/97.

[7] The labor benefits ratio applies to "straight" time only. Overtime benefits are assessed at a different rate, but overtime hours are excluded from this analysis.

[8] Interview with Caltrain staff, 10/27/97.

[9] Nippon-Sharyo only.

[10] ADtranz only.

[11] Caltrain staff interview, 10/27/97.

[1212] MBTA Railroad Operations interviewed by Daniel Jacobs on February 3, 1997

[13] Based solely on the RegioShuttle

[14] Facsimile received from Carole Foster of DART Railroad Operations, dated February 20, 1997.

[15] Caltrain staff interview, 10/27/97.

[16] Production European DMUs are produced in a variety of models and configurations. Both married-pairs (two semi-permanently linked units) and married-triplets (three semi-permanently linked units) are common. The ADtranz Flexliner is available as a married-triplet, but the Spanish National Railways have purchased a married-pair version of the same equipment.

[17] Based on RegioSprinter Only.