CHAPTER 4: INVENTORY AND DESCRIPTION OF RAIL TRANSIT VEHICLES CURRENTLY AVAILABLE FOR POTENTIAL JOINT OPERATION WITH RAILROADS

4.1 OVERVIEW

The broad range of rail transit vehicles that might be considered for joint use needs to be identified, along with the characteristics that differentiate them. The range of vehicles is based upon a variety of LRT and DMU types of equipment, including railroad derivative FRA-compliant and LRV derivative DMUs, but not including conventional commuter railroad equipment (see Figure 4-1 and Table 4-2).

Furthermore, DMU development has recently been focused on more than that of LRVs, because the DMU has a much wider range of designs and characteristics. The newer (less familiar to U.S. markets) LRT derivative DMU option is generally less costly and more likely to be attractive as a rail "new start." The lighter DMUs are sometimes referred to as DLRV (diesel light rail vehicles) and can serve as a precursor to LRT. In addition, contemporary LRVs of varying types are far from being FRA-compliant, whereas DMUs range from designs similar to LRVs to much heavier and generally FRA-compliant types. DMU and LRT included in the range of vehicles are representative of the much larger number of choices that are either currently or soon to be available.

The evolving APTA Passenger Rail Equipment Safety Standards (PRESS) program may influence the potential use of LRT or DMU under joint use operations. The PRESS program is a task force of industry experts funded by commuter rail agencies, assembled under the auspices of APTA and recognized by FRA. Its mission is to develop a new set of rail car safety standards covering the following:

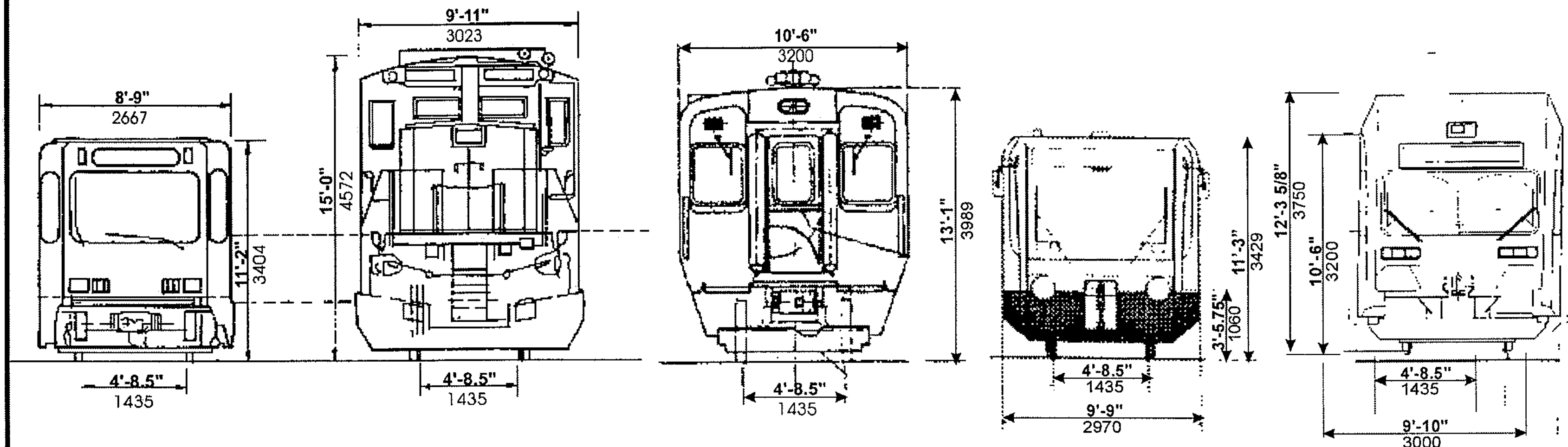
- Collision and Structural Requirements
- Electrical Systems
- Brakes, Wheels, Trucks, and Couplers (LRVs have electronic/redundant braking)
- Systems (Operations and Maintenance)

Resulting standards will be included in an FRA rulemaking procedure wholly or in part, eventually producing a new set of requirements for railcar construction, maintenance, inspections, and testing. As of January 1, 1997, all states having rail transit not regulated by FRA must have had state safety oversight in place. This includes the AGT people movers, as in Detroit, and vintage trolley operations, as in Memphis.

Many different types of DMU and LRT vehicles are available outside North America. Their key characteristics, and their compatibility to operate jointly on railroads and on LRT tracks are best described by category. One suggestion is to divide DMUs into subgroups: High Floor DMU, Low Floor DMU and Electric LRT. The TRB Subcommittee on DMUs (A1E07-1) recommends another system based on three categories: FRA Compliant-RR Derivative, Non FRA Compliant-RR Derivative (largely overseas designs), and Non FRA Compliant-LRT Derivative.

A similar three-category system is recommended and used subsequently in this report to classify DMU, including:

- **Category 1** - FRA-compliant, railroad derivative (e.g. "Budd Car type") for railroad application
- **Category 2** - Non FRA-compliant, LRV or overseas railroad derivative, non streetcar track-compatible for railroad, some interurban and rapid transit application



LRV
45-50 Tons

Diesel Locomotive
180-200 Tons

DMU - Category 1
65 Tons

DMU - Category 2
37-50 Tons

DMU - Category 3
50+ Tons

1 meter = 3.2808 ft.

DIMENSIONAL CONTRASTS -LOCOMOTIVE, LRV, DMU

JOINT USE OF TRACK RESEARCH

Fig. 4-1

Table 4-1
Range of DMU and LRT Vehicles Available for Potential Joint Operation with Freight Railroads

				RELATIVE COMPLIANCE (WITH FRA, AAR, ADA, NFPA)			GENERAL PERFORMANCE		PHYSICAL AMENITIES	
DMU/LRV CATEGORY	TYPE VEH.	MANUFACTURER	MODEL	HIGH	MODERATE	LOW	HIGH SPEED	MODERATE SPEED	RR AMENITY	TRANSIT AMENITY
1	A	ABB	Class 150			●		●	●	
1	A	ABB	Class 165			●		●	●	
1	A	ABB	Express DMU		●			●	●	
1	A	ABB	Flexliner IC3D		●		●		●	
1	A	Bombardier	"DMU"*	●			●		●	
1	A	GEC Alsthom	Alice 203/204*	●			●		●	
1	A	Goninan	Sprinter			●	●		●	
1	A	Nippon Sharyo	N. America "RDC"*	●			●		●	
1	A	Siemens	VT-628/610*		●		●		●	
2	B	ADtranz	Regio Shuttle			●		●	●	
2,3	B,C	Bombardier	Talent			●		●	●	
2	B	GEC	Lint*			●		●	●	
2	B	Siemens	RegioSprinter			●		●	●	
2,3	B,C	SLM	Futura*			●		●	●	
2,3	B,C	Adtranz	GTW 2/6, 4/8, 4/12			●		●	●	
4	C	ADtranz (ABB)	BALT LRV1			●		●	●	
4	C	Breda	MUNI LRV2			●		●		●
4	C	Tokyu Car	NFTA LRV			●		●		●
4	C	Siemens-Duewag	Edmonton LRV			●		●		●
4	C	Bombardier	Monterey/Guadalajara			●		●		●
4	C	Nippon Sharyo	LACMTA Blue Line			●		●		●
4	C	Siemens-Duewag	PAT LRV			●		●		●
4	C	Siemens Duewag	BSDA LRV1			●		●		●

DMU Category — *1= Railroad Derivative DMU* — *2= LRV Derivative DMU* — *3= Dual-Power LRV DMU (or DLRV),* 4 = Electric LRV

Type — *A= High-Floor Diesel Vehicle* — *B= Low Floor Diesel Vehicle* — *C= Electric LRT Vehicle (all Category 4, Type C are high floor)*

Notes: * In Development. *** Averages are based on similar equipment.
High - Fully meets most requirements — Moderate - Marginally meets most requirements except FRA — Low - Non-FRA compliant
List of vehicles represents the list information available at the time this report was written

- **Category 3** - Non FRA-compliant LRV derivative, dual power (diesel-electric/all-electric), fully LRT-compatible [also called Diesel Light Rail Vehicle or DLRV] for railroad and light rail track applications

Other subdivisions, based on degrees of FRA compliance are also possible, but the research team recommends the above system because it describes DMUs on both ends of the operating compatibility spectrum, from railroad tracks to in-street light rail.

The variety of DMU and light rail vehicles, their physical and performance characteristics, and their respective degree of compliance to U.S. railroad regulations, industry standards, and practices have been outlined. These compliance issues and particular Federal requirements may require modifications to current vehicle designs to enable joint operation with freight railroads. Some designs cannot be readily adapted to railroad joint use. To attempt to do so would destroy the integrity of their lightweight design. Purchasing, operating, and maintaining a fleet of DMU vehicles are also monetary factors to take into consideration. The financial and administrative arrangements to support this equipment and service is location-specific.

4.1.1 Historic Perspective and Evolution of Contemporary DMU

Joint use of tracks by different types of operators and the availability and use of self-propelled rail diesel cars are not novel ideas, but these types of operations have not been common in the U.S. for quite some time. The attractiveness and complexities of joint use in today's regulatory, economic, urban land use, legal, and technical environment have generated supportive discussion and some controversy among system planners, operating agencies, rail system experts, community leaders, and elected officials. The issue is controversial. Some precedents with early self-propelled rail cars and joint operations do exist. The Rail Diesel Car (RDC) and its predecessor "doodlebug" and articulated "shuttlejack" self-propelled cars were embraced by the U.S. railroad industry because they reduced impacts of regulations and then-prevailing labor practices. They permitted "changing ends" without throwing track switches or requiring multiple locomotive moves. Prime movers could be quickly replaced and crew requirements were reduced. RDC's were used in a variety of functions and operating environments throughout North America and elsewhere. DMUs have remained in service continuously and evolved into rail bus and LRV forms elsewhere in the world. In the U.S., the successor to the RDC would be today's newly-designed DMU of the three categories suggested above. It has promising potential for new rail starts for many of the same reasons that made its predecessors attractive. Conversely, their rationale faded with commuter rail authorities replacing RDCs at the end of their useful life with innovative push-pull, bi-level, locomotive-hauled equipment.

For purposes of regulation, FRA considers *all* DMUs as locomotives. It does not differentiate between locomotive-hauled consists and independent self-propelled cars coupled into consists.

Most earlier DMU cars were FRA-compliant vehicles in accordance with standards of their era. While technology has progressed and operational/service requirements may differ, the mixed mode of operation with different vehicles is not a new concept. Many of the issues are similar, but the flexibility to respond and constraints arising from current standards are new. Modern signal and control systems can diminish some of these concerns and provide a superior level of co-mingled service.

DMU generically has a range of potential deployment scenarios, including:

- DMU as a free-standing rail transit system, not connected to any other system and not subject to FRA regulation, operating as a new DLRT line.

- DMU as an integrated part of a new commuter rail system or as part of an LRT system, as in the Alternate Rail Technology (ART) system proposed in California.

- DMU as an initial operating segment (IOS) for LRT. IOS for LRT is usually proposed as a central or some other portion of a buildout plan. A DMU IOS scenario would build either the entire line or most of it, but initially at a lower capital cost and level of service.

- DMU as a non-electrified branch of an LRT system. This could be operated as a shuttle, requiring transfer at the junction point or integrated with DMU overlapping service on the LRT trunk line (DMU Category 2 or 3). With Category 3 (dual power) DMU, the operation could be fully integrated with DMU operating in the diesel mode on the branch and in the electric mode on the LRT trunk.

- DMU as a precursor to Light Rail and/or as an interim rail mode, an intermediate step in the incremental transition of railroad infrastructure to light rail (DMU Category 1 or 2).

- As a low-cost rail transit line "one-person" operation (DMU Category 1) on a railroad, as in NYS&W "on-track" system in Syracuse.

- FRA-compatible (Category 1) DMU as a branch line shuttle or hauled in consist with commuter rail or intercity rail trains and reverting to single-car self-propelled mode where the consists split.

- Low-density intercity railroad corridor or branch line shuttles.

4.1.2 Vehicle Operational Control

Two primary modes of vehicle operation are available, the most likely being active manual operation by a qualified engineer. This manual mode is common to domestic railroad operations. However, on some routes, usually where passenger service occurs, existing automatic train protection has been installed to possibly override the engineer. This mode has greater potential for error, but is less expensive and has been used successfully and safely for decades.

The second option is the passive presence of an engineer while train movement is controlled by automatic train control/ automatic train supervision/automatic train operation. The engineer might make announcements and open doors, and is available in case of emergency. This complex mode requires significantly more costly and sophisticated technology, but affords higher levels of safety and redundancy under most conditions.

Either approach is suitable for joint use operations. In the context of a freight-owned right-of-way where transit is a tenant, manual train operation by an engineer is more likely because cost, time, and technology to implement more sophisticated control can delay or stonewall prospective startup projects. An important caveat is that FRA approval of joint operations will be dependent upon the technique used to control the vehicles.

4.2 RANGE OF AVAILABLE VEHICLES

4.2.1 DMU and DLRV Cars

A survey was conducted of car builders to determine current (1997) Light Rail, Diesel Light Rail and Diesel Multiple Unit car features and performance characteristics. These rail car characteristics are fully described in Appendices F, G, and H.

DMU vehicles are typically heavier than LRVs, and are generally easier to initiate into service on former or disused railroads because they are self-propelled and do not require wayside electrical power systems. More recently, however, for non-U.S. applications, much lighter-weight DMUs have been developed to extend the range of availability. This group can be subdivided into high- and low-floor models, as well as compliant and non-compliant with FRA regulations. In some cases, lighter-weight DMUs were derived from LRT vehicles and components. The range of these vehicles has grown such that certain DMUs could not be operated in mixed use with lighter DMUs under U.S. safety regulations.

DMU vehicles described in this representative (at the time this report was written) list are typical of those either currently in use in other countries, or being designed specifically for use in North America. Some of those listed are designed for specific overseas markets and are less suitable for North American application. Several new models were introduced during the course of this research and they have been listed.

Siemens VT 610/628 (Category 1)

The VT 628 is a two-car trainset with a seating capacity of 144. The unit is a high-floor design with a top speed of approximately 75 mph. The Siemens Duewag Type 628.4/928.4 DMU is widely used by the Deutsche Bahn AG (German Railways) for short-distance passenger service. Siemens is modifying its VT 628 for operation in the North American market. The U.S. version of the VT 628 is anticipated to comply with FRA standards. Both DMU-hydraulic and DMU-electric drives are planned to be offered, both sharing a common carbody designed for modular component installation. A low-floor configuration for the middle car of a three-car set is under discussion. The model 610 version has a tilt feature.

Goninan Sprinter (Category 1)

Goninan's Newcastle Works in Australia has supplied a fleet of 22 "Sprinter" DMU-hydraulic cars for the Victoria Public Transport Commission. The Goninan Sprinter is a DMU vehicle with a top speed of over 80 mph. Each car can carry up to 90 seated and 15 standing passengers. It is of a lightweight railroad derivative design which would, however, not be considered fully FRA compliant. Several railroad derivative DMUs are listed as Category 1 because they may be considered potentially FRA compliant.

Siemens RegioSprinter (Category 2)

The RegioSprinter is a double-articulated, low-floor DMU. It has a top speed of almost 65 mph and can accelerate at a rate of 2.4 mphps. This car was designed for relatively short-haul operations, and resembles a light rail vehicle more than a commuter rail car, although it is used for both purposes in Germany, where it operates on railroad branch lines. Over 180 RegioSprinters are being delivered to European operators.

Nippon-Sharyo New Generation "Rail Diesel Car" (Category 1)

Nippon-Sharyo's New Generation "Rail Diesel Car" (RDC) is based on a design in use in the U.S., configured as both an electric MU car for the South Shore and an unpowered push-pull commuter rail coach for MARC. No working prototype of the RDC high floor vehicle exists, although its components are in use. The vehicles are designed to achieve a top speed of 80 mph, with an acceleration rate of 0.78 mphps. Each car has an 87-person seating capacity.

ADtranz Regio Shuttle (Category 2)

The ADtranz Regio Shuttle is a conventional single unit rigid-body DMU supported by two 4-wheel trucks. It has a conventional DMU mechanical power train with automatic transmission. The vehicles have a seating capacity of 75 and a top speed of 75 mph. ADtranz has 92 cars on order and nine vehicles in service in Europe.

Bombardier Talent (Category 2 & 3)

The Bombardier (Talbot) Talent is a multisection modular, low floor concept, available with DMU-mechanical and DMU-electric propulsion. The vehicle has tapered double-end design intended for use on mainlines, with emphasis on passenger comfort and appeal. One prototype car is under test in Northern Holland and over 350 units are ordered by various German railways, mostly DBAG.

GEC LHB "Lint" (Category 2)

This car is conceptually similar to the low floor RegioSprinter but is being designed to a higher specification. The concept being designed includes self-steering, three-section double-articulated vehicles with powered axles.

Bombardier "Diesel Multiple Unit" DMU Rail Car (Category 1)

Bombardier is developing a "North American Car" that could be configured as an electric MU car, an unpowered coach, or a DMU. The design will be based on one of their existing commuter car products, and is expected to meet FRA requirements. It will have a high-floor configuration, and a wheelchair lift will be offered for ADA-accessible operation with low station platforms. This carbody is derived from the Montreal EMU.

ABB Class 158 Express and Class 166 "Network Turbo" (Category 1)

The Class 158 ABB "Express" intercity DMU vehicles are used for regional travel of up to three hours duration. The high floor Class 158 can operate at speeds up to 90 mph. The British Rail class 166 "Network Turbo" provides commuter services around London at speeds up to 75 mph. Cars are air-conditioned and are high floor design. Both the 158 and 166 are built to British loading gauge.

ADtranz/Stadler/SLM "GTW" 2/6, 4/8 or 4/12 (Category 2 & 3)

This self-steering DMU is readily adaptable to Category 3 dual power. It is a low floor modular design, available in three lengths, four traction packages, four widths, multiple units, and four gauges. It features a power module that is self contained and allows passage between the units. The GTW 2/6 is in daily use and also comes as an all-electric LRV. Over 30 units are on order (see Appendix J-2).

SLM "Futuro" (Category 2 & 3)

A modular design available in diesel-electric, diesel-hydraulic, or all-electric versions at multiple voltage, gauge, and unit options. Features include 1500 KN (337 kips) buff strength, 120 km/h (75 mph) top speed, a 3-unit capacity maximum of 308 passengers, and self steering trucks.

GEC Alsthom-"Alice" 203/204 (Category 1)

An FRA/ADA/AAR-compliant version of European Regional Express Transport or "TER" DMUs. Design is modular, with commuter and intercity versions having top speeds of 75 and 120 mph. These DMUs are under development in their North American versions.

ADtranz IC-3 "Flexliner" (Category 1)

A railroad derivative high floor DMU with commuter rail and high speed intercity railroad application. It is in service in Scandanavia and Israel, and toured North America under an FRA waiver as it did not meet all FRA standards. The manufacturer claims 112 mph top speed.

4.2.2 LRT Vehicles

LRT vehicles, in addition to requiring an electrification system, have very low carbody strength properties, compared with railroad car requirements, and they typically have lower top speeds but higher acceleration/braking rates than DMUs.

Regardless of past efforts to encourage development of a standard light rail vehicle (SLRV program), over 27 different types of LRT vehicles are being operated in more than 20 different North American cities. LRT vehicles described below are typical of the high-floor type of vehicle initially being operated in the U.S., but today's LRVs can be designed to serve high or low station platforms, depending on local facilities. Portland, Oregon operates the first low-floor LRVs that were acquired in the U.S.; these are used in mixed consist with high-floor LRVs.

ABB LRV1

The ABB/ADtranz LRV1 has been in operation for the Baltimore MTA since 1991. The fleet of 35 vehicles has a high- and low-station platform loading capability and is designed in a six-axle articulated configuration. This vehicle is one of the larger LRVs in operation, with 108,000 lbs. empty weight and 90' + in length. MTA has ordered an additional ten vehicles, the first of which is near completion.

Breda LRV2

Breda's LRV2 is being introduced into service on San Francisco's Municipal Light Rail System. The fleet will total 52 vehicles that can operate in consists of up to four coupled vehicles. The passenger capacity is 60 seats per vehicle. While being a high floor car, it can serve high- or low-station platforms.

Tokyu NFTA LRV

The Tokyu LRV, of which 27 operate in Buffalo since 1985, has an empty weight of 71,000 lbs. and a seating capacity of 51 per vehicle. It is configured as a single-unit rigid frame (non-articulated) car.

Siemens-Duewag Edmonton U-2 LRV

This LRV has been operating in Edmonton since 1982, with the current fleet consisting of 37 vehicles. The vehicle configuration includes a six-axle articulated car with the capability to run five vehicles in one consist. The U-2 design is based on a S-D standard design originating in an order for Frankfurt, Germany. Similar vehicles have been produced for Calgary and initial orders for San Diego.

Bombardier Monterrey LRV

The Bombardier LRV is a relatively new vehicle that has been in operation in Monterrey since 1993. It has a top speed of 50 mph and can seat 58 people per vehicle. The car is longer than most at over 96 feet, with the ability to operate up to a four-car consist. A similar model is the Bombardier Guadalajara LRV.

Nippon Sharyo LACMTA

The Los Angeles County MTA purchased 54 Nippon Sharyo LRVs to be used on their Blue Line. However, these vehicles have recently been used on the Green Line to support service demands. This LRV is one of the larger vehicles, with seating for 76 people and an empty weight of 98,000 lbs.

Siemens-Duewag BSDA LRV1

This LRV has a 90,000 lbs. empty weight and a seating capacity of 72. Bi-State has been operating these vehicles in St. Louis since 1993 and can run up to six-car consists. A similar model (Siemens-Duewag PAT LRV1) is operated in Pittsburgh. This design or a derivative is used in Denver, the newest model is at San Diego, and is proposed for Salt Lake City.

For a detailed listing of vehicle characteristics, see Appendices F and G. See Table 4-2 for a summary of rail car compliance, performance, and physical characteristics.

4.2.3 Dual-Power Vehicles

None of the listed DMU offerings feature dual power, defined as the ability to operate from an on-board internal combustion engine (prime mover) and from wayside (contact/third rail or overhead catenary system) traction power sources. In the DMU context, "dual power" means the ability to use different traction power sources (i.e., third rail, overhead catenary, or on-board diesel generator). "Dual voltage" means the ability to operate from different traction voltages or current types-such as 750vDC *and* 15,000 vAC.

Some of the small-bodied DMUs are derived from LRV designs and feature mechanical or hydraulic transmissions that propel the car. This drive-train arrangement has advantages, but is not easily adaptable to dual electric/diesel power. Dual power typically requires a prime mover, a generator/alternator, and electric final drive to propel the car. Addition of current collection and power conditioning equipment creates a dual-power vehicle.

Dual-power capability has planning implications for expanding or modifying rail transit systems. Application of a dual power DMU (Category 3 vehicles which might be called DLRVs) permits an expanded incremental approach to new starts and ultimately full LRT service. The advantage of this arrangement is the flexibility to use non-electrified routes and then operate over an electrified line and derive maximum performance provided by each primary power source. Maintenance arising from additional equipment and complexity associated with dual-power sources is a disadvantage, as is added weight, which may diminish performance. Service reliability and availability may also be affected.

As an example, Metro North Commuter Railroad has used dual-power locomotives (FL-9) in service. This practice resulted from a predecessor's desire to operate trains through both electrified and non-electrified territory without either the passengers having to transfer or locomotives having to be changed. As a practical matter, diesel-powered equipment is capable of operating over electrified territory in the diesel mode, as proposed for the Philadelphia-Harrisburg DMU service.

4.3 INDUSTRY STANDARDS AND OTHER REQUIREMENTS

To enable safe, efficient, and satisfactory comingled operation of non-railroad vehicles on North American railroads, vehicles must comply with current railroad requirements, regulations, and configurations. These standards have evolved over decades and are based on equipment used in interchange safety guidelines. Many are industry standards derived from recommended practices established by the Association of American Railroads (AAR) to ensure operational and equipment compatibility among all railroad properties regardless of the right-of-way owner or operator. While compliance ensures suitability on any domestic railroad, it also creates a "barrier to entry" by requiring any vehicle to comply with these standards.

FRA's Congressional mandate to establish minimum safety standards for passenger equipment and APTA's PRESS program will have a significant influence on the evolution of prospective DMU/LRV joint use vehicles. These standards are under development by an industry-wide consortium of experts, regulators, operators, and consultants. Final recommendations may be incorporated in part or entirety by FRA. This work may result in "multi-tiered" requirements, depending on characteristics of the operation and technologies used to control train movement. FRA waivers may still be required where non-compliant cars are proposed to be operated.

Major requirements that could cause significant changes in vehicle design for compliance or safety are vital to joint use proposals. Key criteria to determine compliance with federal regulatory requirements and industry standards and practices also need to be outlined and analyzed. Some of these compliance issues are graphically portrayed on Figure 4-1 and in Appendix F (contrasting size, weight, coupler and floor height, operator's position, etc.).

4.3.1 Carbody Strength

Two Federal regulations that will have the greatest effect on rail vehicle design and construction, and may preclude use of some or most existing designs, are the Body Structure - MU Locomotives requirements (49CFR-Part 229.141) and the Americans with Disabilities Act (49CFR-Part 38). In the past, body structure requirements (49CFR-Part 229.141) were split into two sets of requirements. One set covered cars used in trains where total train weight was under 600,000 lbs., and the other set covered requirements for cars used in trains with total train weight over 600,000 lbs. Requirements include design and tests for compression at the draft sills, vertical load on the anti-climber, vertical load on the coupler carrier, collision post shear, and truck locking to the carbody.

Structural requirements (49CFR - Part 229.141) for cars in trains over 600,000 lbs. include:

- 800,000 lbs. compression at draft stops without permanent deformation.
- 100,000 lbs. vertical load on anticlimber without exceeding yield point.
- Vertical downward load on coupler carrier of 100,000 lbs. without exceeding yield.
- Collision posts on each side of the diaphragm opening, with ultimate shear of 300,000 lbs. at the top of the underframe.
- Truck locking to body at a minimum ultimate shear value of 250,000 lbs.

FRA is also proposing several new carbody structural design requirements intended to improve the safety of passengers and operators, including:

- The anticlimber arrangement designed to resist greater vertical and lateral buckling forces.
- The collision posts made stronger and preferably extended to the roofline.
- Corner posts full height (extending from the underframe to the roof) and capable of resisting a load of 50,000 lbs. at the underframe attachment and 80,000 lbs. at the roof attachment.
- A cab crash refuge or survivable area for the crew in the event of an impending collision.

- A rollover strength value of 2g (twice force of gravity) acting on the mass of an individual vehicle.

- A side impact strength to protect against collisions with highway traffic such as tractor-trailers.

- In the event of a derailment or rollover, a truck-to-carbody attachment to keep the truck attached to the car.

- Seat components designed to withstand loads due to impact of passengers up to 25 mph.

- Glazing strength requirements increased to adequately protect crew and passengers in higher-risk environments.

Although new requirements are in "proposed" form only, FRA has expressed its intention to apply these requirements in the certification process (*absent research on joint use*). FRA is likely to look with disfavor upon vehicles that are not compliant with present standards, and will be disinclined to grant waivers or rule favorably on compliance of new equipment that does not incorporate new standards. Additional engineering and material is not expected to significantly increase capital or operating costs, and performance will be marginally affected. Increasing availability of information on joint use practices and regulation, combined with risk assessment techniques, hold promise for selective, new shared track projects. Therefore, these regulatory issues should not be considered "obstacles" to desired improvements, including potential joint use applications. Crashworthiness will also be improved, which is the top priority of FRA. Such rail car features are more quickly and easily implemented than more sophisticated signal systems on railroads.

4.3.2 Crashworthiness Features

Crashworthiness is the emphasis of the features described above. There are practical limits to the benefit of such features, since not every crash event can be accommodated and added weight and materials reduce performance and seating capacity. A risk analysis or cost/benefit assessment of features will provide improved decision-making directed at survivability. The trade-off to increasing crashworthiness is in collision-avoidance features designed into operation and control systems.

A recent study by the Volpe Transportation Systems Center (Tyrell, Severson, et al., "Evaluation of Cab Car Crashworthiness Design Modifications." March 1997) estimated that structural design modifications to the leading ends of cab cars adds approximately 700 lbs. to car weight and $2000 to initial cost, a modest cost and weight penalty for improved crashworthiness.

One useful criterion is the ability of the operator to control elements of risk and operational variables. As an example, the operating agency can control train movements, speed, headways, and routes and, therefore, can minimize risk employing management techniques, predetermined operating practices, and pertinent technology. Movements of road traffic at grade crossings, however, cannot be so well controlled, and automobile driver behavior can bypass all safety devices. Some form of energy-absorbing design should therefore be incorporated at the front/operator's position on these vehicles.

The "Locomotive and Cab Car Crashworthiness Working Conditions Report" to Congress, September 1996, issued by USDOT FRA Office of Safety and Compliance, follows nearly verbatim. It stipulates four general goals of crashworthiness, as follows:

- Maintain an envelope or minimum volume of survivability for crew and passengers which resists extreme structural deformation and separation of main structural members.

- Protect against penetration of the occupied compartment.

- Protect against occupants being ejected from the compartment.

- Protect the occupants from secondary impacts within the interior of the compartment.

To make an accident of a train survivable, two design features are required. The occupied spaces must be strong enough not to collapse and the initial deceleration of the occupants must be limited so they are not thrown against the interior of the train with great force. Achieving these general objectives can be the most difficult challenge facing equipment designers.

Crash energy management is a design technique to help equipment designers meet this challenge. Unoccupied spaces or lightly occupied spaces are intentionally designed to be slightly weaker than heavily occupied spaces. This is done so that the unoccupied spaces will deform before the occupied spaces during a collision, allowing the trainset occupied spaces to initially decelerate more slowly and minimizing the uncontrolled deformation of occupied space. Conventional practice has resulted in locomotives and vehicles of essentially uniform longitudinal strength, which causes uniform structural crushing through the unoccupied and occupied areas of the train (in vehicular parlance, "crumple zones").

Interior crashworthiness study evaluates the influence of interior configurations and occupant restraints on injuries resulting from occupant motions during a collision. For a sufficiently gentle train deceleration, compartmentalization can provide sufficient occupant protection to keep widely accepted injury criteria below the threshold values applied by the automotive industry. If installed and properly used, the combination of lapbelts and shoulder restraints can reduce the likelihood of fatality due to deceleration to near-certain survival for even the most severe collision conditions considered.

The value of crash energy management design is not in the energy absorbed. Only a small percentage of the kinetic energy in a collision can be absorbed within a reasonable crush distance. The real safety benefit comes from allowing the occupied spaces to decelerate more slowly, while decreasing the likelihood that occupied spaces will fail in an uncontrolled fashion. If the occupied spaces are initially decelerated more slowly, people will be pinned to an interior surface of the trainset with less force, resulting in fewer and less severe injuries. Once pinned, occupants can sustain much higher subsequent decelerations without serious injuries resulting. Also, since unoccupied space is intentionally sacrificed, less occupied space overall will be crushed.

Crash energy management design involves a system of interrelated safety features, in addition to controlled crushable space, that could include:

- design techniques to keep the trainset in-line and on the track for as long as possible during the initial impact.

- interior design eliminating sharp corners and padding surfaces likely to be struck by people with shock absorbing material.

- attachment of interior fittings and seats with sufficient strength not to fail during collision.
- a crash refuge for the vulnerable crew members in the cab.

To help maintain survivable volumes, particularly during collisions at higher closing speeds, minimum standards for the following structural design parameters would be needed. These include antibuckling to keep the train in line and on track, end structures and anti-climbers to prevent override, corner posts to deflect glancing collisions, and sufficient rollover strength. To limit decelerations of crew members and flying objects striking the crew, standards would be necessary for the following general design parameters under the dynamic conditions created by the collision scenario.

These include minimum longitudinal/ lateral/vertical seat attachment strength and minimum longitudinal/lateral/vertical fitting attachment. Achieving attachment strength requires careful design to create a differential in structural strength between the seating areas and non-occupied areas that would be allowed to fail. By contrast, maintaining uniform rigidity throughout the trainset would result in unacceptably high initial deceleration of the crew compartment and possibly make the accident non-survivable.

The Federal Railroad Administration encourages railroads and manufacturers to develop equipment and locomotives incorporating crash energy management systems. DMU (&LRV) equipment (in joint service) should be designed with a crash energy management system to dissipate kinetic energy during a collision. Vehicles should be designed to crush and absorb energy in a controlled manner by "zones" when subjected to end loads in collisions that exceed the static load capability of the structure. The zones will be as follows, from highest to lowest priority.

Zone A usually-occupied area of the vehicle, i.e. the cab

Zone B occasionally-occupied areas of the locomotive (passageways, toilets, etc.)

Zone C unoccupied space (equipment cabinets and utility space)

The locomotive should be designed with energy crush zones B and C, which are 100 percent stronger than Zone A, ahead of the occupied control cab in the direction of travel. The greater the crush distance that can intentionally be designed into the vehicle before reaching the cab occupied volume, the more survivable a collision will be. Since the control cab is necessarily near the leading end, little crush distance is available to protect the crew in the cab. As a result, the decelerations of the crew can be fast and a special crash refuge is needed to increase survivability of collisions with a closing speed of greater than 30 mph.

The system should limit the maximum and average deceleration of the crew in the control cab for the first 250 milliseconds after impact. This duration was selected as the time required for people to make their initial impact with an interior surface and be pinned by inertia against that surface. After that time, the peak deceleration can be increased without causing serious injuries.

An analysis based on a collision scenario with a specified closing speed should be performed to verify that the crash energy management system meets these guidelines. Assumptions made as part of the analysis to calculate how the kinetic energy of the collision is dissipated, should be fully justified. The analysis must clearly show that the crushable volumes of the locomotive crush before collapse of the cab volume starts, and that the deceleration of crew in the occupied cab is limited to the recommended levels.

Other less expensive, but unconventional, crashworthy features are rearward-facing seats. This device produces a dramatic improvement in injury reduction and survivability. Since it is understood that such seating may not be popular among passengers, a compromise approach would involve combining this seating with a single cab per car. This configuration would have a second car with forward-facing seats, such that the lead car in a collision would always have rearward-facing seats. Such a train would then consist of two cars in married pairs with a cab station at one end of each car. Commuter railroads in the Northeast often run with rearward facing seats in some sections of a car.

4.3.3 Smoke and Flammability (NFPA 130)

Beyond FRA jurisdiction, compliance with current flammability guidelines and smoke emission requirements will be necessary. In the past, European vehicles were assumed to not be compliant with North American standards, but recently fire resistance standards have been introduced in European practice as well.

A complication arises in confirming that those European standard materials used in imported LRV and DMUs meet U.S. (NFPA 130) requirements. Laboratory tests that measure performance of materials under specified conditions are required to determine suitability.

Although NFPA 130 pertains specifically to electrically propelled passenger-carrying vehicles of a fixed guideway transit system, there are many aspects of the standard which could be applied for safety reasons to mechanically driven vehicles. The NFPA 130 standard makes reference to several ASTM, IEEE, and FEDSTD test procedures for a category of materials used within rail transit vehicles. The materials typically included are:

- Seating cushions, frames, shrouds, and upholstery.
- Interior panels (including wall, ceiling, partition, windscreen, HVAC ducting, window, light diffuser, and modesty panel).
- Flooring (structural and covering).
- Insulation (thermal, electrical, and acoustic).
- Miscellaneous (elastomers, exterior shell, and component box covers)

The testing of prospective materials to U.S. standards will involve a relatively small cost. While the extent and applicability of standards may depend somewhat on the operational classification "transit" (to which the standard applies) or "commuter rail" (to which the standard does not generally apply), new equipment will be likely outfitted to the highest standards. Car builders may be able to select substitute materials that meet U.S. requirements, since properly tested materials and documented reports are readily available. A major task for the car builder will be to identify the materials, find U.S.-based suppliers that have tested these materials, and change design specifications. This arrangement will not likely present a major impediment. It is reasonable to assume that standards for fuel storage, leakage, and collision protection will be required in new vehicles and will also need structural and engineering accommodations.

4.3.4 Fuel Emissions

Cars in operation (Appendix G) have been built to European emission standards that are more stringent than those in the U.S. Table 4-3 compares the Euro II emissions standard with the U.S. EPA standard for highway and off-road vehicles. Since DMU vehicles satisfy the Euro standard, their emissions values do not appear to present a problem for operation in the U.S.

Table 4-2
Emissions Standards of European and U.S. Vehicles

		Euro II Std	EPA High-way	EPA Off-road
Oxides of Nitrogen (NOx)	g/kW-hr	7.00	6.70	9.25
Carbon Monoxide (CO)	g/kW-hr	4.00	20.77	11.40
Hydrocarbons (HC)	g/kW-hr	1.10	1.74	1.34
Particulate Matter (PM)	g/kW-hr	0.15	0.13	0.54

4.3.5 Contrast Between Railroad and Rail Transit Vehicles

AAR recommendations are intended to provide compatibility and interchangeability for rail equipment in interchange service. They are recommendations only and are not binding. While LRVs are not operated in interchange service, some areas of compatibility will be required, especially if the cars are operating on tracks that are part of the general railroad system.

Couplers and Air Brakes

The issue of coupler and brake compatibility is not one of bringing routine rail freight and rail transit into combined consists. Emergency or failure-induced movement of equipment and position of couplers, buffers, and anti-climbers is the concern. In case of failure of a DMU on a railroad with mixed traffic, the freight railroad may have to push or tow the DMU to clear the track. Existing European designs do not match AAR standards for couplers. Also, for the freight railroad to tow the DMU, the freight locomotive must connect with the DMU's air brake system (if so equipped) and recharge it to release the brakes. This arrangement will require compatibility of the air brake systems' operation and brake pipe pressure. This compatibility does not exist in most or all current European designs.

While air brake compatibility may require different brake equipment, this is not a serious impediment to applicability. Air brake details are a contractual issue that can be negotiated in the normal course of car procurement.

Coupler type is also not of serious consequence. However, the coupler height will require structural modifications on some DMUs. This is the equivalent of mandated uniform bumper heights for highway vehicles. Structural modifications can eliminate the advantage of using an "off-the-shelf" design, unless a car builder has an existing design already adapted to the U.S. market. Compromise couplers and tow bars can be employed to rescue a failed vehicle if non-standard couplers are used. If vehicle consists are used with more than one non-articulated car not with a permanent or semi-permanent draw bar in married sets, then couplers must be designed for passenger service (typically "H" tightlock) or commercial electropneumatic coupler. Modern DMUs or EMUs are also equipped with semipermanent drawbars and can be configured in rakes or as married pairs or triplets.

Communications and Train Control

Operation on a railroad with mixed traffic will require certain communications and train control compatibility. Automatic Train Stop/cab signal equipment (if desired) and radio communication equipment will have to be compatible with that of the primary operation (freight or passenger). These are typical issues to be dealt with in the normal course of a rolling stock procurement. Complementary equipment to receive and decode the signal, and thereby control the vehicle, will be mounted on the car. The active or passive role of the vehicle operator can be determined by the operating authority. Some of this equipment can be transferred between rolling stock types.

The vehicle power conditioning, propulsion, and control system needs to be compatible with the existing signal and communications system serving the route. If a new signal and communications system is planned for a route, then its design must insure that existing or prospective vehicles produce no detrimental EMI/EMC impacts.

Where DMU technology is planned, only limited impacts on an existing signal system are likely. If an electrified operation is contemplated using EMU vehicles, then a new signal system is essential since it is normally incompatible with an older, non-electric technology. EMI/EMC is a consideration with electric traction systems. However, this poses no difficulties or insurmountable obstacles, since it is a mature technology with numerous domestic applications. The phenomena are well understood and appropriate technical accommodations are incorporated. High voltage AC or DC propulsion have unique issues which require appropriate treatment.

Shunting track circuits can be unreliable for lightweight equipment. This has to do with the surface condition of the rail and wheels. High rail use and friction braking (as opposed to disc brakes) improve this situation by scrubbing the wheel tread. Multiple-unit trains rather than single cars help, as well. Some adjustments in the signal system are also possible. Cars can be equipped with features to improve their ability to shunt the track circuits. If new communications-based technology is applied, then this concern is averted. Track circuits would then be necessary only to check rail integrity.

New DMUs or EMUs will be equipped with standard train radios suitable for use with the radio system which controls the line. If communications-based signal technology is anticipated, then appropriate features may be incorporated. Nevertheless, standard FRA-compliant radio equipment is essential for a joint operation.

Safety Appliances, Marking Devices, and Glazing

The incorporation of FRA-compliant safety appliances, marking devices, and glazing may require minor modifications to a car builder's design, since most are produced for a non-domestic market. These features are necessary for safety and operational standardization and to insure labor familiarity, and normally do not require significant cost or structural accommodations.

4.3.6 Americans with Disabilities Act (ADA)

Providing accessibility and compliance with the Americans with Disabilities Act (ADA) involves floor height for access and egress (with respect to relationship and gap between car floor and station platform surface), door and passageway widths, and restroom design.

Floor Height

Most of the Category 1 and some Category 2 DMUs and LRVs available and proposed are high-floor designs. Access and egress must be accomplished by high-level station platforms or a motorized lift device, since use of stairs is not ADA-compliant. Another issue that becomes apparent when dealing with station platforms is the difference of several inches in floor heights between current overseas DMUs and standard North American commuter railroad practice. Without correction, this situation would precipitate a platform-height mismatch for combined operation with light rail vehicles or commuter rail equipment. Also, some of the overseas DMUs are narrower than the typical U.S. passenger railroad vehicle width.

Therefore, a high platform mating with foreign DMU would not clear freight or passenger railroad trains. Use of lifts could achieve ADA compliance with a high-floor DMU serving a low-platform station. Operational drawbacks could occur, though, such as maintenance requirements, potential delays, and scheduling service.

If a low-floor-design DMU is used, bridge plates and mini-high platforms are typical solutions. Such devices would minimize the likelihood of having problems if track were shared with a freight railroad. Low-floor configurations may be more attractive to community groups and the public, since stations are less obtrusive, but these too can intrude into freight clearance envelopes.

Low-floor vehicles require different placement of car-mounted systems components. Typically more equipment is mounted in the roof, which impacts the shop/servicing facility. Often different wheel/axle/drive systems are used that result in maintenance and inventory complications. Final drive mechanisms influence the adaptability of low-floor designs. Low-floor car technology is evolving and some of these concerns will be addressed. However, high-floor cars offer the best variety of equipment and performance for joint operation applications at this time.

Door and Passageway Widths

Noncompliant DMU entrance doorways must be widened to provide ADA clearance. This condition includes sufficient width to allow the wheelchair lift arm to pass through and have adequate remaining clearance for ADA passage. On vehicle types with vestibules, the vestibules will most likely have to be widened to meet the ADA 40-inch requirement and allow for maneuvering of the wheelchair. Both doorway widening and vestibule widening would require loss of passenger-carrying space. Such design changes substantially affect the car structure and, as mentioned previously, this situation can have a major effect on DMU delivery.

Door placement is also critical for car shell structural design. In the case of low floor cars, placing the door between the bolsters will create a "notch" in the side sill, and heavier or additional structure will be required. Low floor vehicle design is strongly affected by door position because doors must be positioned fore or aft of the trucks. High floor cars mating with high platforms can have doors positioned irrespective of truck location.

The interior car layout must also satisfy current and proposed emergency requirements. Such requirements include windows that can operate as emergency exits, roof escape hatches, a defined number of emergency exits, easily operable doors and hatches for passenger use, and recommended emergency equipment.

Restroom Designs

Restrooms provided in some DMUs are not currently ADA-accessible, and would require redesign, while others already comply. Depending on the type of service expected of the DMU, the restroom could be eliminated entirely.

4.3.7 DMU Vehicle Preliminary Compliance

For the purpose of considering compliance, DMU vehicles are split into two categories: a) those that were designed and built for operation in mainly European countries (predominantly Category 2), and b) those that are still "on the drawing board" and are being designed for use in North America (Category 1). There are four models of DMU vehicles designed for or adaptable to North American operation: the Siemens VT 628; the Nippon Sharyo DMU; the Bombardier North American DMU; and the ADtranz IC3 Flexliner. Each of these vehicles will have a high degree of compliance with North American railroad requirements, as would be expected. However, it should be noted that because these DMU designs, as North American adaptations, are still at the concept or prototype stage, their ability to comply with FRA and other requirements such as ADA has yet to be demonstrated. In addition, should the proposed FRA carbody structural requirements be accepted, there will be a completely new set of requirements that the concept or prototype DMU vehicles must meet. For example, to satisfy FRA carbody structural strength requirements, major changes to existing DMU carbody designs will be needed. Cost and lead time associated with re-design, manufacture, and testing of a new carbody have yet to be quantified. This, along with a limited market, may be a deterrent to a more speedy maturing of these designs.

Remaining DMUs included in the range are in operation or have a prototype being tested. These vehicles have been designed and built to European requirements and effectively demonstrate differences between European standards and those of North America. Due to these differences, the degree of North American regulation compliance achieved by the European DMUs is marginal to low. Therefore, no service-proven DMU Category 2/LRV derivative vehicles are available that can be operated on North American railroads without a waiver from FRA. The 1996-97 DMU demonstration efforts in the U.S. were carried out with such waivers (see Appendix B).

4.3.8 LRT Vehicle Preliminary Compliance

Joint operation of LRT vehicles co-mingled with freight vehicles on North American railroads, as in the Karlsruhe model, faces significant barriers. LRT vehicles are not considered compatible in a mixed operation concurrently with freight traffic in a manner consistent with current FRA regulations.

Each portion of the proposed joint route must be electrified to facilitate continuous LRV operation. This can limit railroad operational flexibility to extend or modify service routes. Electrification will impact the freight operation and therefore may require concurrence depending upon track ownership, traffic requirements, or safety issues, limiting the railroad's service options and flexibility in any case.

FRA buff strength requirements may require extensive modifications and additional weight for LRVs to comply. New regulations may offer potential options for a different approach. While vehicle compatibility between LRT equipment and freight trains may be difficult to achieve, improved signal technology and separation techniques may mitigate risks and concerns and ultimately gain regulatory concurrence. LRVs typically feature <200,000 lbs. while FRA requirements for trains are 800,000 lbs.

4.4 VEHICLE PHYSICAL CHARACTERISTICS

While the majority of the characteristics exhibited by both types of vehicles are likely to be suitable for North American operation, some physical characteristics may need changing. These are discussed below for both DMU and LRT vehicles. Vehicle physical characteristics and dynamic envelope will need to be compared to clearance plate and critical infrastructure dimensions for the route. Additionally, similar freight equipment data needs to be compared to passenger equipment features to verify that no conflicts arise. This section addresses compatibility of DMU and LRVs with railroad environment and DMUs in light rail environments.

4.4.1 DMU Vehicles

Physical characteristics of DMU vehicles such as car length, width, height, seating capacity, and weight varies substantially. The general configuration designed into any DMU vehicle will normally depend on the requirements of the operator and where the vehicle will be used. For example, horizontal curvature abilities exhibited by vehicles vary widely according to their size and drive train design, and whether the car is articulated or non-articulated. Although articulated DMU cars should have the ability to negotiate tighter curves than long rigid carbodies, DMU vehicles are typically significantly smaller than freight consists used on existing railroads. Articulated LRVs typically have minimum radius limits of about 80'. Short single-unit cars of earlier vintage such as PCCs are capable of negotiating near 40' radii. Therefore, curving capabilities and gauge should not present a problem for designs of DMU cars on railroads.

DMUs on light rail trackage *is* a problem. Curving ability is also a function of truck wheelbase and therefore needs to be checked. "Steerable" trucks such as featured on the GTW 2/6, Futuro and "Lint" models will increase the vehicle's ability to negotiate curves. Vertical curve dimensions need to be compared to vehicle characteristics (also articulated joints) to ensure its ability to negotiate the terrain. Limited modifications to physical plant may be possible if the right-of-way permits it.

If street-running or non-mainline railroad running is required on some sections adjacent to the joint use, vehicles will need to negotiate horizontal curves with a radius less than 270 feet. Should such a tight curve be required, assuming same overall length, the articulated car design will have an advantage. In addition, length, width, and height of vehicles may also be a factor in street running. Train length must be no longer than the length of the associated city block, and width and height must be such that the vehicle can pass under existing bridges, through tunnels, and down narrow streets. Drive train is also a factor in a vehicle's ability to negotiate tight radius curves.

Route Negotiation

Planning for DMU service connections with light rail, commuter rail, and freight lines emphasizes certain design features. Light rail in-street track curvature is typically of 100'-150' radius. Generally, articulated LRVs can traverse 80'-radius curves. Standard railroad DMUs require in excess of 250' as single cars and 300' or more in coupled consists. LRV-derivative DMU cars approach 250' minimum radius. Limitations are partially the result of mechanical linkages between the prime mover and the truck-mounted gear case. Electric motor drive employing motor leads from the body mounted power source can permit a shorter truck wheel base, which improves curving ability. In contrast, universal joints, cardan shafts, and mechanical hydraulic transmissions combine to prevent cars so equipped from negotiating the short radius curves typically found in street trackage.

Another point of potential incompatibility between DMU and in-street light rail track concerns braking. Electric LRVs are typically equipped with regenerative braking, and some have magnetic track brakes. This enables these cars to decelerate rapidly in mixed vehicular and pedestrian traffic. The absence of regenerative braking, retarders, or magnetic brakes in non-electric DMUs reduces their ability to run in mixed traffic.

HVAC Systems

Heating, ventilation, and air conditioning (HVAC) systems installed on existing DMUs are other physical characteristics that may need to be changed to satisfy environmental conditions in parts of North America. Due to high and low extremes in temperature often experienced in many parts of the U.S., it is expected that vehicle air heating and cooling equipment installed on DMU vehicles designed for operation in Western Europe will not be sufficient to keep the interior at a comfortable temperature, as demonstrated recently with European DMUs on North American tour. Some vehicles do not have air cooling equipment fitted, since this feature is not required in some European countries.

Current U.S. requirements typically specify that the vehicle have an interior climate of 75°F at 55% relative humidity in ambient conditions of 88°F dry bulb and 73°F wet bulb with a passenger loading between 150 and 170. To satisfy this requirement, DMU vehicle manufacturers may need to install heating and cooling systems with greater output capacity. This change might be implemented at the expense of available propulsion power, causing somewhat reduced performance on the track.

Design modification to accommodate this requirement is anticipated. Such a modification will be more difficult to achieve in a low floor LRV derivative DMU than in a railroad derivative DMU. An auxiliary power unit (APU) can be installed in a DMU to power HVAC and other auxiliary systems. This requires a separate, smaller M-G set and fuel tank. While occupying more space and requiring additional maintenance, an APU would not degrade vehicle performance and would ensure passenger comfort in the event of prime mover failure. Alternatively, if the auxiliaries are powered off the prime mover, some load shedding features would permit turning off the AC during acceleration, and limit operation during idling. Regeneration can also help, if the car is so equipped. Low floor DMU designs shift equipment traditionally located under the floor to the roof area.

4.4.2 LRT Vehicles

LRT vehicles are generally smaller and lighter than DMU vehicles and have electric transmission, hence, they can negotiate tighter curves and are more suited to street-running. However, due to their size, the number of passengers that can be carried may be diminished, depending upon articulation features. Their performance enables them to nimbly move in mixed pedestrian and vehicular road traffic.

Although LRT vehicles included in the range of this report have proven service histories in North America, physical requirements of light rail service and commuter rail service for joint operation differ significantly. Since LRT vehicles are typically designed for shorter trips, where passengers are unlikely to spend more than 30 minutes on a vehicle, LRT vehicles have a relatively low "comfort factor." Seats are typically closer together, are less comfortable, and air comfort equipment is not adequate for long-haul journeys. Should LRT vehicles be required for longer trips, car equipment that provides an improved level of passenger comfort would have to be specified in terms of seating and HVAC.

4.4.3 Other Car Design Issues

Since joint operation is presumed to run over existing railroad trackage, wheel profiles need to conform to standard AAR profiles. Wheel diameters typically fall between 30 and 34 inches. Standard rail wheels are preferred from a supply and maintenance (wheel truing, wheel presses, etc.) perspective. It is not uncommon for rail agencies to trade wheels and other parts back and forth to relieve temporary materials shortages. The diameter is also a function of the load, drive arrangements, floor height, and other vehicle characteristics. Additionally, the ability to negotiate standard switches, frogs, and special trackwork is desirable.

As far as car materials, stainless steel is lighter weight and more fireproof. Its relative strength makes it very survivable in collisions and allows use of monococque construction for sound structure. No maintenance is needed for the exterior, just a periodic oxalic acid cleaning. Aluminum is cheaper, but not as durable. It needs less special tooling and is most common. Regular steel is the least desirable material, but is also the cheapest.

Based on the need to comply or at least adapt to FRA requirements and provide certain performance and physical characteristics, choice of materials is best left to the manufacturer. Otherwise, everyone specifies their own and there is less chance of standardization. Additionally, most small startup services do not have the staff or expertise to create a rail car specification. They want to take an off-the-shelf item and procure it through the normal process.

4.5 VEHICLE PERFORMANCE CHARACTERISTICS

DMU and LRT vehicle performance differs, with DMUs resembling railroad vehicle performance and LRT vehicles resembling rail rapid transit. For example, DMU performance would be more suitable for suburban commuter rail station spacing, with the LRT more suitable for closer urban, inner suburban, or street corner station spacing. New generation DMU manufacturers claim LRV performance in their products. Key characteristics of this performance include:

- Maximum Speed
- Acceleration and Deceleration
- Weights and Physical Dimensions
- Minimum Negotiable Horizontal Curve Radius and Turnout Rating
- Minimum Vertical Curve (Sag and Apex)
- Range and Fuel Capacity
- Power Output of Primary Power Source and Tractive Effort

4.5.1 DMU Vehicles

As with physical characteristics, performance requirements of the DMU vehicles will depend on the operating environment. Top speeds offered by the range of DMU vehicles described in this paper varies from 65 mph to 100 mph. The speed that each vehicle consist will need to achieve and will be allowed to achieve depends on several factors:

- Required Journey Times
- Distance Between Stations
- Stopping Distances
- Civil Speed Restrictions
- Railroad Crossings at Highways
- Speed of Freight Trains Sharing Track

Given these factors, available DMUs are expected to satisfy each of the relevant comingling performance requirements, without significant changes to propulsion and braking equipment.

Since diesel vehicles will typically be smaller than freight vehicles with which they are sharing the track, acceleration and deceleration will be better, as will braking distances. Acceleration and braking distances will become even more important when the possibility of street running is considered.

The distance that each type of DMU can travel before refueling differs significantly, varying between 700 and 1500 miles. This distance will determine the amount of stops necessary in a journey and also the number of refueling points required along the route.

Because of trade-offs between performance of a vehicle and its economy, the operator will need to consider which criterion is of most importance. For instance, one DMU model has an acceleration of 2.5 mphps (meaning 24 seconds to reach 60 mph), but needs refueling every 750 miles. Another

DMU accelerates slower at 1.08 mphps (meaning 55 seconds to reach 60 mph), but is claimed to run for 1500 miles before needing refueling.

The performance differences described for these two DMUs calculate to an additional 30 seconds of schedule time for each station stop. This performance has to be evaluated in the context of freight operation and traffic on the route. Vehicle performance is a critical factor in the selection of a candidate vehicle for passenger service in a joint operation environment. Improved vehicle performance generally increases track capacity.

Exterior noise levels of DMU vehicles included in the appendix range from approximately 75dB to 85dB. These levels compare favorably with existing railroad vehicles, which typically generate higher noise levels. With improvements to engine mufflers and air intake grilles, exterior noise levels on DMU vehicles should decrease further. Interior noise levels on DMU vehicles tend to be similar to exterior noise levels and as a result may be high for U.S. operation. Improvements in heating and ventilation equipment installed on some vehicles should reduce interior noise to a satisfactory level.

4.5.2 LRT Vehicles

LRT vehicles generally accelerate and brake more quickly than DMU vehicles, are much quieter, and have an infinite running range (assuming continuous electric power). However, top speeds achieved by the typical LRT vehicle are less than 55 mph. This speed level is not thought to be high enough to operate jointly with much higher-speed freight vehicles on mainline tracks. Freight could potentially be slowed by joint operations, although on lightly trafficked freight and short line railroads, this often would not be an issue.

The first 70% low-floor LRV purchased in the U.S. for Portland, Oregon has a top speed of 55 mph. This speed is particularly adaptable to the Portland operational setting, and is not necessarily the top speed that could be achieved. The Portland low-floor LRV has a service acceleration and braking rate of 3.0 mphps.

4.6 OPERATIONAL CONSIDERATIONS

In addition to vehicle design, configuration, and performance, certain vehicle operational issues are important relative to potential joint operation.

4.6.1 Maintainability

Perceptions about DMU maintainability differ significantly among professionals in the rail transit environment and their counterparts in the railroad industry. This situation is largely a result of the almost universal familiarity of North American rail transit agencies with European rail vehicles and their associated maintenance philosophies and a corresponding absence of overseas rail products on North American railroads.

European railroads and rail transit systems generally utilize a maintenance philosophy that combines more frequent replacement of lower-cost components and more specialized maintenance staff than are typical for American railroads. This difference in philosophy, combined with the effect on design of widely divergent operating requirements (i.e., a preponderance of heavy freight trains operating over long distances, compared with mostly lighter European passenger trains operating over shorter distances), has created a perception that European rail equipment designs are overly complex and less robust than American designs. This situation may present difficulties during joint co-mingled operation, since DMU and LRT vehicles would likely need to be maintained according to schedules used for freight vehicles. Currently, FRA specifies certain scheduled railroad maintenance examinations according to the calendar. These requirements may prove difficult, expensive, and inappropriate for rail transit vehicles. Therefore, FRA requirements and local freight maintenance should be fully understood before operating alternative vehicles such as DMUs. Maintenance programs based on accumulated use and periodic intervals recommended by the manufacturer may be more suitable for this equipment/duty cycle.

Maintainability needs to consider frequency of required maintenance. Vehicles are normally taken out of service for scheduled maintenance; therefore, less frequent maintenance is preferable. Reliability needs to be factored into the situation, because no history is available for review. In a small-scale service, loss of equipment due to failure is detrimental. Therefore, data on reliability needs to be incorporated in the procurement contract. The fleet size and equipment availability are related through shop margins. Backup equipment is readily available in the event of "over the road" failures.

4.6.2 Wheel-to-Rail Interface

Two issues related to wheel/rail interface have been associated with modern DMU vehicle designs overseas and with the RDC in the U.S.: slide under braking, and uncertainty of track circuit actuation. These problems have generally been related to use of disc brakes rather than tread brakes. For example, modern DMUs in the United Kingdom (UK) use disc, while 1950s-vintage heritage units are equipped with tread brakes. These problems are being addressed and few major technical problems occur overall with DMU operation in overseas locations such as the UK, largely as a result of the evolution of their designs over many years.

Slide Under Braking

A combination of a lower level of wheel tread conditioning and higher braking rates has caused some problems with slide on modern DMUs in the UK, and there have been a few buffer-stop collisions allegedly resulting from this issue. Although slide control systems are fitted, these are bypassed during emergency brake applications. Consideration is being given to retrofitting one-shot sanding equipment to cope with emergency stops in low adhesion conditions.

Track Circuit Actuation

Modern DMUs in the UK have been affected by this problem, which is associated with low-voltage track circuit operation. Lighter axle loads and improved riding qualities of the new trucks, combined with the absence of tread brakes, has led to increased electrical resistance between wheel and rail due to buildup of contaminants on the tread surface. These are no longer cleared by braking or the wiping action between wheel and rail due to wheelset oscillations. The result has been occasional "disappearance" of trains from the signaling system due to non-operation of track circuits. The solution to this situation has been to install an active device that induces a voltage in the local circuit formed by the axle and the rail, thus overcoming increased resistance and operating the track circuit reliably. Furthermore, some advanced signal/train control technologies do not depend on track circuits, which renders the concern moot. Track circuits may continue to have a role in broken rail detection, but this situation is independent of vehicle operation.

4.6.3 Fueling and Primary Power Sources

Diesel Fuel

Depending on the operating range of a candidate DMU and the duty cycle associated with a specific candidate corridor, significant impacts regarding the type and location of required fueling station facilities could be encountered. DMU or locomotive fueling facilities exist in some corridors, but would need to be added in others. Any proposed operation will probably use or adapt an existing facility for this purpose, particularly if a contract operation is planned. It is not uncommon in the rail and marine industries for fuel to be delivered by tanker trucks as needed, similar to home heating oil deliveries. Fuel facilities are normally subject to a host of environmental controls regarding storage, handling, spills, and safety. Creation of new facilities is an impediment to service startup.

Electric Traction Power

If electric traction vehicles are selected, then "fuel" is distributed via the electrical network and permanent facilities are not necessary. However, a limited number of diesel-powered vehicles will probably be essential to any operation and a means of fueling them would be necessary.

CHAPTER 5: SHARED TRACK BY RAILROADS AND RAIL TRANSIT

This research is structured in recognition of the productive debate surrounding joint use. Chapter 5 identifies major issues in the joint use debate derived from the first four chapters. While the issues will be identified and prioritized in Chapter 5, they are analyzed in Chapters 6 through 8 of this report. This chapter synthesizes the first four chapters and reveals the nature of key issues within four chapter headings: Regulation, Operations, Physical Plant, and Vehicles. Chapter 9 revisits these issues to analyze and draw conclusions from international experience and an assessment of risk and safety. The key issues are specifically addressed by the risk analysis (Chapter 6), though not all key issues can be quantified by that process. Chapter 9, Findings and Conclusions, explores ways to resolve contrasting views and develop consensus positions on key joint use issues. Ultimately, this research is intended to support decision making toward national and local policies on joint use.

All of the four data collection chapters culminate in an issues identification which sets the theme and pace of the remainder of this report and future research. A common understanding of "issues" is desirable:

> ***issue:*** *"a point of question in law or fact: a matter in dispute by two or more parties; a point of debate or controversy; a matter not yet finally settled and on the settlement of which something else depends; something entailing alternatives between which to choose or decide; a point at which an unsettled matter is ready for decision; a final outcome, result, or consequence." (Webster)*

5.1 CONTRASTING INTERESTS

One of the ingredients of issue making is contrasting viewpoint. Perspective and policy may vary when addressing the same issue by two or more interests. Two parties may agree that something is an issue, but disagree on the resolution of the issue. As a start toward issue identification, primary interests and their prime motivations may be summarized as follows:

- **Rail Transit Owners/Operators** (generally public sector) - *Improved, cost effective transit service for the public, including system users.*
- **Freight Railroad Owners/Operators** and their shippers (generally private sector) - *return on private investment through competitive freight service.*
- **Transit Riders** who pay fares and ride trains (individual and collective citizenry) - *affordable, convenient, and safe transportation to fulfill their individual travel needs.*
- **Transportation Regulators** at Federal and state level (public sector) - *safe, competitive transportation to protect the public/users and private providers.*
- **Rail Equipment Builders and Vendors** (generally private sector) - *return on investment by supplying transportation providers with competitive rail passenger and freight apparatus.*

The purpose in listing these motivations is not to debate their content, but to illustrate how equally laudable objectives can conflict in a public policy forum.

5.2 MAJOR ISSUE CATEGORIES

Chapters 1 to 4 have provided a base of research information on joint use. While these chapters provide structure for joint use research, they do not alone constitute issues. They do provide a convenient and organized way of dealing with joint use issues. Again, they are:

- Regulation
- Operating Practices and Standards
- Physical Plant and Infrastructure
- Vehicles

Note that these four categories are used to organize the content of successive chapters. The German Ministry of Railway used these same categories when conducting its risk analysis!

5.3 AN APPROACH TO IDENTIFYING ISSUES

Some of the issues become evident simply from the comments and debate on this research. A more systematic approach is to diagram the potential debate between various interests and the four major issue categories.

The matrix below applies the five institutional interests and their policies to the four issue categories drawn from the preceding four chapters. This array helps to identify the points of specific attention, and of conflict and consensus between interests. It also begins to define joint use as a policy issue.

Table 5-1
Policy Matrix

		Euro II Std	EPA High-way	EPA Off-road
Oxides of Nitrogen (NOx)	g/kW-hr	7.00	6.70	9.25
Carbon Monoxide (CO)	g/kW-hr	4.00	20.77	11.40
Hydrocarbons (HC)	g/kW-hr	1.10	1.74	1.34
Particulate Matter (PM)	g/kW-hr	0.15	0.13	0.54

(**P** = Primary, interest, **S** = Secondary, **M** = Minor or No-interest)

The matrix above begins to identify traditional harmonious or conflicting relationships as they apply to their respective interest in joint use. It is intended to organize and portray contrasting interests toward joint use and the prevailing attitudes that drive these interests.

Not all of the issues identified can be quantified. Some will be of strong policy content leading to analysis by alternative scenarios. Others can be fit within a risk analysis for a rigorous and precise quantification. To the extent that each issue is measurable, it is accompanied by a concise statement suggesting how the issue is to be treated in the risk or policy analysis later in this report. All of the issues will have related ancillary or subordinate issues which are listed below:

5.4 SPECIFIC ISSUES DRAWN FROM THE MATRICES

Each issue, expressed as findings listed below, are classified by the four categories drawn from the first four chapters' analysis. A fifth "comprehensive" category is reserved for those issues which cannot readily be assigned to one but may be the subject of two or more categories. The key findings are expressed as issues along with related ancillary issues. Those having a double asterisk (**) would be most subject to risk analysis. Others would be subjected to a policy or technical analysis and recommendations.

These appear in priority within each of the five categories. It is suggested that Category 1, Regulation, is the most difficult and comprehensive, and is therefore the first priority.

1. Regulation Issues

a. There is at least one central issue that motivates this research and from which all the other issues derive.

The central issue in the joint use debate emerges: **Is joint rail use between DMU rail transit, LRT, and freight railroads a sound policy worth advancing?** Currently, comingled joint use or non-conforming equipment are permitted by regulation only by exception. This research is predicated on the advancement of joint use as a worthy policy to advance, to test with risk analysis, and to consider in light of applicable overseas experience.

Ancillary Issues: **Balancing public safety and public convenience: Can risk, cost, and amenity for the public be compared and balanced to provide both?**[**]

Measurables/Policy: ***Capital cost savings from joint use vs. joint use risk and related costs.***

b. The rail transit or freight railroad operator, being subject to regulation, regards regulation as a constraint on the free exercise of management options. Regulation is also regarded as a protective device in cases of market competition. Depending on who is the tenant and who is the landlord for the railway proposed for joint use, the attitude toward regulation may be positive (protective) or negative (constraining). The issue emerging from this controversy is: **What (if any) are the options or mitigations that can be applied to regulations which prevent or impede joint use?**[**]

Measurables/policy: ***Risk quantification vs. list of most effective mitigations which quantifiably reduce risk.***

Ancillary Issue: **Is overseas experience in reconciling or overcoming regulatory barriers to joint use transferrable to the North American experience and if so how?**

Can one or a combination of risk mitigations be applied on a case-by-case basis, to enhance joint use options without overhauling the regulatory structure or outrunning technical analysis now underway?[**]

Measurables/policy: ***Overseas Joint use accident experience compared to U.S. transit joint use risk experience.***

c. Regulation *for the transit rider* is linked to personal safety in the delivery of service. The interests and perspectives of the transit rider in addition to transit and railroad operators and regulators were considered in conducting this research. The issue that emerges from the expression of diverse interests on this regulation is: **Does joint rail operation inherently jeopardize personal and public safety for rail passengers, train crews, and the public in proximity to the rail line?**

Ancillary issue: **Do the advantages of expanded transit service enabled by joint use outweigh any loss of personal safety to the transit rider?**[**]

Measurables/policy: ***Risk experience before and after joint use implementation on a specific route (U.S. experience is meager, but overseas experience may be instructive).***

d. Safety regulation is also an issue for transit operators, freight railroads, and apparatus vendors because it helps determine risk and fix liability. Though related to operations and vehicles, a major issue for this research is:

What are the quantifiable risks and liabilities from various degrees of joint use (ranging between integrated operation, temporal/ operating windows and complete physical separation)?** Safety risk and liability issues are proposed for treatment in a detailed risk analysis performed in Chapter 6.

Measurables/policy: ***Priority ordered list of preferred risk mitigations and their specific values in a guide for assignment to a specific rail route based on local conditions.***

e. With the recent Federal requirements that states oversee rail transit operations in their domain, and in recognition that transit has in the past been regulated by state and local governments (rights of public convenience and necessity), and recognizing that rail transit is traditionally metropolitan or regional, **Can regulation of rail transit by state and regional entities realize a level of safety comparable to that of the Federally-regulated railroad system?**** The market entry issue, a traditional role of Federal and state transport regulators, is, in this situation, moot.

Measurables/policy: ***Transit risk experience (local/state regulated) vs. railroad risk experience (Federally regulated).***

2. Operations Issues

a. Recognizing that very different regulatory and operating circumstances exist in North America, **What elements of Japanese reciprocal running and European joint use operating practices can be transferred to the North American railroad and rail transit environment?****

Measurables/policy: ***List of overseas specific operating practices as risk mitigation techniques (for potential application).***

b. **Should other issues of survivability and social amenity be blended into the joint use analysis?** These include fire protection, evacuation, ADA (a policy issue - note "c" below) to the extent that they're affected by the operating environment being considered in this study.

c. Local traffic controls have a bearing on LRVs and DMUs operating in traffic and pedestrian environments. **To what extent can local traffic controls, rights-of-way fencing, and grade crossing protection be used to mitigate joint use operating risk and liability?**** (While measurable, this issue is characteristic of most light rail, DMU, and railroad operations individually and *is not unique to joint use*).

3. Physical Plant Issues and Train Control Issues

a. **Which fail-safe signaling and control systems currently under development or employed in collision avoidance, can cost effectively be applied to joint railroad/transit use in North America?****

Ancillary Issue: **To what extent can fail-safe train control such as PTS/PTC described earlier mitigate risk and liability in joint use service?**

Measurables/policy: ***While it is a popular notion that PTS/PTC can reduce risk, there is an insufficient body of evidence at this time to support the claim. This is a potentially measurable issue.***

b. The House Transportation and Infrastructure Committee Advisory Group has suggested that separating ownership of right-of-way and infrastructure from operations and rolling stock may be a more cost-effective way of providing passenger services, while introducing the private sector initiative into "the business." How this will affect regulation and operation is unknown, but it introduces an issue into the joint use debate: **How would separation of infrastructure from operations (and perhaps rolling stock) affect the feasibility of joint use?****

Measurables/policy: ***Overseas, where these railroad entities have been separated as cost and management centers, more time is required to test and measure separation as a risk mitigation factor. These operations have been in effect for a short duration or are still in transition as of this writing.***

c. The cost of new build alternatives to joint use are also considered in the advancement of rail transit service expansion. New rights-of-way, subways, and elevated alignments are costly alternatives to joint use.

4. Vehicle Issues

a. **What vehicle design innovations being developed in Asia and Europe can be applied in North America?**

Ancillary Issue: **Which of the crashworthiness measures (crumple zones, operator refuges, interior surfaces, and fixation) can be applied to DMUs and LRVs as mitigations to increase safety and permit joint use?****

Measurables/policy: ***List of rail car crashworthiness measure arrayed as to level of effectiveness.***

5. Comprehensive Issues

a. **Crashworthiness vs Crash Avoidance was identified early in this research as a comprehensive issue.**** The Europeans (and to some extent, the Japanese) emphasize crash avoidance as preferable to crashworthiness. In North American regulatory culture, crashworthiness has a prominent place. These contrasting policies are not absolute, since research is advancing on three continents in each of the two precautionary measures. This is a complex issue that will be treated in risk analysis.

Ancillary issue: **Can balance be achieved between car performance and car structural design/weight, similar to that accomplished in automotive design, that attempts to combine both objectives of weight reduction and agile performance?**

b. **What are the cultural, institutional, and social conditions which harbor joint use in some locations and not in others.** (This policy issue should include Pacific Rim Canadian and European experience).

Having concluded the information collection and issue identification portions of this research (Chapters 1-5), attention turns to joint use potential remedies and mitigations relating to the issues identified in Chapter 5 and appears in a format easily converted to a freestanding Risk Assessment Guide. Chapters 7 and 8 provide overviews and specific examples of successful joint use of tracks between railroads and rail transit operators in the context of the key issues.

Chapter 7 also explains how the German Federal government used risk assessment and institutional reform to achieve the advantages of joint use. Finally, Chapter 9 synthesizes the scope of joint use research, summarizes findings, and provides conclusions on the future of joint use in North America and the means to consider in achieving it.