CHAPTER 3: PHYSICAL PLANT ISSUES ASSOCIATED WITH JOINT OPERATIONS

3.1 OVERVIEW

Physical plant is the game board on which the LRT/DMU joint operations with railroad issue is played out. The Baltimore and San Diego joint use precedents dedicated fully converted freight lines to LRT with the transit operator as host. The freight carrier could also conceivably remain as a host and the transit operator become the tenant, as in some European experience. The fundamental assumption underlying this facility conversion is that this rail transit passenger service would be applied to a line previously dedicated exclusively to freight movement. While this provides an adequate clearance and track geometry standard, the facilities will undoubtedly be substandard for LRT in other ways. Infrastructure that is adequate for exclusive freight service will require adaptations to station configurations, signaling and train control, grade crossing protection, track configuration, and possible effects of electrification. Maintenance-of-Way (MOW) of this infrastructure will reflect operational needs of a proposed joint operational facility.

Influence of right-of-way and infrastructure characteristics for joint operation with respect to risk factors and mitigation are also considerations in joint proposals. Risk is not always quantified by actuarial methods, but rather can be perceived to jeopardize freight operation or burden it with liability costs. This perception has resulted in numerous objections and negative responses to joint operations proposals throughout the U.S., whether the proposed mode sharing track with freight is high-speed rail, intercity, commuter, or light rail transit.

There are costs associated with modification of an existing freight-oriented physical plant to enable a mixed mode use. Each party in a joint use arrangement should be aware of the financial impact of capital and operating cost increments and agree in advance on the allocation of cost for such a planned operation.

3.2 DESCRIPTION OF THE PHYSICAL PLANT

The physical plant for a typical railroad or transit system consists of tracks, interlockings, crossovers, turnouts, signals, structures, and buildings placed within a right-of-way. In scale and purpose, North American railroads with few exceptions have evolved into efficient freight carriers. As streetcar derivatives, however, light rail systems are typically electrified operations, supported by an electric traction system that includes wires, poles, and substations added to the physical plant. "Light Railway" is a term traditionally used in the railroad industry and derived from English law relating to railways under local domain (as opposed to those controlled by the crown) to describe a light duty and usually, but not always, lightweight rail carrier; primarily, but not exclusively, a passenger operation (note glossary for full definition).

The light DMU concept does not require an electric traction power system, although this can be an option for diesel/electric hybrid (Category 3) cars. For joint use candidates, a commonality of track gauge is assumed. DMUs can be readily adaptable to existing railroad infrastructure of a minimum track class 3 (40 mph for freight and 60 mph for passenger). But compatibility and reciprocal running on a common infrastructure requires even more flexibility.

Table 3-1
Track Classes Applicable to Joint Use (LRT/DMU)

FRA Track Class	Freight	Passenger
1	10 mph	15 mph
2	25 mph	30 mph
3	40 mph	60 mph
4	60 mph	80 mph

Physical plant also requires a comprehensive maintenance program to ensure its safety and reliability. This effort depends upon skilled labor using specialized, complex equipment on a regular basis. It also requires setting a standard based on the mix of traffic expected to use the track. Maintenance is a costly and labor-intensive component of the railroad infrastructure. Often, it has to be performed at night or during service lulls to minimize conflict with revenue services. The prospect of joint operations increases the urgency and complexity for a conscientious maintenance program.

For a light density freight line to be characterized by deferred maintenance or excepted track is not unusual. Infrequent traffic and low number of movements encourage the rail plant owner to minimize expenditures on maintenance. Upgrading this plant for rail transit passenger traffic will require considerable investment. For example, any route considered for joint operations needs a thorough inspection to determine safety improvement requirements, needed increments for a "state of good repair," and FRA standards compliance.

3.2.1 The Freight Environment

Operation of non-compliant and lighter-weight vehicles on a light density or other level of freight-handling corridor produces a number of conflicting objectives and gives rise to significant safety, operational, and maintenance issues. Nevertheless, these concerns are neither new nor insurmountable. Track maintenance equipment, hi-rail vehicles, flangers, spreaders, and cranes of standard railroad type are transferred to LRT operations, often by highway carrier. While not routine, the special movement of non-revenue equipment is usually operated when the LRT is shutdown. Employees, in conjunction with operating rules, are capable of maintaining a safe operation regardless of what type of equipment is occupying the track.

Joint operation requires modification in work rules and practices, including aspects of scheduled maintenance and standards used to monitor the "state" of the physical plant. It is essential that employees be retrained and hazards recognized to enable infrastructure, equipment, rolling stock, and related procedures to be more "friendly" to a non-compliant light rail transit passenger operation in a freight environment. This training can be enhanced by the addition or improvement of technology to control or maintain the railroad plant.

Inherent conflicts are prevalent between operations of light rail transit or other passenger service and freight service. Typically, infrastructure to support a freight-only operation will differ from that which supports an exclusive passenger or mixed service. Contrasting service characteristics (described below) affect this infrastructure differently.

These differences translate into infrastructure compromise and physical plant modifications needed to facilitate joint operations, including:

- Grade crossings
- Right-of-way, roadbed, and track
- Structures, bridges, and stations

- Yards and shops (DMU or LRT maintenance facilities) and system buildings
- Work equipment and MOW services and facilities used in plant maintenance
- Command and control systems
- Electric traction facilities
- Track geometry (e.g., superelevation and speeds on curves)

3.2.2 FRA Perspective

In considering those physical plant features essential to supporting joint operations, FRA considers three conditions as most influential to joint use success:

- Insularity - Physical, temporal, or other controlled means of separating different types of rail traffic.

- Grade crossing minimization - Avoidance of grade crossings and potential collisions with highway vehicles and pedestrians.

- Adequate signal and traffic control - Train movements controlled and protected from catastrophic failures and first contingency failures.

3.2.3 Determination of Physical Plant Requirements

Beyond some basic configurations, layout and resources within a railroad/transit physical plant depend on the specific operations to be supported. Relatively simple operating plans typically require comparably simple physical plants. Mixed train operations or a shared schedule can become rather complex, and therefore require a more extensive and varied physical plant. In this regard, the following questions about the physical plant can be influential in determining its eventual configuration. These questions are intended to reflect a proposed joint service on a new system and as applied to an existing system where joint operation is newly introduced.

- What is the mix of freight and light rail transit or other passenger trains using the system?

- What are contrasting performance characteristics of the trains comprising this mix?

- How many stations are proposed and where will station stops be located?

- Will station stopping patterns be relatively simple or complex?

- How will high or low platforms affect dwell time and required dimensional clearances?

- What are maximum and differential operating speeds?

- How many highway grade crossings exist, or is grade separation proposed?

- What is the desired frequency of service and probable scheduling? (existing and proposed)

- What is the width of right-of-way and the number of tracks that can fit within it?

- Are any new structures required?

- Is future expansion, e.g., added branch lines or more frequent service anticipated?

- Where will yards, shops, and service facilities be located? Where, if any, are they now?

- Will the line be electrified, now or in the future?

Table 3-2
Contrasting Rail Freight and Passenger
Service Characteristics

Freight	Passenger (Rail Transit)
Longer and varied train lengths	Shorter, standard length trains
Varying speeds and stopping patterns	Station dwell times at fixed locations
Heavier car loadings	Light axle loads
No platforms on main tracks	High/low-level platform encroachments
Larger clearance envelopes	Smaller clearance envelopes except for wire
Rationalized diminished infrastructure	Additional track/interlockings
Slower speeds, unscheduled stops	Higher speeds, scheduled stops
Mixed fleets, equipment size, and performance	Standardized fleets and trainsets
Control of right-of-way and operations (roles can be reversed)	Often the tenant with limited control provided by contract
"Drill" operations, varied schedule	Precisely scheduled operation
Day-to-day operational risk minimized	Public risk/public exposure minimized
Cost-driven maintenance	Safety and schedule-driven maintenance
Freight customer priority	Passenger priority
Efficient use of equipment and plant resources and employees	Peaking demand for equipment and plant resources and employees
Return on investment	Maximize ridership
Signal and communications systems with limited capability or lacking entirely	More sophisticated signal and communications systems
Infrequent, random, and extended grade crossing occupancy	Shorter, but more frequent, scheduled grade crossing occupancy
Lower speed allows compromised track geometry	Higher speed requires precise track geometry

- What type of signal system exists (if any) and is planned for the line?

- For single or double track, what are the locations of passing sidings (related to headways and car performance)?

3.2.4 Physical Plant Maintenance Issues

Operators understand that every mile of track, signal system, and physical installation generates maintenance requirements, and accompanying fixed operating costs including tax liability. This condition has caused freight railroads to rationalize their plants, to keep operating costs down and to increase use of existing capacity. Joint operation runs counter to this trend, because it increases demand for available capacity and requires additional features such as crossovers and sidings to permit light rail transit or other passenger traffic to run around freight traffic and vice versa. Storage sidings may also be required to place maintenance equipment so that operational tracks are not blocked.

An important maintenance concern is responsiveness to incidents on the right-of-way. The sense of urgency of the freight operator to such conditions may not be adequate for a time-critical joint operating passenger service tuned to the next peak period. Response priorities will need to be established, therefore, prior to such incident occurrence. Where weather could pose operational constraints, switch heaters and snow removal equipment need to be provided for passenger service. Flood detection, falling debris, and dragging equipment warning systems are often used on freight lines, and these devices are likely to become essential to reduce risk in a passenger operation.

Engineering and maintenance issues can also arise in joint operations. Axle loads of loaded freight trains are considerably higher than those of a typical DMU or LRV, but these vehicles will usually be operated at higher speeds and duty cycles than freight trains. Track maintenance standards, rail weight, and track appliances and superelevation differ for each operating mode. The special demands imposed by joint issues relate to allocation of maintenance costs between respective users.

Other engineering issues with capital and maintenance cost implications that need to be resolved are choice of rail weight or use of wood ties versus concrete, although this issue is only of interest on a new route. Issues pertaining to the type of signal system are also important. Light rail transit systems are moving toward "automatic train control" (ATC) systems that include car-borne interface with vehicle operators, whereas freight remains a manually controlled system. The safety issue of operating a "non-equipped" freight locomotive over an ATC system presents technical challenges for future mixed operations.

3.3 ELEMENTS OF THE PHYSICAL PLANT

The physical plant elements pertaining to joint use are presented below. Each are considered as to their characteristics, design, vulnerability to risk, and remedies to mitigate joint use.

3.3.1 Grade Crossings

Primary risk and operational impact for railroad owners, transit system management, train employees, and the public are confronted at grade crossings, both public and private. The latter usually is a signed crossing onto private property (e.g., farms, industries, and large land holdings) and has only a limited number of crossing instances, usually by persons familiar with the frequency of train traffic. These are typically protected only by signs. Public crossings are readily accessible and are signed and protected by automatic gates and/or warning lights of various types. Overseas, such crossings are sometimes manned, though most manned crossings are being replaced.

Increased rail traffic accompanying the introduction of new light rail transit passenger service in joint operations will increase conflicts between train and highway traffic and will result in more "down time" for crossing gates, thereby further delaying vehicular traffic. Passenger train traffic and vehicular traffic will experience simultaneous peak demand, increasing the potential for conflict. Coordination with local highway and police authorities and awareness of these conflicts is an important part of the joint operations planning process prior to initiation of joint services.

Crossing protection should be reassessed when major service changes are contemplated. On light density lines, grade crossing protection is limited to signage, without automatic gate closures signaling the presence of a train. On more heavily traveled routes, some form of automatic gates and lights are usually in place. Additional levels of sophistication can be implemented as the extent of vehicular and rail traffic and potential conflicts justify such improvements. Grade separation is the ideal solution, but is often too costly and physically difficult to accomplish without impacting immediate surroundings. Therefore, other current techniques such as four-quadrant gates, constant warning times, and signal system warning technologies should be explored. While these are costly, they should be selectively applied where accident experience dictates their use. Additionally, local police and highway authorities can work with transit police to improve enforcement and coordination with traffic signals and highway grade crossing configuration. These precautions should accompany any new light rail service regardless of whether or not joint use is practiced.

When a heavy locomotive-drawn train collides with a highway vehicle, the results are devastating. Rail equipment is not immune to severe damage or derailment. If the collision involves a passenger train, a head-end positioned locomotive offers protection to trailing passenger cars through its weight/mass and energy-absorbing capability. If push/pull cab cars lead or new lightweight DMUs are used as single or paired units, a collision with a heavy truck will produce major injuries and possible fatalities to the DMU occupants. Accident records disclose that many crossing accidents are caused by the highway user, a fact that needs to be understood by local authorities.

Vulnerability to grade crossing incidents partly explains the requirement for improved crashworthiness under proposed new FRA standards. This concern is compounded by the unpredictable nature of automobile driver behavior. Protection for the train and automobiles is fundamentally dependent on responsible human action. Gates do not ensure safety nor do they offer redundancy in the event of human failure or disregard. Other techniques in use or under development that could potentially be applied include:

- **Four-quadrant gates**: placement of dropping gates in both directions on both sides of the crossing, eliminating the chance for a driver to "run around" the gates. This technique is used in some European countries. The potential to trap a car on the rail crossing between dropped gates is an undesirable feature, though regarded by some as an oversold risk. Crossing occupancy detectors are being developed, particularly in high speed applications. Gates can be driven through by trapped vehicles.

Small pedestrian gates are also employed on the outer surface of the crossing. These are interlocked with the vehicular gates.

- **Arresting barriers**: an experimental technology under development. In Illinois, a number of programs to advance these systems which involve installing aircraft-carrier style cables or movable barriers that operate in conjunction with the warning protection system. These devices prevent entry of a vehicle onto the crossing. These devices are likely to be expensive and complex, and therefore, reserved for locations with special conditions or high incident rates.

- **Obstruction detection**: a special sensing system that provides an indication to the approaching train crew that an obstacle is in the trackway. The sensor interlocks to the railroad signal system and will command the train to stop or slow. This type device is under development with some applications in use in Europe, where high speed trains are deployed. The risk for long freight trains is potential derailment from involuntarily and automatically going into emergency braking.

- **Reduced operating speeds/visible and audible warnings**: primarily human technique that depends on the engineer to slow down near grade crossings and sound the train horn or bells. Implementing this technique impacts schedule performance and often local communities enact noise restrictions to preclude sounding warning horns or bells. Ditch lights, strobes and other rail vehicle mounted devices are common. High visibility point schemes using safety stripes or contrasting colors have also proven effective. Electrified rail transit vehicles with regenerative and track brake systems reduce stopping distances.

- **Constant time warning systems**: current application of standard rail signal system technology to provide a constant warning time to highway traffic when a train is approaching prior to the gates dropping. This arrangement improves driver behavior since their waiting time is standardized regardless of train speed. It includes time delay track circuits to account for differences in freight and passenger train track occupancy duration. Such systems can be costly.

- **Traffic signal preemption**: technique used to control traffic flow into and out of the crossing area to prevent queuing or entrapment in the trackway while a vehicle is waiting for a light to change. This preemption is essential when a traffic signal and rail crossing are proximate. (Reference ITS market service packages APTS1, APTS7, AVSS5, AVSS10).

- **Vehicular crossing closure**: method to provide complete safety for both the railroad and highway user, but can be unpopular with the local population or emergency vehicle manager. It should be explored when multiple grade crossings in close proximity are in place, particularly if alternative traffic management options can be applied.

- **Grade separation**: like closure this remedy is effective, but expensive and difficult to implement, depending on community sentiment, local terrain, adjacent land uses, and funding.

- **<u>Automatic crossing gates/flashing lights and audible warning systems</u>**: standard crossing warning systems added to unsigned crossings when light rail transit or other passenger rail service is introduced.

- **<u>Civil speed limits</u>**: enacted by local authorities to control train speed through a municipality. This restriction can have a negative effect on operational flexibility and service speed.

- **<u>Local education and public information programs</u>**: informs local authorities and driving public about the nature of crossing hazards and encourages improved driver behavior at crossing sites. "Operation Life Saver" is a good example.

- **<u>Photo Enforcement</u>**: CCTV deployed to detect and apprehend motorists who violate the downed gates at grade crossings employed on LACMTA Blue Line. Enforcement measures and results should be widely publicized to heighten motorist awareness.

- **<u>Median Barriers</u>**: to prevent motorist at grade crossings from swerving into opposing lanes of traffic, thereby bypassing staggered crossing gates. Passive barriers ranging from curbing, raised median cones, or paint stripes are commonly applied to LRT systems.

- Combination of foregoing techniques.

Selection of methods for grade crossing protection is a function of road traffic volume and mix (car, truck, bus), rail movements, speeds, highway configuration, traffic signaling, proximity of rail stations, sidings, and presence of sensitive uses, such as schools or hospitals. Many commuter railroads use these techniques to operate across numerous grade crossings on a daily basis. However, FRA-compliant equipment is in use in these instances in a purely "railroad" (non-transit) environment. More to the point, a number of light rail systems [e.g., San Diego and Los Angeles (Blue Line) in California] also operate regularly with these grade crossings at normal speeds using these same methods. Nevertheless, grade crossings merit the addition of features to minimize hazards, and the Los Angeles LRT has provided some useful learning experience in this regard. Increased attention from local authorities and community leaders is aroused more by accidents or fatalities than by changes in rail traffic or protection systems. More discussions regarding rail/roadway interface appear in the Transit Cooperative Research Project Report 17 of 1996 dealing with developing light rail transit in urban areas, as well as in Chapter 1. Grade crossing protection is *not*exclusively a joint use issue.

The Federal Highway Administration funds selected grade crossing protection improvements through state highway departments. This program should be investigated whenever joint operations or increased traffic on rail lines is proposed, to supplement whatever funds are available from federal and local transit sources.

3.3.2 Right-of-Way, Roadbed, and Track

Route

Track capacity is dependent on the number of tracks, placement of sidings, frequency and design of station stops, interlockings, equipment performance and design, and the in-place signal system. Track access is also a concern on light density freight lines since these lines are often used to set out or pick up cars in slow moving freight operations (referred to as "drill"). Freight operators and shippers will require satisfactory access to sidings and industrial leads. This adds to the maintenance obligation, while imposing a time burden on mainline use by scheduled trains. Some of this problem can be corrected by costly addition of passing sidings or remote control of switches and signal systems.

Further, light density lines are often sufficient for freight as single-track, but the speed and flexibility needs of passenger equipment and service are not fulfilled. Addition of passing sidings or time separation of traffic may be considered common remedies. Restoring track to gain capacity on a formerly multiple track right-of-way is an option, but may limit maintenance options since vacant track bed is a favored method for track crews to access otherwise inaccessible work sites. If two tracks are available, interlockings with reverse signaling placed strategically can provide the ability to "run around" slower moving trains. Drill operations may need to be confined to periods when passenger trains are not operating. Limited track capacity also restricts the opportunity to perform track and structure maintenance. Two factors generating increased demand on capacity include longer, slower moving freight trains that use a portion of the time window more than faster, more frequent passenger service, and maintenance activities that demand their own time window. Passenger service increases this need for track maintenance (thus increasing the time and space demands placed on a formerly low-use freight branch). Ensuring that the aggregate demand can be met necessitates either major additions to the physical plant or careful operations planning, or both.

North Carolina's Raleigh-Durham project is instructive for potential application of joint use - selectively. This project subdivides the alignment into segments for separate asset merits consistent with traffic demands and physical constraints. Applying this technique to joint use would indicate operation in which shared track might only be used over short segments of the route. Parallel tracks would be constructed where conditions dictate. Karlsruhe, Germany uses this technique in its joint use.

Track Structure

The foregoing discussion on track structure assumes standard gauge commonality between joint use participants. Historical and overseas precedents for dual gauge exist as explained in Chapters 1, 7, and 8. Different gauges in North America is a rare obstacle for contemporary joint use.

A rail route consists of a roadbed and track built to specific geometry and structure standards and maintained to FRA-specified functional tolerances. These standards and their tolerances are driven by line speed requirements and function. This produces a conflicting requirement, because a low-density freight line can be operated and maintained safely at Class I (maximum freight speed 10 mph) or II (maximum freight speed 25 mph), whereas Class III (maximum passenger speed 60 mph) or Class IV (maximum passenger speed 80 mph - noted in Table 3-1) is required for satisfactory passenger service. In general, if the roadbed and track are suitable for minimum track class III freight operation, DMU or LRV or any other revenue passenger operation can be implemented without major track rebuilding.

Existing track construction and maintenance standards for passenger service requires costly and time-consuming maintenance activities using specialized equipment. Passenger operations require a higher level of maintenance and more frequent inspections, which may not be justified by freight movements alone. Heavier weight of freight loadings and traffic tend to degrade track structure more quickly and accelerate frequency of maintenance. In a joint operation context, a poorly maintained freight corridor can affect suspension of rolling stock, accelerate wear and tear on passenger equipment, and degrade passenger comfort.

Track design standards have been established by AREMA, but railroads normally apply their own standards as deemed appropriate. Regardless of the selected standard, railroad infrastructure must be FRA-compliant for speed and class of track. This requirement does not apply to rail transit, which is independent of the railroad systems in North America. Suitability of these standards for DMU or LRV equipment needs to be considered, since typical transit track standards may not be adequate for movement of freight rolling stock. Ability of wheels and flanges to negotiate track components needs to be confirmed for each type of equipment operating over the physical plant. Different wheel designs (different from AAR standard freight/locomotive wheels) may experience incompatibility with respect to special trackwork, excessive wheel or rail wear, corrugation patterns, or maintenance requirements, and could lead to derailments.

If the DMU is intended to integrate with the LRT using a streetcar wheel tread, wheel flange profile, and track, integration with a railroad and its track standard becomes problematic. Consider the situation of a non-electrified DMU new start which functions as an extension of an LRT route over an active railroad branch line. The DMU wheel flange size and profile will dictate to which of these systems the DMU can integrate, unless the LRT uses railroad wheel flanges and tread.

Unbalance and cant deficiency will also influence operating speeds and maintenance requirements. Homogenous speed regimes of passenger equipment are preferable for track construction and maintenance, while mixed operations preclude optimization of track designs for speeds and superelevation on curves. Typically, superelevation, which is added for passenger comfort while providing a faster ride, increases inside rail wear with slow freight and increases the risk of toppling high center-of-gravity intermodal freight railroad rolling stock.

Track maintenance concerns include impact of freight loads. On a low-speed, light-density line, this may not be an issue. However, lower-class track standards will not be acceptable for light rail transit or other passenger service. Therefore, determining the track classification is essential for passenger operation and associated costs needed to be allocated. Additionally, substandard track can accelerate damage to LRT and DMU equipment, or at least create an uncomfortable ride for passengers. Parties negotiating a joint operation will need to consider a maintenance program consistent with different types of speed and traffic and decide on the allocation of costs for a higher standard.

Total gross rail loads and axle loads create different track design requirements. Typical freight Gross Rail Load (GRL) is 263,000 pounds. Typical loadings on four-axle or six-axle DMU and LRT vehicles built to European designs are listed below.

Table 3-3
Contrasting Rail Vehicle Weights

Vehicle	GRL (lbs)	Axles	Tons per Axle
SD 50 EMD freight locomotive	368,000	6	31
52'-long Gondola, loaded with steel	263,000	4	30
Modern RDC	128,000	4	15
RegioSprinter DMU	100,000	4	12.5
Siemens LRV, (PAT)	86,000	6	7

Cars for freight operations are being designed for a new standard of 286,000 pounds GRL. Axle load gauges should be designed to accommodate this standard wherever locomotives and carloads are expected to travel. Maintenance-of-way yards should be designed to accommodate 61' long gondola cars with a GRL of 286,000 pounds. An ideal standard for track radii and turnouts is the requirements for 89'-4" ETTX cars. However, this requirement will increase land needed at proposed sites. A benefit of this standard is the unrestricted placement of track and construction material and delivery of DMU and LRT vehicles on flat cars.

Jointed rail is suitable, but continuous welded rail (CWR) provides a smoother ride with less impact on the equipment. CWR is normally used on high-density lines and may not be justified for LRT or DMU service. Use-hardened, second-hand rail with little wear and good profile is acceptable and has its precedents in the LRT sector - St. Louis, for example. There, the CWR is welded in place.

Turning Radius Geometry

LRT cars have more liberal turning radii capability than freight railroad equipment, especially if coupled into trains. Category 2 and 3 DMUs currently represent a mid-range turning capability between railroad and LRVs. It is recommended, therefore, that geometry for turning radii on curves and through turnouts be sufficient to permit 50'-long nominal freight cars and 4-axle switching locomotives to negotiate the track (#6 turnout, 22° 41' or 253'). Geometry of the turning radius is a function of the number of axles, the wheelbase (center-to-center distance between axles), coupler and drawbar configurations, and bolster position. Minimum turning radius must consider these relationships. Typical radius values are shown below for various vehicles as single units, except where noted. In trainsets, the radius requirement tends to increase.

Table 3-4
Contrasting Rail Vehicle Size - Minimum Radius

Train	Size - Minimum Radius
EMD GP-38-2 Locomotive	302 feet with 50′-long boxcar (coupled)
EMD F-40PH-2 Amtrak version	175 feet for a single unit
Siemens RegioSprinter DMU (Category 2)	264 feet for an articulated unit
Conventional RDC DMU (Category 1)	250-foot radius (23 deg. curves) single unit
FRA-compliant DMU (Category 1)	250-400 feet
DMU - dual power (Category 3)	125 feet (proposed) articulated, in trains

It appears that the turning radius of 4-axle switching locomotives is not a constraint, due to shorter wheelbase and engineering. The articulated RegioSprinter currently has the same turning radius as a longer non-articulated conventional Budd RDC; however, the manufacturer is designing the DMU to a shorter turning radius. European DMU equipment may need special design accommodations. The key issue in yard, stations, or storage facilities is space. Therefore, smaller geometric design demands are an attractive feature of the newest equipment. Furthermore, where this new equipment is used on existing facilities, it may be required to conform to available geometry since site modification may be expensive; need time-consuming reconstruction; or be infeasible physically, economically, or environmentally. The type of DMU drive train will influence its ability to negotiate tight radius curves, with electric drive train providing inherently lower radius capability than mechanical/hydraulic drive trains.

3.3.3 Structures, Bridges, and Stations

Structures associated with a rail or transit operation most typically consist of bridges, tunnels, and stations, as well as underground utility and overhead utility crossings or right-of-way occupation. If electric traction power is required, additional structures (poles, feeders, conduits, substations) will be present. Two key criteria of structures in the context of a rail operation are: load-bearing capacity and dynamic clearance envelope (that vertical and horizontal clearance requirement for passage of a moving vehicle at track speeds).

Any structure suitable for a freight operation is assumed to be adequate for light rail transit or rail passenger transit operation. Loading and clearances for joint use of railroad standards should not be a concern. This presumes that sufficient vertical clearance exists for catenary. If utility occupations or crossings are involved, new passenger service should not create constraints to joint operation, unless electric traction facilities are installed or new stations are constructed close by, or they occupy a parallel vacant track bed that is required to expand rail transit capacity. The focus of joint operation relative to structures is clearance allowance for safe movement of freight/passenger traffic and the need for additional structures or specialized facilities to serve co-mingled light rail transit or other passenger operation.

If utility occupations or crossings exist or are planned, railroad operators have access to standard drawings that establish acceptable clearance, engineering, and construction requirements for installations over, under, or parallel to the railroad right-of-way. Addition of passenger transit equipment is not likely to affect this procedure as long as the utility does not occupy space necessary for rail transit joint operation.

Structures create clearance restrictions on rights-of-way, which then limit movement of equipment over these routes. Good examples are tunnels and through truss bridges. Railroads and regulatory agencies, such as the California PUC, create a clearance "plate" or envelope, that diagrams maximum dimension of loaded rolling stock and minimum dimension for physical structures on the right-of-way. These dimensions account for construction and maintenance tolerances. They also consider broken suspension allowances and dynamic (bounce and sway) car body movement. In general, a line satisfactory for freight operation should be of sufficient clearance for light rail transit or other passenger equipment. A check with a "dynamic car outline," is prudent. Sample car body outlines and clearance requirements are provided in Figures 3-1 and 3-2. See also Figure 4-1.

Clearances

Railroad freight and passenger rolling stock dimensions typically exceed clearance requirements of light rail vehicles (both LRT and DMU). If the line features electrified overhead traction power distribution, vertical clearance is more critical and becomes sized according to voltage levels. The higher the voltage, the greater the need for a gap between energized wire and wayside structure (Figure 3-1 - Sample Wayside Dimensional Clearances, Figure 3-2 - Sample Vehicular Dimension Clearance). Proximity to overhead bridges, station platforms, tunnels, tree canopies, and underground and overhead utilities become design factors for third rail and overhead catenary. Desirable top of rail to energized wire clearances for joint use trackage are in the 23'-26' range. At least one new LRT with joint use trackage has a minimum 22'-5"

GENERAL INSTRUCTIONS

Clearance requirements shown on this plan apply only to new construction or reconstruction. Existing structures and tracks may be maintained and extended at present clearances, unless otherwise required by Local or State Authorities

Structures must not be located nearer to the track than the minimum clearance limits shown on this plan and these distances should be exceeded where possible Consideration should be given to the probability of increased distance between track center lines, widening roadbed shoulders and widening and deepening ditches, and the structures located accordingly.

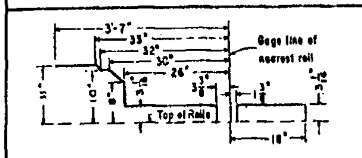
For standard distances between track center lines and the spacing of tracks where intertrack clearance limiting objects are located, see M.W. 4, Paragraphs 62.0 to 62 3 inclusive.

Where physical conditions impose insurmountable restrictions, necessitating clearances closer than those specified, the matter must be submitted to the Chief Engineer - Maintenance of Way for any modifications, and also to the Local or State Authorities, if necessary, over the signature of the General Manager.

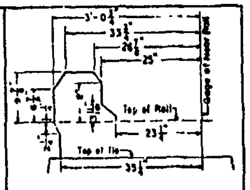
Minimum clearances shown on this plan are from level tangent track For curved track the following provisions apply:

Vertical - Same as for tangent track measured vertically above top of high rail, except above top of near rail for passenger and freight platforms

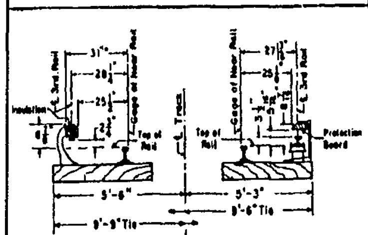
Lateral - Outside and inside clearances shall be measured radially and horizontally and increased by 1 inch per degree of curvature over that shown for tangent track. In addition, the inside clearance for superelevated track shall be further increased by 1 inch per inch of superelevation for each 5 feet of height above the top of low rail



Limits of Car Retarder

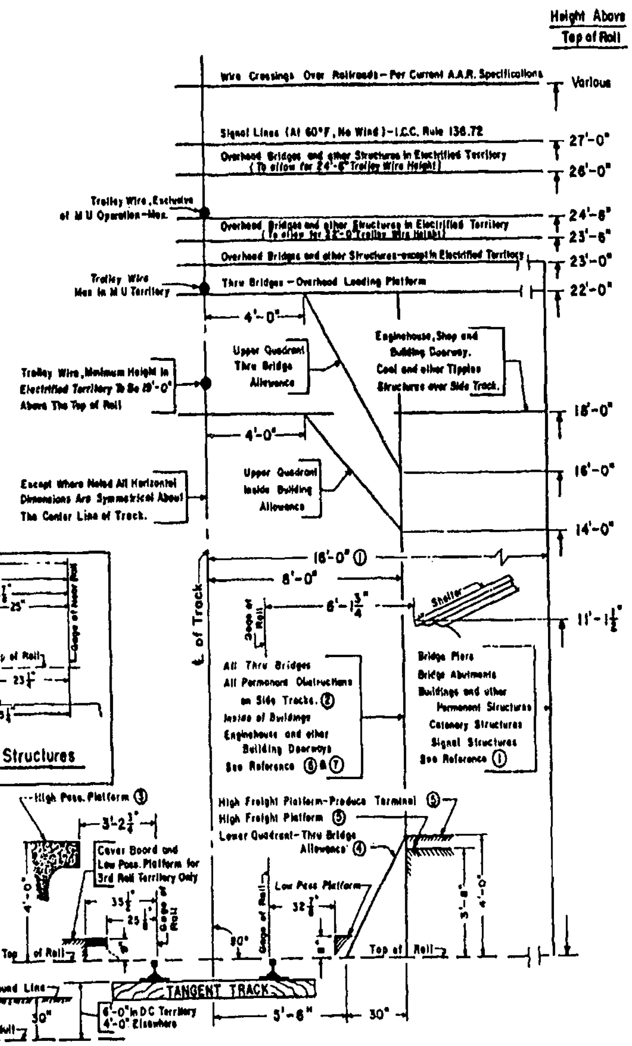


3rd Rail Structures



Location of Under-Running 3rd Rail, Bracket & Insulated Protection.

Location of Over-Running 3rd Rail, Bracket & Protection Board.



REFERENCES

① - On main running tracks, where practicable, a lateral clearance of 18'-0" instead of 16'-0" is desired

② - On private side tracks the standard clearance to platforms, of 8'-0" to be obtained if possible. Where the industry demands a less than standard clearance for platforms, a minimum of 6'-6" from center line of track may be used, subject to State approval where required, on one side of such tracks only, provided a full 8'-6" clearance is maintained on the opposite side of track, or track centers to adjacent tracks are not less than 14'-0". The State of Illinois prohibits freight platform clearance between 6'-2" and 8'-0" unless P.U.C. approval for other clearance is obtained. Reduced clearances on private sidings are permissible only where industry signs the Conrail "Standard Side Track Agreement" and will erect and maintain Close Clearance signs illuminated at night.

③ - Unless authorized by the Chief Engineer - Maintenance of Way high passenger platforms must not be constructed on track having curvature in excess of 1°-40' or where speed requires elevation of outer rail in excess of 1".

④ - Request must be made for encroachment of upper and lower quadrants from 8'-0" horizontal clearance of thru bridges in the States of Indiana, Massachusetts and Ohio.

⑤ - Safety lines, yellow or white, 6'-6" from center line of track are required on freight platforms in the District of Columbia. These lines are recommended in Delaware, Maryland and Pennsylvania.

⑥ - For side clearance to handrails on bridges, trestles and turntables see appropriate Standard Plan

⑦ - State Clearance Requirements at Variance with Dimensions Shown on This Plan

Location	General Clearances		Inside Bldgs. & Doorways	
	Horizontal	Vertical	Horizontal	Vertical
Canada	8'-4½"	22'-6" Ⓖ	8'-4½"	22'-6" Ⓖ
Connecticut	8'-6"	22'-6"	8'-0"	22'-6"
Delaware; Maryland; D.C.	8'-6"	22'-0"	8'-0"	18'-0"
Illinois	8'-0"	21'-6"	8'-0"	H
Indiana; West Virginia	8'-0"	22'-0"	8'-0"	22'-0" ✱
Massachusetts; Michigan	8'-6"	22'-6"	8'-6"	22'-6"
Missouri	8'-6"	22'-0"	8'-6"	22'-0"
New Jersey; Virginia	No Regulations – Use Conrail Dimensions			
Ohio	8'-0"	21'-0"	8' 0"	21'-0"
Pennsylvania	12'-0"	22'-0"	8'-0"	18'-0"
Rhode Island	8'-6"	18'-0"	8'-0"	18'-0"
New York	8'-6"	22'-0"	8'-0"	22'-0"
Kentucky	—	22'-0"	—	—

Ⓖ = Measured from base of rail, all other vertical measurements shown are from top of rail

H = Height of cars governs

✱ = West Virginia, 22'-0" building doors and 18'-0" inside of buildings.

Clearances tabulated from A.R.E.A. "Legal Clearance Requirements" page 28-3-25 dated 1975.

NJ TRANSIT RAIL OPERATIONS 70051-B

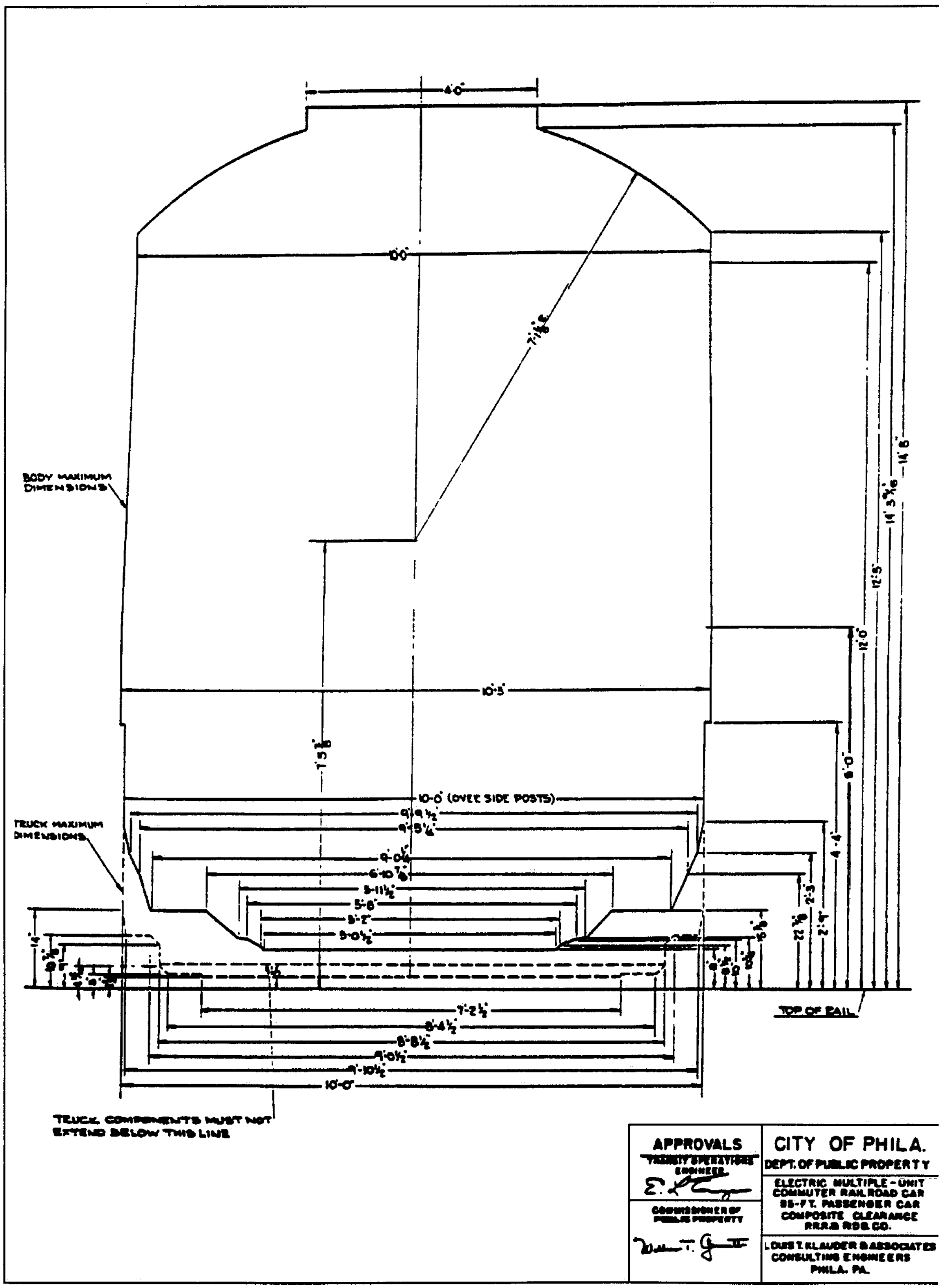
STANDARD

MINIMUM ROADWAY CLEARANCES

January 1, 1983

Office of Chief Engineer - Maintenance of Way

Sample Vehicular Dimension Clearance Overhead Bridges - Figure 3-2



vertical clearance for nominal 750vDC traction wire. High cube double stack cars require a 20'-6" dynamic envelope at a minimum.

DMU equipment eliminates these concerns, particularly if the candidate route is suitable for freight rolling stock (and the DMU or LRV derivative are categories 2 or 3). Typical LRV and DMU have a minimum width of 8'-6" to 9'-4". Mainline railroad passenger cars are 10'-0" to 10'-6" wide and freight cars may be 10'-8" wide. These dimensions seem to imply that exclusive use of smaller equipment allows some flexibility in design of new facilities, although certain caveats come into play in the event that movement of freight equipment is proposed.

Close side clearances are a hazard to brakemen on freight cars. Close clearance areas are normally identified by a warning sign at the affected location. Additionally, even with passenger equipment, on-board crewmen may position their head or arms outside physical car limits.

The excess height/width envelope of freight cars poses a hazard to fixed objects proximate to the right-of-way. Desirable joint use design standards would accommodate an outline defined by AAR Plate "F." Plate "B" is an adequate railroad standard envelope for rail transit purposes.

The most severe condition not incorporated in the clearance outline is the "load shift," in which a freight cargo load inadvertently shifts outside its acceptable envelope and strikes a passing train or wayside structure. This unpredictable situation poses a serious hazard, since normal clearance requirements do not take specific account of random events. Some devices and techniques can provide a warning, but no standard or fully satisfactory method is available currently to eliminate this danger. Mechanical "telltales" have been employed by railroad and tunnel operators to identify oversized or shifted loads before they enter a facility or track segment. It becomes a management or procedural effort to minimize this risk. Remedies include time separation of bi-directional moves on adjacent tracks or restrictions on movement of certain types of freight cars.

Other factors that may affect this situation are the presence of bridges, which could require only unidirectional movements resulting from clearance restrictions, or provision of only one track across a bridge. Tracks have been removed and single-track bridges constructed on freight railroads to reduce maintenance costs. While suitable for freight traffic, such conditions are potential sources of unacceptable delays for light rail transit or other passenger traffic. Nevertheless, single-track operations may be desirable on bridges to avoid bridge structure close lateral clearances and load shift hazards. An operational rule for safety may require time-separated unidirectional movement to enable passenger and freight traffic to effectively pass one another. Adding a new span where abutments and wing walls had anticipated multiple tracks may also be a cost effective solution.

Crash Walls and Barriers

If crash walls and barriers are erected near highway abutments and bridge piers, these structures may pose a hazard to train and vehicle passengers and must be considered in a risk analysis. More positively, they are intended to "steer" a derailed car or protruding cargo away from piers, columns, and posts to minimize damage.

Stations

Stations are built either to a high- or low-platform configuration. Choices of these configurations are dictated generally by rolling stock equipment or by operator policy. Passenger equipment may be designed to serve high-level only, low-level only platforms, or both. Americans With Disabilities Act (ADA) accessibility requirements including level boarding must be met regardless of the arrangement. Each station should be equipped with adequate lighting, weather protection, emergency call service, parking (if appropriate), drop-off lanes, and passenger notification communications. Each station also requires regular maintenance, particularly for snow removal where appropriate. Highway access, vandal-proof features, and adequate security are also essential ingredients.

On lines carrying freight trains, low-level passenger platforms are easiest to accommodate since they can simplify conformity with freight clearances and avoid the need for gauntlet tracks or other physical measures to accommodate high and wide freight loads. Low-level platforms are also less expensive to build and can be as simple and inexpensive as an asphalt pad and a bus shelter.

High-level platforms facilitate train/ passenger access through level boarding, but are more costly to erect. In England and Japan, railway designers have made station platforms high for trains, but low for passenger access simultaneously. Often, the platform is at original grade level and the trackbed excavated to provide level boarding. Edge-of-platform warnings and barriers are necessary for passenger safety. High-level platforms also simplify fare collection and entry control which requires barriers. Self service fare systems common to new LRT systems, diminish this advantage. High platform structures are more prominent, and therefore can be more intrusive on the "public vision" in urban settings. In joint operations, the major problem encountered with high-level platforms is encroachment on freight car clearances. The presence of a platform edge close enough to a passenger car threshold at approximately 48" above top of rail is likely to intrude on safe passage clearance required for freight equipment. One technique is to add a wooden edge to the platform that is easily replaceable if damaged when struck. This device was used on NYCT inter-divisional (IRT/BMT) lines and permits conversion of lines from narrow to wide stock (and back). Fixed wooden platform edges do not, however, solve the problem of joint track use by rolling stock of varying width.

Gauntlet Tracks

Another more complex solution is the addition of gauntlet tracks at the station to allow high and wide freight movement around intruding higher platforms. Side clearance restrictions can be mitigated with gauntlet tracks, which are frequently used in tunnels, bridges and stations to permit offset movement of freight equipment in areas of limited side clearances. Gauntlet tracks stagger the track gauges to permit passage of trains around restricted clearances, but do not permit the passing of trains. At stations, these devices can permit movement of freight loads while maintaining proper platform/carbody dimensions. Typically, gauntlets are interlocked. Gauntlet tracks have an associated maintenance cost and signal system modification requirement. Their use, therefore, is not particularly attractive to a freight operator. A preferable solution from the freight perspective is a low-level platform which, with the advent of low floor DMU and LRV designs, is becoming a preference for light rail transit operators as well. The choice of DMU or LRV rail transit options is based largely on their modest cost and demand relative to rapid transit and high capacity commuter rail which require high platforms (see Figure 3-5 and Exhibit J-1).

Bridges

Undergrade, overhead, or water crossing (fixed or movable) bridges create no special requirements for joint operations, since structures designed for freight are more than adequate to accommodate light rail transit or other passenger trains. However, provision of safe passenger evacuation routes from a disabled train on a bridge must be considered. Operating rules to instruct train crews on door opening while on bridges, passenger evacuation, and rules governing the trains themselves when crossing bridges are commonly enacted and enforced.

3.3.4 Yards, Shops, and System Buildings - Operations & Maintenance (O&M)

It is assumed that freight operation needs no additional support facilities to maintain its present level of service, but that inception of light rail transit passenger service on a freight line requires some (O&M space) accommodation. The management structure of the joint service will influence the extent and location of support facilities.

A transit agency preferring separately owned and managed maintenance support facilities will have to provide them. Acquisition of land, erection of buildings, and provision of labor and management skills to support a rail operation is a major undertaking but accompanies most rail transit "new starts." If public funds are involved, a more extensive review and approval process may increase cost and delay the provision of such services. This separate effort is often not justified for every rail transit service increment.

Savings arising from joint use can be realized through selective sharing of maintenance facilities and resources or adapting existing vacant or disused facilities, especially if DMU is the preferred mode. Infrastructure and equipment maintenance may well be in place on an operating freight line, to enable many of these "front-end" costs to be avoided if allocated between the two entities. Specific factors need to be analyzed and include special shop tools and test equipment, truck and wheel maintenance, skills and training of personnel, inventory availability and procurement, car cleaning, car servicing, and shop facilities to service roof-mounted, low floor, and articulated equipment. While light rail and heavy rapid transit shop facilities are shared (SEPTA wide gauge at 69th St., Philadelphia and RTA E. 55th St., Cleveland), there is no *recent* precedent for joint use of maintenance facilities between LRT and railroad. Though rail and bus transit for a metropolitan area may be unified under a single management structure, only the bus and LRT are traditionally linked, if at all. Rail commuter affiliates of transit systems keep separate, railroad-type O&M facilities.

If the transit agency or the affected railroad cannot jointly undertake this work, another option would be to seek separate private O&M services under contract. This privatization could apply to either LRT or DMU service and could be contracted with the transit vehicle manufacturer. In Baltimore and San Diego, the respective transit agencies own the right-of-way and perform the transit vehicle servicing and MOW themselves, though it is common to contract out specialty work, such as transmission, prime mover, or traction motor rebuilding. Contracting out "power by the hour" or mile is becoming common in the railroad industry and usually applies to leasing of rolling stock. With proposals to DBOM (design, build, operate and maintain) fixed guideway transit, joint O&M facilities seem more remote, unless the contractor is a railroad. As in other joint use precedents, the largest electric interurban railways maintained passenger and freight stock jointly.

Yards

This term refers to the space and track provided for train storage and equipment maneuvering. Minor "running repairs," coach cleaning, and visual inspections are also routinely performed at locations specified in these areas. If the transit passenger service is a contract operation, the contractor may provide these facilities. Separate storage for passenger equipment (if a joint facility) is preferable, and technicians will be able to prepare and inspect equipment free from interference from adjacent joint activities. If variable transit consists are common, additional track space will be necessary. One concern is that of "retrieving" equipment in the event of failure; therefore, a self propelled yard switcher or a road/rail shop shunter needs to be available.

Layup yards may be required where the transit passenger service begins or ends if the route is long or capacity is limited. An example of a joint use yard is in San Diego, where North Coast "Coaster" railroad commuter rolling stock is stored during midday at the San Diego Trolley Yard. Tracks are isolated, however. Yards at rail transit endpoints avoid deadhead mileage and crew hours and thereby reduce operating costs, although this arrangement is not always feasible, especially for staged system implementation. If LRT or DMU is proposed for a former commuter line that featured a zoned service, yards or turn back points may survive intact to be adapted for rail transit yards. A "yard" can be a running track used to store trains in non-peaks if more than one track is available. Satellite yards require security monitoring and mechanical inspection capability to dispatch passenger service.

Equipment Maintenance and Service Shops

Shop activities include scheduled inspections, preventive maintenance, minor and major repairs on board, cleaning (including toilets), wheel truing, car wash/blowdown, paint and parts storage, and inventory control. Test equipment and skilled labor will need to be provided to perform these services. If transit rolling stock is introduced to railroad staff, shop positions, training, parts, servicing equipment, personnel, and other resources need to be allocated. In a contract operation, these additional resources can be derived from excess capacity and integrated with current programs. Parts, catwalks, pits, training, and tools for new vehicles will need to be provided. If low-floor rail transit cars are used and equipment to be serviced is roof-mounted, it would likely mean a substantial separate new space configured to access high components. The shop management plan will need to be assessed to ensure that equipment is serviced at proper intervals. Coach cleaning, crucial to successful passenger service, is likely to be a new requirement in a freight environment. How to provide traction power within the car shop for car movement and testing is another major decision.

If LRT equipment is used, then additional specialized facilities may be required to provide alternate shop power, special testing, personnel safety, trained staff, and parts. Some work can be outsourced, but adequate spares need to be available to substitute for components removed for service. Separation of car storage and running repair functions, but combining certain other functions, should be explored. Potential combined functions include component rebuild, procurement, and parts inventory.

Work Practices - Rail and Transit

Railroad and transit organizations use differing work practices that complicate labor arrangements and that can prove hazardous when operations are mixed.

Problems inadvertently arise when equipment is being serviced and moved.

Maintenance of equipment shops require door openings and service platforms suitable for equipment and prime mover. Important concerns for personnel safety and practicality include:

- Identifying restricted track by posting signs and clearance posts, and listing the restriction in the freight railway's Employee Timetable "Special Instructions."
- Building new service facilities to accommodate the clearance envelope of the largest equipment likely to use the route.
- Using conventional railroad carshells that reflect conventional clearances and minimum turning radii.
- Reapproval training for railroad and rail transit personnel using common areas.
- Writing or amending rule books to cover new items and facilitate updated training.
- Installation of sacrificial/breakaway components where necessary at close clearances.

Mainline railroads perform a great deal of car maintenance on outdoor tracks. To prevent injury to employees, rolling stock being serviced is clearly identified by a blue flag or light. This procedure is referred to as a "Blue Flag" law (Rule 26 and required by 49 CFR218.31ff). Transit personnel rarely use such procedures, since cars are serviced primarily in shops. However, energized rail transit equipment in a shop environment is "flagged." Derails or switch locks are typically not used to provide additional protection. A standard flagging practice will be essential for a "joint operation" and a more conservative approach is suggested. Operators and owners will need to develop "joint" standards if fleets and service personnel are mixed.

Railroad organizations have rarely used car equipment subcontractors and suppliers on site once new rolling stock has been accepted for service, except in the leased power by the hour/mile contracts cited above. Transit operators might not adopt this policy, however currently proposed fixed guideway turnkey or DBOM arrangements will provide experience in contracting selected maintenance functions by single and joint use facilities alike. Managing entities should consider having a training program in place for both employees and subcontractors where necessary.

System Buildings

This term refers to other buildings associated with maintenance or operation of the rail plant, administration, and management of the service. In a contract operation, existing resources should be adequate. However, a passenger agency may wish to create a customer service center or provide office space for supervisory personnel in the owner's facility. Crew welfare facilities are included in this category if they are not incorporated into other structures.

Fuel Storage and Handling

Fuel flow is a concern, since locomotives have large fuel tanks and require a high flow rate to expedite filling, whereas DMUs have small tanks and lower flow rates.

A RegioSprinter has a capacity of 700 liters while an SD-40-2 freight locomotive has a capacity of 14,000 liters. These contrasting capacities impact cruising ranges of vehicles and required placement and size of refueling facilities. Despite these disparities, concentrating fuel and sanding in one existing location can lower risk of community and environmental rejection.

Potential hazards are higher with high fuel flow rates, but the risk is reduced in a single state-of-the-art fueling facility over two or more such facilities. Fueling pads will require spill containment provisions. Additionally, hose nozzles, hose reels, and pumping equipment may need to be tailored to DMU rolling stock. Fueling at passenger facilities is done, but should be avoided in a joint use environment where rolling stock servicing facilities are nearby. Use of existing facilities is preferred, since construction of new fuel storage is costly; risk is lessened and new "hazards" are imperiled by time-consuming approvals and exacting procedures.

3.3.5 Work Equipment, MOW Services, and Facilities

This subject covers specialized equipment, tools, materials, "outbuildings," and inventory storage areas used to maintain the physical plant. Included in this category can be track, ties, ballast, signal and communications cable, electric power transmission lines, substations, catenary, track maintenance machines, inspection equipment, steel, heavy lift widening and repair, cranes, trucks, and machine shops used for system upkeep. Crew welfare facilities may also be included. An existing freight operation is likely to have adequate resources to support its system, but due to increasing centralization of track maintenance on major railroads, the support resources may be roving or remotely located. The scope of this section covers joint use impact on existing facilities and potential for adapting facilities and maintenance institutions to joint use practice.

Joint operations should not exert a major impact on these resources, but subtle effects would be expected. Standards may change, resulting in more inspections and frequent maintenance. If interlockings are added, more switches need to be maintained. Added rail traffic may require additional sidings for strategic placement of work equipment. Passing sidings will add to the length of track to be maintained. If the signal and communications system is enhanced, maintenance requirements are likely to grow and additional trained staff and equipment will be necessary. Grade crossing maintenance, which will include inspection of the warning protection system and the crossing surface condition, is likely to become more vital. Right-of-way cleanup and brush clearing uses special equipment and is appropriate for a passenger route. It also tends to improve the local image of the railroad.

The acquisition of new specialized work equipment will help to ensure successful joint use operation. Mechanization with state-of-the-art apparatus can reduce labor-intensive track maintenance functions. Increased demand for track time characteristic of joint use justifies new equipment to reduce downtime. LRT managements do "import" railroad-type maintenance-of-way equipment by highway track to maintain their facilities. The work is performed by a railroad maintenance contractor.

New MOW and structures facilities (yards and storage areas) are constructed as needed to accommodate clearance envelopes of freight cars, because delivery of track and other materials will occur on freight cars suitable for interchange.

Railroad track and signal maintenance are subject to extensive FRA-mandated maintenance standards. In San Diego and Baltimore joint operation, FRA standards are followed, although not required. Documentation of such compliance is advisable. Moreover, monitoring of maintenance activities is necessary for cost control in a contract operation. Incentive clauses for compliance with prescribed standards should also be considered.

Three factors important for a rail transit passenger service are maintenance scheduling, emergency services, and improvement programs. Rail transit passenger operators should have right of approval of scheduled MOW maintenance to minimize impact to scheduled service. The operator needs to verify that resources are readily available in the event of an MOW-related failure. Where passengers are involved, delays (no matter what the cause) are to be promptly corrected and service resumed quickly. This condition is vital to operator credibility. An additional caveat is that basic changes to the physical plant need to be reviewed and approved by the operator. Relocating signals or switches, modifying track geometry, or relocating sidings can also have significant impacts on passenger service reliability.

3.3.6 Command and Control Systems

Command and control is of primary concern to co-mingled joint operations of railroad and rail transit services. When freight (and possibly passenger) railroad service is mixed with transit agency commuter rail service, only FRA-compliant equipment and regulations are involved. Furthermore, the two examples of U.S. joint operations of rail transit and freight railroads (San Diego and Baltimore) do not involve co-mingling. These systems depend on temporal separation, and thereby avoid the command/control issue.

Modern state-of-the-art systems afford an opportunity to address FRA concerns and reduce emphasis on crashworthiness features on rail cars. It will take time and effort to implement such systems, but it is possible to do the following:

- provide operational insularity for freight and passenger equipment.
- provide redundant systems protection that eliminates potential for human error.
- increase capacity of existing tracks.
- reduce the need for major structural modifications and re-design to DMUs or LRVs.
- mitigate risk factors by eliminating some hazards without compromising safety of passengers, employees, or the public.

New components and materials in railroad signaling technology improve reliability and durability or ease installation, but guiding principles have not changed in decades. New techniques are under development (in prototype stages) or in use that extend beyond constraints of existing technology. They may or may not be suitable for universal railroad application, but offer potential to improve safety and reliability and selectively build the case for joint use.

FRA has recently initiated a regulatory and technical program for Positive Train Control (PTC) to avoid collisions. This activity is still evolving and final rules have not been issued, but it does offer excellent opportunities to apply these techniques in a joint operations scenario. This approach tests the capabilities of older technology, because current methods are limited in their capacity to fulfill proposed objectives.

The PTC train control system is designed ideally for a line dedicated to either freight or passenger traffic with homogenous train length and speed, ideals contrary to joint use operations. The control system therefore becomes a key to the feasibility of joint use in a mixed mode scenario. Higher performance equipment helps, but does not necessarily increase average speed or line capacity. In fact, simply increasing vehicle speed can decrease line capacity. An "occupancy envelope" that incorporates time, speed and distance relationships can be established through a control system.

Modern signal technology can limit consequences of human error and provide redundancy to avoid a single point failure. Additionally, systems can provide warnings for dragging equipment, hot-box, protruding cargo or equipment (swinging rail cardoor) intrusion, flood, rock slide, and other hazards to the right-of-way available. Such features are more important where passenger traffic is involved. The following six points outline important aspects of this challenge.

1. Current Signal Technology

Existing technology accomplishes two vital objectives: it monitors integrity of the rail (referred to as "broken rail protection," an FRA requirement if signal system is in place) and detects track occupancy. Signal technology also monitors the position of switch points and warns of hazardous conditions. Signal technology has successfully been applied to control train speed and movement and sometimes employs features such as Automatic Train Stop (ATS) to enhance safety in the case of human error. Other system components can provide beneficial features or even provide for automatic train operation. Nevertheless, the technology is limited, maintenance-intensive, vulnerable to vandalism and tampering, and does not fully satisfy requirements of an intensive co-mingled joint operation.

2. FRA Perspective

Certain recent events have induced FRA to improve rail system safety. Naturally, the signal system is a focal point of crash avoidance. This condition has mandated a program concept referred to as Positive Train Control (PTC). PTC has evolved through a variety of stages and technical definitions. Specific regulations have not been promulgated, but changes are being considered. FRA has been encouraging R&D of PTC/PTS and communication-based train control technologies, and is participating in incremental demonstration and application projects. These are in various states of nomenclature, development, and testing.

- Amtrak Northeast Corridor Line, New Haven to Boston, accompanying electrification (including risk analysis).
- Minnesota Iron Range (Burlington Northern ARES (Advanced Railway Electronics Systems) - no implementations since.
- Detroit-Chicago Incremental Train Control Systems (ITCS) (Michigan DOT/Amtrak/Harmon) - pilot testing.
- Bay Area Rapid Transit (BARTD)/ Hughes/Harmon - train separation/ control in testing.
- Chicago-St. Louis "Advanced" or ATCS Train Control System (PTC) trial on revenue service (Illinois DOT, FRA, AAR)
- Pilot PTS (Positive Train Separation)- Seattle-Portland-Columbia River Gorge route (BNSF/UP/GE Harris) - fourth release in development and pilot testing.
- Pilot PTC-Harrisburg to Manassas route (NS/CSX/CR/Rockwell) - RFP to be released.
- PTC testing at Pueblo Transportation Technology Center, Inc. (TTCI) Test Track.
- FRA Differential Global Positioning System (DGPS) system support.

These test/application plus Rail Safety Advisory Committee (RSAC) activities are designed to validate PTC, identify benefits, and advance rulemaking. Application costs are in the $5B range.

PTC is intended to enhance safety and increase capacity for conventional railroad operations. It is also beneficial to joint operations and eases regulatory concerns.

3. Rail Industry Perspective

Freight and rail transit operators and other passenger railroads are in a continuing dialogue with FRA regarding proposed PTC regulations. Some have been or are participating in the programs noted above. Numerous technical and economic issues are emerging as this effort matures. Major freight carriers are generally content with present technology and regulations, and are wary of costs. Passenger services (Amtrak and commuter rail) perceive a benefit, but are concerned about the cost of change with meager capital budgets. Additionally, no standard technology or software/hardware components are comparable to those available from signal system suppliers.

4. Rail Transit Perspective

For their individual and isolated metropolitan-based systems, rail transit has applied a variety of control systems, but has typically sought more sophisticated practices for their high density services than found in most railroad systems. Rail transit also has the advantage of operating on a physically isolated infrastructure in a homogenous environment of equipment, consists, speeds, communications, and performance, without the need to conform to some other carrier's standard. Some older systems operate quite adequately on older rail-based technology. Newer systems use partially or fully automatic control to operate their trains and depend on traditional signal technology. Recently, two systems (BARTD and NYCT) have been engaged in experimental applications of communications-based train control. While safety is of utmost importance, other objectives are increased capacity and reliability, and lower maintenance costs. Success of these two programs is likely to encourage more extensive applications of this technology nationwide.

5. Advanced Signal Technology (Communications-Based Train Control)

This technology applies radio frequency, digital, and computer technology within a number of subsystems to provide control functions. Its characteristics include:

- reduced wayside apparatus, but retains a wayside subsystem to provide links and device interfaces.
- automatic positioning subsystem to locate vehicles.
- vehicle-borne subsystem to monitor and control movement and communicate with wayside systems.
- control center to generate movement authority and incident management, and provide tactical traffic planning.

Specific components and designs of this signal technology make a greater contribution to comprehensive rail system capabilities than to joint operating enhancements. Resultant benefits include:

- improved safety by controlling speed and traffic movement in relation to route, consist size, and equipment performance.
- movement control (independent of track circuits) and more precise information regarding train location.
- monitored presence of work crews, equipment, and grade crossing operation.
- accommodated freight set-outs and pickups.

- increased line capacity.
- reduced wayside apparatus maintenance and resistance to vandalism.

6. Application Considerations

Application of different train control systems occurs on a progressive basis when dealing with an existing freight route. An overlay approach is used to maintain integrity of existing signals and track circuits while the communications-based system is installed, tested, and activated. This condition will allow non-equipped vehicles to operate on the older signal system, although without the benefits inherent in the new system.

Given the state of the art of railroad signal technology and predetermined freight railroad policy, implementation of a communications-based system is likely to be slow. The first and foremost obstacle is cost, since benefits to a freight operation will probably not be significant on a light density line, where joint use is most adaptable. However, offsetting savings, such as track circuit maintenance, are possible. Secondly, fleet management becomes an issue, since freight rolling stock often traverses many routes nationwide, or in pools controlled by different conventional signals, whereas a passenger fleet can be dedicated to a communications-based system route. This situation demonstrates that standardization of signal technology is not yet common to communications-based systems. Consideration of mixed signal technology must be continued. Under these circumstances, track occupancy information is available now, but position and movement information will only be available to the communications-based system equipped vehicles. In current railroad signal systems, train separation is not fully failsafe controlled.

A negative aspect of the dual train control technology is that essentially two different systems must be maintained and troubleshooting will be more complex. A rough cost estimate to equip a locomotive with appropriate hardware ranges between $30,000 to $50,000 per unit. While the rail transit equipment may be deducted, the locomotive is less likely to be. Hardware for DMUs would be similarly priced; however, this would be included in the initial vehicle cost and may be lower since no retrofit work is required. An additional expense is the cost of a control center, communications systems, and some wayside devices. While more detailed information is required for a budget estimate, a relative order-of-magnitude cost for a modest sized LRT/DMU service could range from several million dollars to some $10 to $15 million. Communications systems constitute much of the cost and FCC-allocated bandwidth is scarce.

This new technology would reduce some safety concerns and could apply as a risk mitigation to ease acceptance of joint operations. Costs and the state of the art of technology render a quick conversion unlikely.

3.3.7 Electric Traction (ET) Facilities

Unlike predominant European joint use experience, electric traction for North American railroads is now rare. The possible synergy of shared existing catenary as well as shared track is reduced in the U.S. Structures associated with light rail electric traction propulsion systems therefore complicate clearance requirements for host railroads beyond mere physical encroachment into the car operating envelope. An electrified operation confines movement of electrically-propelled vehicles to electrified trackage. Relative to DMUs, electric LRVs are therefore less suited to low cost rail "new starts," initial operating segments (IOS), "demonstration" operations, trial services, or plans where complex route flexibility is desired. In spite of its advantages, an electrified operation also has major capital and operating cost implications. Justification for DMU as an IOS alternate to LRT, independent from wayside electric power, is likely to come from one or more of the following:

- The desire to quickly extend existing or planned central area LRT street running.
- The desire to use only a segment of a proposed LRT line in joint operation with a nearby railroad.
- Low initial estimate of traffic on the proposed LRT route.
- Flexibility to adapt to any primary energy source in the future.
- Resistance by a host railroad to stringing traction current wires for propulsion above their tracks.
- Potential signal interference.

Pennsylvania DOT is considering initiation of a transit-type DMU commuter operation on an electrified line (Amtrak's Harrisburg Line) used for passenger service. No other major electrically-powered *freight* movements occur in urban/suburban areas in this country, nor are any seriously contemplated, reducing opportunities for joint use of existing railroad electric traction power. Nevertheless, joint use of track between transit and rail freight remains a valid concept; if environmental or energy concerns dictate electrifying freight railroads. Other than in Cleveland, LRVs and heavy rail rapid transit trains do not share revenue tracks and overhead catenary; again, historical precedents notwithstanding.

Traction Power Substations

Substations house high-voltage AC electrical equipment installation that receives, controls, alters, and distributes electrical power to trains. These facilities can be located at a convenient and safe distance from the right-of-way. *Railroad traction* substations are rare outside the Northeast (U.S.). DC substations are common on light rail systems or other rail transit applications. Domestic traction power substations commonly fall into two output categories. The first has high voltage AC of 11-12.5kv or 25kv output and at least one 50kv common carrier railroad. Catenary is employed with high voltage AC. DC traction voltages range from 550-750 vDC and are conveyed to the car by trolley wire, catenary or third (over or under-running) rail. Higher voltage DC 1500-3000vDC) railroad voltages have nearly disappeared with Montreal and Chicago being the only domestic survivors, until the former was recently converted to 25kvAC.

Traction Power Distribution (overhead contact or third rail system)

This system delivers power to the vehicles and needs to closely follow the track alignment and maintain precise relationship to a vehicle-mounted current collection device through its range of speed and motion. Components of this system (poles for catenary and along every fifth tie for third rail) are placed along the right-of-way. They conform to specified transit clearance dimensions and, consequently, can create a restriction on freight vehicle and load dimensions. Typically, third rail is only used in exclusive and physically-separated rights-of-way, although there have been some exceptions. Usually, third-rail systems are better suited to high-density, fully grade-separated routes, and are not likely to fit a current "joint operations" profile. An overhead contact/ catenary system is more probable for LRT. With respect to joint operation with freight movements, vertical dimension is most critical, particularly where bridges and tunnels restrict vertical clearance, or where high-elevation cars (e.g., doublestacks or tri-level autocarriers) are moved. Overhead contact requires an additional clearance for electrical safety in addition to physical clearance requirements to avoid mechanical damage. Bridges often require special designs for an electric traction (ET) system, and movable bridge spans add further complexity and cost. An additional margin of separation between catenary messengers and wayside infrastructure is required for high-voltage AC to avoid flashovers, but this is uncommon for LRT DC voltages.

Traction Power Return

This subsystem provides a return path for electrical current. It does not have nearly as much impact as the distribution portion, although it complicates maintenance and safety planning for a rail operation (freight or passenger). The rail needs electrical continuity devices (bonds between butt ends of the running rail), the signal system requires impedance bonds, stations and no structures need to be grounded and bonded, and the integrity of the return path must be maintained during track maintenance. This situation will have limited impact on joint operations, but does add to system capital costs while providing little appearance of direct benefit to potential users. While not a joint use issue, protection of buried utilities from stray traction currents or in-street trackage requires counter-electrolysis measures.

Maintenance-of-Way (MOW)

MOW for electric traction power adds a dimension to planning and managing joint use infrastructure. Substation and overhead line maintenance is required on a regular basis, which adds service outage requirements, since an additional period of track occupancy is required (although it often can be "piggybacked" with track maintenance). Additionally, when track maintenance is performed, ET forces are involved to maintain integrity of the rail return system. They are also involved when maintenance is performed to ensure the safety of other employees. When maintenance is planned, "clearances" are required to remove power, allow for safe working, and reapply power. This arrangement adds to the complexity and service interruption to perform required work.

3.4 CONCLUDING COMMENTS

Based on the above issue-oriented discussions, opportunities for mixed and joint operation related to physical plant elements should take into account the following concerns:

- Safety problems generated by different track loadings, clearances, and physical constraints. These conditions result from increased weight of freight equipment, its higher and wider dimensions, and turning radii.

- Safety and protection at grade crossings for a variety of equipment sizes and performance.

- Safety of train movements and provision of their adequate separation by new technology signal and control system.

- Safety and environmental problems resulting from fuel handling and storage procedures.

- Availability and quality of skills and resources to maintain different fleets of equipment, since generally the skill level requirement on car and control systems electronics is higher with component changeout, and outsourcing of component repair is more common.

- Schedule adherence and reliability in light of increased demand for track capacity by freight operators, transit passenger operators, and maintainers.
- Command and Control/Monitoring Operations.
- Train mix, including the occurrences of hauling hazardous materials.
- Allocation of costs and responsibilities for infrastructure upgrade and maintenance.