Shared-Use Corridors
Survey of Current Practice and Recommendations for the Future

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The paper addresses current practice in shared use of rail corridors. For this purpose the paper reviews an inventory of such corridors performed recently for the Federal Railroad Administration. Design elements related to the design and construction of light rail transit (LRT) systems in joint use corridors, currently operating or under construction, are discussed. Design elements examined in existing and under construction joint use systems include grade separation, intrusion fences, crash walls, retaining walls, grade crossings, and drainage facilities. Recommendations for future action in regard to design and operation are developed based on the findings of the survey of the current practice. To assist the LRT designer with new projects, examples from existing LRT systems operating in shared corridors or such systems under construction is provided. The authors hope that this paper might serve as the first step in developing official design criteria and standards governing transportation corridors shared by LRT and freight railroad operations.

INTRODUCTION

In the last 20 years the light rail transit (LRT) systems, previously known as trolley operators, have been reintroduced in urban areas of increasing population density. Such urban areas have utilized highways and roadways to their full existing traffic capacity and adding lanes is either unfeasible or of lower cost-effectiveness from regional transportation and transit planning. The LRT, utilizing a few light rail vehicle (LRV) cars used for each trip, is also suitable for low-volume operations. It has provided an emerging mass transit means that have been reintroduced with a regional development vision of meeting future transit demands, to supplement and replace existing means of transportation and to revitalize declining existing urban centers.

The flexibility of the LRT of mixing with traffic on city streets, while also achieving relatively high speeds, enable it to take advantage of existing rail corridors and relatively lower costs. The number of transit project systems constructed in either abandoned or active freight rail corridors in the United States has increased in the last two decades. As this paper is being written, several transit systems within freight–LRT shared corridors are in construction or in various stages of planning and design. This trend is anticipated to increase due to the opportunities and advantages associated with the use of freight corridors in relation to land use category, available right-of-way (ROW), and economic benefits in light of dense urbanization in areas needing mass transit, existing zoning designations, and the rising land costs.

With all the advantages that the shared-use corridors offer to the transit authorities in developing LRT systems, the use of existing freight corridors for mass transit impose challenges. Most of the freight corridors were designed and constructed for transporting goods and materials. Also, the design and construction took place many years ago under old freight rail standards and not mass transit. The character of the area in which the freight rail was extended in swamps, flood plain or just the lowest area in the town receiving drainage that became the last tier of development after the freight rail was constructed and started operations. Grade crossings of local and major roadways were constructed after the rail was in place and some existed prior to the construction of the rail. However, the urban development condition in those days and frequency of freight rail operations have changed to densely populated areas with heavily traveled grade crossings. The mass transit now being developed needs to be designed under modern mass transit standards for project life of tens of years.

The Federal Railroad Administration (FRA) has a legal responsibility for the development and enforcement of safety regulations for the United States railroad industry while the development of the LRT project is usually sponsored by another federal agency, by the Federal Transit Administration (FTA). In a few cases, track is shared, and FRA regulations apply. However, in many locations, LRT share a common transportation corridor, or ROW, with freight trains. When track is shared, passenger-carrying vehicles must meet stringent safety requirements or freight and passenger operations must be time-separated. Regulations established jointly by the FTA and FRA and published in the Federal Register were reviewed (*1*). The existing regulations are general in nature. There are no specific design requirements. However, in practice, freight and passenger-carrying vehicles must meet stringent requirements, even when the LRT track and the freight railroad are as close together as two tracks on a double-track railroad. FRA defined these operations as "common corridors" when rail transit and railroad tracks are less than 200 ft apart, track center to track center. FRA regulations define adjacent tracks (shared ROW) where tracks are 25 ft or less center to center, while shared corridor relate to freight tracks and transit tracks, such as LRT, separated by more than 25 ft, but less than 200 ft, center to center.

The following sections were prepared based on findings obtained from a census of numerous existing shared corridors (*2*). These findings include spacing between track centers, use of structures such as fences crash walls or retaining walls for safety, shared minor facilities such as rail to rail crossings at grade or shared grade crossing protection, operating practices (including type of train control) such as spacing between the freight and transit tracks, time separation and operating speeds and traffic control practices. The following sections also cover design elements related to grade separation, fencing, crash walls or retaining walls, embankment profile and drainage and flooding protection. The design elements and recommendations for future design and operation have been developed based on the findings of survey of current practices and design experience related to LRT operating systems, systems and systems under various design phases.

DEFINITION OF SHARED-USE CORRIDORS

The FRA has a statutory obligation to promulgate safety regulations for the "general rail network"—the approximately 150,000 route mi of standard-gauge track in the United States used by both passenger and freight trains.

Operators of rail public transit services, other than commuter rail that uses the general railroad network, come under state rather than federal regulation. Passenger-carrying equipment does not need to meet the same standards set by the FRA for passenger cars and locomotives operating on the general railroad network. Neither does FRA regulate operating practices, signal systems, track design, or track maintenance.

Transit systems are regulated by states, unless the transit operation actually shares track with an FRA-regulated operator (in which case FRA regulations apply). But what if a rail public transit operator shares a transportation corridor with FRA-regulated passenger or freight service? These are "shared-use rail corridors", and at present there are no standards or regulations applicable to such operations.

In a recently issued report, FRA defined three types of shared-use rail corridors (*3*):

1. Shared track, in which heavy or LRT vehicles operate on the same tracks used by freight trains. FRA regulations govern this type of operation, in which time separation (no simultaneous operation) is required in most cases.
2. Shared ROW. In this case the transit vehicles run on separate tracks, but track centers are less than 25 ft (that is, separation between the centerline of the freight track and the centerline of the passenger track is less than 25 ft). FRA requires railway maintenance workers to observe specific safety precautions when multiple main tracks are adjacent.
3. Shared corridor. Transit and freight operators share a transportation corridor, but tracks are separated by at least 25 ft and no more than 200 ft. FRA believes that intrusion by derailed freight or transit cars onto a parallel railroad track is unlikely beyond 200 ft.

In addition, FRA defines "shared minor facilities". These are:

- Rail/highway crossings where transit line and general railroad system share crossing protection;
- Level crossings (diamonds) between transit tracks and general railroad system tracks; and
- Shared movable bridges.

The focus of this paper is on shared ROWs and shared corridors, with shared minor facilities requiring some consideration during the design of the light rail facilities. Although the focus of this paper is light rail, it also addresses heavy rail design issues in shared corridors for considering additional data that are of interest to light rail in such environment. Table 1 summarizes the route mileage of shared-use rail corridors in the United States.

TABLE 1 Shared-Use Rail Corridor Mileage: Current and Planned

Type of Operation	Shared ROW	Shared Corridor	Total
Current Operations			
Light Rail	66.7	12.0	78.7
Heavy Rail	63.3	80.6	143.9
Planned or Under Construction			
Light Rail	71.5	1.2	72.7
Heavy Rail	17.0	--	17.0
TOTAL	218.5	93.8	312.3

Note: "Planned" is limited to those projects where construction is underway or FFGAs have been reached with FTA

EXISTING SHARED-USE CORRIDORS

As Table 1 shows, at present there is about twice as much heavy rail trackage as light rail trackage in shared-use rail corridors. The majority of the heavy rail trackage, however, is classed as "shared corridor" (more than 25 ft from the nearest freight track, center to center), while the light rail trackage is mostly "shared ROW" (less than 25 ft, center to center, between tracks). Also, substantial light rail mileage is planned or now under construction on shared ROW. In the near future, the light rail mileage on shared ROW will come very close to the total mileage of heavy rail in common corridors (the majority of it more than 25 ft from active freight or passenger tracks).

The reason for this is clear. As interest in mass transit has grown in the past decade, planners have discovered that existing rail corridors can be good locations for construction of new light or heavy rail transit systems. Rail corridors tend to run through commercial and industrial areas with few or no permanent residents (and thus no one to object to a new rail facility). As freight railroads have reduced their fixed plant, tracks have been removed. This means that there is often room on the existing ROW for a single- or double-track rail transit line. However, since freight rail lines generally are not grade-separated, it is easiest to use existing rail ROWs for light rail operations, which do not generally require grade separation.

By contrast, heavy rail facilities require grade separations, and this often means either elevated structures or tunnels are needed. While grade separations do reduce the risk of accidents involving transit vehicles and freight or passenger trains on adjacent rail lines, they are also costly.

A recent survey of shared-use rail corridors by FRA revealed a number of common design practices. The objective of the survey was to identify all current transit operators, and all those with Full Funding Grant Agreements (FFGAs) from the FTA for proposed new construction, with lines that:

- Share track (covered by existing FRA regulations),
- Share ROWs with freight or commuter railroads,
- Share corridors with freight or commuter railroads, and

- Had connections or grade crossings with active freight or commuter lines.

The survey identified a total of 30 rail systems that had either shared track, shared ROW, or a shared corridor with the general railroad system. Several of the systems surveyed are in the midst of expansions of service. In several instances, major projects will add shared track, ROW, or corridors. Information on planned expansions has been limited to those for which funding has been identified, or where construction is actually underway. Table 2 shows agencies with shared ROW or shared corridor operations.

Note that Port Authority Trans-Hudson (PATH) rail operations are not shown in Table 2. The Hudson & Manhattan Railroad (H&M; predecessor to PATH) ran its first trains in 1908. Although it was a rapid transit railroad, the fact that it was an interstate operation and connected with (and shared trackage with) the general railroad system resulted in its being classified as an "interurban railroad" by the Interstate Commerce Commission (ICC), and therefore subject to ICC regulation. Railroad labor unions represented H&M employees, and trains were operated in accordance with standard railroad operating rules.

When the FRA was created in 1966, the railroad safety regulation was transferred from the ICC and FRA acquired regulatory responsibility for what was now PATH (owned and operated by the Port Authority of New York and New Jersey). Since PATH is already under FRA regulation, it was not included in the survey of common use rail corridors.

In general, transit systems sharing transportation corridors with freight railroads have good communication with the railroads and have established emergency notification procedures in the event of an incident on either the freight railroad or the transit system. Some transit systems have policies of placing fencing between the transit tracks and the railroad, to prevent maintenance workers or passengers from inadvertently wandering onto the freight ROW.

In locations where the transit and freight operators share rail–highway crossing protection, a high degree of cooperation is necessary. In San Diego, which has both shared trackage and shared ROW, San Diego Trolley (SDT) employees maintain crossing equipment on the east side of the shared ROW, while North County Transit District (NCTD) employees maintain equipment on the west side. Because NCTD commuter trains fall under FRA regulation, and freight trains also use the tracks, all SDT maintainers are trained in FRA standards and practices, and inspection of the equipment is carried out in accordance with FRA rules. In fact, all SDT track and maintenance personnel are FRA compliant due to the large amount of SDT trackage shared with freight trains.

As might be expected, there is a wide variation in traffic density and operating speed of the rail lines sharing corridors with transit lines. Rail lines in these corridors range all the way from infrequently used branch lines or industrial tracks with 10 mph speed limits to heavily-used mainlines with much higher operating speeds. Whatever the operating situation, however, all transit operators interviewed noted that encroachments had been rare.

In a few cases, transit lines are adjacent to rail lines used principally, or solely, for commuter rail service. This is true at one location in Chicago, where the Purple Line from Howard Street to Evanston (heavy rail) parallels a former Chicago & Northwestern Railroad main line that carries Metra commuter trains and no regular freight traffic, and also in Boston,

TABLE 2 Transit Systems with Common Corridor Operations (Existing)

City	Operating Agency	Route Mileage			Shared Minor Facility (type)	Notes
		Shared Track	Shared ROW	Shared Corridor		
Atlanta	Metropolitan Atlanta Regional Transit Authority	--	--	25.0	None	Three separate line segments. Track spacing varies; all track is fenced.
Baltimore	Maryland Mass Transit Administration	10.9		7.2	Track connection, diamond, grade crossing protection	Shared corridor with CSX Hanover Sub, heavy rail. Track spacing all > 25 ft. Light rail, shared track North Avenue to Timonium.
Boston	Metropolitan Boston Transportation Authority	--	21.6	--	None	Two segments of shared ROW on Orange Line; one on Red Line. See text.
Camden, NJ	Port Authority Transit Corp. (PATCO)	--	5.5	--	None	Track spacing almost all < 25 ft. No fencing. 5.3 mi shared w/NJT; 0.2 mi. with CSAO.
Chicago	Chicago Transit Authority	--	11.9	3.4	None	Purple and Blue Lines, track centers > 25 ft. Others < 25 ft. All fenced.
Cleveland	Greater Cleveland Regional Transportation Authority	--	14.3	1.0	Diamond crossings (two)	Red Line, shared ROW. Unfenced. Light rail: shared corridor.
Dallas	Dallas Area Rapid Transit	--	4.2	0.9	Track connection, grade crossing protection	Track at Dallas Union Station > 25 ft. Planned: 28.4 mi shared ROW.
Denver	Regional Transportation District	--	11.8	--	Grade crossing protection	10th and Osage to Littleton/Mineral, shared ROW. Track spacing > 17 ft.
Jersey City	NJT -- Hudson/Bergen LRT	--	4.2	--	None	Track centers vary. Generally < 25 ft.
Los Angeles	Los Angeles County Metropolitan Transportation Authority	--	15.9	1.6	Diamond crossing, grade crossing protection, Blue Line	Green Line: 1.6 mi shared corridor, mostly elevated structure on RR ROW. Blue Line on shared ROW; fenced
Memphis	Memphis Area Transit Authority	--	2.0	--	Diamond crossing, grade crossing protection	Historic trolley operation. Shared ROW with CN industrial track. Trolley on exclusive track parallel to freight track.

continued

TABLE 2 (*continued*) Transit Systems with Common Corridor Operations (Existing)

City	Operating Agency	Route Mileage: Shared Track	Route Mileage: Shared ROW	Route Mileage: Shared Corridor	Shared Minor Facility (type)	Notes
New York	New York City Transit	0.3	--	3.3	Track connections	Two shared corridors; short segment of shared track with subsidiary South Brooklyn RR. Track connections at 38th Street and Linden yards.
Oakland, CA	Bay Area Rapid Transit	--	--	18.6	None	Three segments. Planned 17 mi extension to San Jose will share rail corridor
Philadelphia	SEPTA light rail	--	--	--	Diamond crossing	Diamond in street, protected by standard highway crossing warning devices
Portland	Metropolitan Area Express	--	8.5	--	Lift bridge	Steel Bridge shared with UP; double-deck lift span with railroad underneath
Portland	Portland City Streetcar	--	--	--	Diamond crossing	BNSF spur may be out of service; no signal protection
Sacramento	Regional Transportation Dist.	--	6.9	3.0	None	16.5 mi shared ROW under construction or planned; 20 ft track centers standard
St. Louis	Bi-State Development Agency	--	3.5	--	Diamond crossing; track connection, grade crossing protection	1.9 mi adjacent to UP; 1.6 mi adjacent to industrial track owned by Bi-State
Salt Lake City	TRAX	12.0	--	--	Diamond cr., two track connections; 33 grade crossings	Shared track with UP; no shared ROW or corridors
San Diego	SDT	31.1	--	5.7	Track connections	Shared track on two lines; shared corridor on Old Town/Mission Valley line.
San Francisco	SF Municipal Railway	--	--	--	Four diamonds	Third Street Line (under construction)
San Jose	Valley Transportation Authority	2.1	1.5	--	Track connection	Shared ROW with Caltrain; shared track, see text. Planned shared ROW, 6.8 mi
San Pedro	Port of Los Angeles	1.5	--	--	Track connection	Shared track with Pacific Harbor Line (temporal separation)

continued

TABLE 2 (*continued*) **Transit Systems with Common Corridor Operations (Existing)**

City	Operating Agency	Route Mileage Shared Track	 Shared ROW	 Shared Corridor	Shared Minor Facility (type)	Notes
Scranton	Lackawanna County	4.0	--	--	Track connection	Shared track with Delaware Lackawanna Railroad (temporal separation)
Seattle	Waterfront streetcar	--	0.5	--	None	Shared ROW Bell Street to Broad, BNSF
Tacoma	Downtown trolley	--	--	--	Diamond crossing	Crossing of BNSF Lakeview Sub; see text
Tampa	Downtown trolley	--	--	--	Diamond crossing	Crossing with CSX, protected by flagmen
Washington, D.C.	Washington Metropolitan Area Transportation Authority	--	10.0	22.1	None	All track in common corridors fenced, with intrusion detectors.
TOTALS		62.1	124.6	91.8		

where the Red Line to South Braintree (also heavy rail) is closely paralleled by a single track carrying only commuter trains from South Station to Plymouth and Middleboro. Clearly, the risk of derailments, shifted loads, and intrusion is less on these lines than on busy freight main lines.

In virtually every common corridor, there are protocols for contacting the freight operator if a problem occurs on the transit line. The reverse is also true. In most cases, the freight railroad has special instructions or timetable notices to crews that, in the event of an undesired emergency (UDE) brake application, or if a derailment or shifted load is suspected, they are to notify the dispatcher and inspect their train. Dispatchers are also instructed to alert the light or heavy rail operator if a crew experienced a UDE or some other difficulty.

There is a wide variation in construction standards for transit lines in shared-use corridors. In some locations, transit tracks are spaced only 12 or 13 ft, center to center from the closest freight track, without fencing of any kind, giving the appearance of a multiple-track rail line. In some new construction such as the "south line" in Sacramento, the design standard is a 20-ft center-to-center spacing. Light rail lines are likely to be spaced closer to freight tracks than heavy rail lines. The one exception to this is Cleveland, where the grade-separated heavy rail shares unfenced ROW and structures with adjacent grade-separated freight trackage. Cleveland, however, is unusual in that the Red Line uses overhead catenary. Other heavy rail lines employ third rail, and the ROW is fully fenced. Where shared ROW exists, generally the transit tracks are separated from freight trackage at least by fences, and sometimes by differences in elevation or "crash walls" (concrete barriers).

In a number of locations, a heavy rail line on an elevated structure follows an existing, at-grade freight railroad ROW. The San Francisco Bay Area Rapid Transit (BART) line from Oakland to Fremont, for example, is adjacent to the former Western Pacific Railroad main line (now used only for industrial switching) for most of the distance from Oakland to Fremont. It is at the same grade as the freight line only briefly, at Hayward (where the BART maintenance shop is located). The aerial structure for the Green Line in Los Angeles follows the alignment of the BNSF Harbor Subdivision from El Segundo to the southwest end of the line. In Atlanta, several branches of the Metropolitan Atlanta Regional Transit Authority (MARTA) system follow freight lines, but are sometimes grade separated and often at a considerable distance from the freight trackage (50 ft or more). MARTA trackage is fully fenced.

Grade separations provide a fairly high level of safety for the transit operator. A catastrophic high-speed freight derailment might damage or even destroy one or more of the supporting columns of an elevated structure, but such derailments are statistically unlikely.

DESIGN ELEMENTS OF SHARED-USE CORRIDORS

The design of LRT systems, and joint operations of LRV and freight trains in shared-use corridors is driven primarily by safety concerns, particularly the safety of passengers, whether directly or indirectly. The safety concerns have resulted in physical separation of freight from light rail in some existing operating systems and systems under design and construction. The following paragraphs provide a review of several design elements considered lately for planning and design of LRT projects in shared-use corridors.

Time Separation

Time separation of CSXT freight operations and NJ Transit's South Jersey LRT System (SJLRTS) was incorporated in the design of the SJLRTS. This design will require freight operations by CSXT during the late night hours while the SJLRTS operations are paused only to resume commuter services in the early morning while the freight operations are paused. Time separation actually provides very safe and efficient use of LRT and freight sharing the same tracks and rail system. At present, the FRA requires time separation of freight and LRT operations, although FRA has indicated its willingness to consider some type of advanced signal system that could provide positive separation.

Distance Separation

Distance separation such as more than 25 ft between freight track and LRT track centerlines is normally desired by the FRA. In many corridors, existing freight ROWs do not provide room for such a distance. Track centers in some shared-use rail corridors are as close as 13 ft, without fencing between tracks. At present, there are no regulations that require operation of either freight or LRT trains at lower speeds in this situation. Future design guidelines might require reduced speed on close track centers because of the potential of impact related to exceeding the distances allowed by the design dynamic envelope, primarily as a result of a potential derailment. The design of adequate separation distance should be an acceptable safe balance among several parameters of which operating speed may be a major parameter. Other measures considered lately in design of shared corridors include intrusion fences, crash walls, retaining walls and grade separation.

Intrusion Fence

Intrusion fence is a fence or other structure designed to detect an intrusion of the LRT clearance envelope by derailing, or derailed freight rolling stock; by large a defective appurtenances such as freight car doors; or by a significantly shifted load such as an improperly secured container on flat car container or trailer on flat cars. Such requirement was made by the FRA in connection with a proposed Hudson–Bergen LRT (HBLRT) extension side by side with existing CSXT and NYS&W freight tracks. Intrusion fences alone were required by the FRA for the proposed extension of the HBLRT project where the LRT and a NYS&W siding are both on embankments with a distance of 33 ft between their track centers. Due to low operating track speed, the FRA has not required any crash walls between NYS&W's and the LRT tracks.

Grade Separation

Grade separation is provided in shared corridors when the proposed LRT tracks need to cross a railroad yard, when there are many roadway grade crossings and when the existing corridor is inundated by riverline and tidal flows. The grade separation normally elevates the LRT tracks since the safety standards for the mass transit operations require more stringent safety measures and adherence. Also, the light rail operations require lower design load than freight operations. Grade separation has been achieved by elevating and supporting the LRT tracks on embankment, piers or on fill placed between retaining walls, depending on the function the grade separation is intended to serve.

Crash Walls

Crash walls have been required by the FRA for the protection of piers designed for the proposed grade separated HBLRT extension crossing the North Bergen CSXT yard, a multimodal railroad yard. The FRA requires the crash wall to protect the piers from a potentially derailing freight train. The crash wall height is required to be either 6-ft or 12-ft high, depending upon the centerline distance between the nearest freight track and each pier, as per American Railway Engineering and Maintenance-of-Way Association (AREMA) Standards Part 2, Section C-2.1.5. While indicating that the National Transportation Safety Board found no clear break point in the distribution of the distance traveled from the centerline of the track by derailed equipment, AREMA suggests to retain the 25 ft minimum distance within which collision protection is required. Yet AREMA recognizes that "the distance traveled by equipment in derailment is related to the speed of the train, the weight of the equipment, whether the side slopes tend to restrain or distribute the equipment and the alignment of the track. In cases where these factors would cause the equipment to travel farther than normal in a derailment, the required distance shall be increased." AREMA adds that other structures not mentioned in the standards may still require crash wall protection. However, the FRA required intrusion walls, in addition to crash walls, in cases where both the LRT and the CSXT tracks are on embankments with a vertical distance difference of less than 6 ft. This FRA required a crash wall on one side of the proposed LRT tracks, where CSXT operate s a live track with speeds that exceed 25 miles per hour (mph), even though the distance between the CSXT and LRT track centerlines would be 34 ft. On the other side of the LRT tracks, where NYS&W siding tracks exist on a distance of 33 ft between track centerlines, the FRA required an intrusion fence only. Apparently, the FRA requirements are less stringent in regard to sidings where travel speeds are relatively low. The FRA indicated that the where retaining walls were designed and on a vertical distance of 5 ft between the freight track and the LRT track, the retaining wall can be designed and built as a crash wall with an intrusion fence in addition.

Retaining Walls

Retaining walls are used to support higher tracks on contained fill to reduce the width of an otherwise used embankment. As such, the retaining walls act to grade separate the LRT tracks from the freight track by elevating former above the latter. Since such design result in significant construction costs, alternative studies should provide comparisons with cost to acquire adjacent property for providing sufficient distance between the track centerlines for the acceptable safety. It is likely that in high population density areas where an LRT system is planned, the real estate cost is relatively high. For the HBLRT extension project, the FRA required retaining walls to be built as crash walls with intrusion fencing between the LRT and CSXT track, even though the centerlines distance would be 34 ft. However, on the other side of the LRT tracks, where NYS&W siding is located on a distance of 17 ft from the LRT's track centerline, the FRA required an intrusion fence only.

Grade Crossings and Traffic Impacts

Grade crossings and traffic impacts are a significant issue from the point of view of the community. Obviously, the local traffic issues at the grade crossing are not of the FRA concern as long as the rail and traffic signals are designed and operating according to FRA's standards. Often when an LRT alignment is planned to share an existing railroad corridor crossed by local roads at grade, a traffic issue is being introduced, since it is designed to operate in a higher frequency (as high as 6 minutes headways) and higher speed (as high as 45 mph) than the freight train operate. In some areas where a new LRT line is planned for construction, the railroad operates on a frequency of one train to two trains per day and on an average speed of 10 mph. The impact on traffic is more pronounced where the grade crossing roads are equipped with automatic gates and every time a freight train or an LRT train that pass by activate the controller, the gate operate in a cycle of descent prior to the LRV or train crossing, staying down during the time the train enters the grade crossing and it ascent after the LRV or the train clears the grade crossing. It is understandable that an LRT operation under a frequent timetable or headways of 6 to 12 min with automatic gates at the grade crossings result in impact on currently occurring traffic queues. For example, a period of at least 30 s "warning time" that elapses between the time when the flashers are activated and the time when the train enters the crossing. The Manual on Uniform Traffic Control Devices (MUTCD) mandates a 20-s minimum but some states such as New Jersey require providing 30 s. The 12-s gate descent takes place during this period and thus it does not exacerbate the negative effect of the warning. A period, usually in a range of 7 to 15 s, elapses between the time when the train enters and the time when the train enters and the time it vacates the crossing. The duration of this period varies according to the street width, train length and average speed of the train while it is occupying the crossing. In addition, an 8-s period that elapses between the times that the gates begin and complete their ascent should be considered.

Drainage Facilities

Drainage facilities in shared-use corridor need to be addressed in the design of new LRT lines in old freight rail corridors. Experience with at least three LRT projects in freight rail corridors indicates that in some areas the freight rail tracks were originally constructed in wetlands and floodplains. In some cases, the freight rail was constructed on top of past streams located in low topography and that had been filled with the introduction of other means of transport such as trains, automobiles and trucks and for urban development. An example is the Hoboken Creek that was filled between Paterson Plank Road and 16th Street in the City of Hoboken, New Jersey for the construction of the Jersey Junction Railroad and adjacent urban development (*3*). Hoboken Creek flooded by runoff originated at the top of the Palisades and tidal rise in the Hudson River. Both flooding sources required the design of special drainage structures to protect the newly constructed HBLRT. Inherently, such stream reaches were subject to inundation resulting from runoff flowing down gradient to the low areas. When they were filled or relocated by the railroad, the water channels were filled with soil up to the bank, usually to the levels equivalent to the frequently occurring tidal levels, while neglecting the runoff conditions and inundation that occurred from the rainstorms. The freight railroad operators appeared to avoid drainage facilities design, either because of the relatively low frequency of train- trips or because of the nature of the transport that is freight. The low trip frequency result in a lower risk or probability of being inundated and damaged, while freight affected by flooding normally has carried liability limited to the value merchandise hauled which has been likely to be covered by insurance. Mass transit systems such as LRT operate very frequently, 6 to 12 min headways are not unusual in densely populated areas. In areas where inundation result from flash flooding, there is a high probability that the LRT system would be affected by storm events, while the risk of flooding to less frequently operating freight trains is significantly lower. Furthermore, the potential impact of flooding on passengers transported by the LRT is not comparable to the lower risk of damage and liability to freight. In addition, it should be remembered that commuters are customers would be repeat riders, if the transit system is safe and reliable. In the same juncture, it is clear that safety and damage concerns of flooding on freight systems are significantly different and less in potential impact. Therefore, protection of LRT systems in shared-use corridors by providing drainage facilities is an issue that should not be ignored keeping in mind the number of passengers who may be affected by flooding.

Like earthquakes, flooding occurring during extreme storms such as the design storm event is unpredictable but may result in significant damage and impact to commuters. All LRT projects, including projects located within shared-use corridors, need to be designed and constructed with drainage systems that adhere to federal and/or state standards, despite the inherent differences in LRT versus freight. Even though some modern elements have been introduced in the drainage design standards of freight rail operators, such standards have not been implemented along many miles of freight rail corridors operated solely for freight. Therefore, one of the significant challenges in design of modern and safe LRT systems in shared-use corridors is folded within the existing freight rail ROW. The existing freight facilities and shared operations make the task of designing an LRT for future operations of tens of years with today's standards to be not an easy task. An example of a project where such challenge has been tackled is the HBLRT where facilities have been designed consistent with modern criteria and with effective drainage systems.

RECOMMENDATIONS FOR FUTURE DESIGN AND OPERATIONS

No much has been documented for shared-use corridors in technical manuals, design handbooks or regulatory issues. Even though there are many operating transit systems in existing freight rail ROW. The "Catalog of Common Use Rail Corridors" by Randy Resor, prepared for the FRA in 2003, is the first step in a needed process of preparing an inventory of existing shared-use corridors and operations of transit and freight trains, preparation of technical research for facilities design for side-by-side safe operations of both mass transit and freight trains, develop research and standards for maintenance of freight tracks for minimizing derailment probability, develop research for operations of shared-use corridors and roadway crossings of tracks and develop design criteria.

Inventory and Compilation of Existing Data

Again, the "Catalog of Common Use Rail Corridors" is the first step. There are additional data that need to be collected for research. Records for the inspections of the freight tracks and trains, records for maintenance of tracks and other equipment (including trains, signals and switches), records of accidents (particularly derailments) need to be collected. All the collected data and records need to be reviewed and prepared for research.

Technical Research for Safe Facilities and Joint Operations

The wealth of data from successfully operating can be also used as the basis for developing design charts, tables or directives. The basic parameters that influence the design, construction and simultaneous operations of freight and LRT within the same corridors are the distances between the centerline of tracks, vertical distances between the tracks, speeds of operations, alert systems, protective structures and other options of separation such as grade crossings. Other parameters may provide a guide for probability of derailment that can be considered in future design.

A review of the existing operating systems indicates that there are shared-use corridors where the distance between the centerline of the freight track and the mass transit track is 13 ft without fencing. Example can be found in New Orleans Public Belt's ROW where the regional transportation authority operates the Riverfront Line that includes a streetcar (not a light rail). However, the speed limit of the freight railroad is 15 mph in the downtown area adjacent to the Riverfront Line. The economic advantages of avoiding construction of crash walls and fences, where possible, would be great over the years to come with the extent planned new light rail in shared-use corridors. While the practice and a wealth of data have existed for many years for the shared-use corridors operating under various track centerlines, operational speeds of both LRT and freight trains, vertical distances and protection structures, no official research has been performed to develop design relationships among these parameters and other parameters such as probability of derailment, cost of construction of intrusion walls, crash walls, retaining walls, and grade separation. Basic relationships needed are primarily among the following parameters: centerlines distances, operational speeds of both LRT, trips frequency and probability of derailment, whether expressed graphically, in a tabular format or in text, would provide more insight for review of the existing agency regulations and potential update of the agency requirements in regard to shared-use corridors.

Research for Maintenance of Facilities and Derailment Probabilities

Existing records collected for the maintenance of existing freight tracks, accidents and derailments need to be reviewed and used for understanding of maintenance and operational safety requirements in shared-use corridors. Particular emphasis should be placed on studying the probability of derailment occurrences under various operational speeds and facility condition, dynamics of derailments and impacts. Also, understanding of inspection and maintenance frequency and operation speeds required to avoid or minimize probability of derailment is very important for developing standards for maintenance for safe operations. Here the FRA can provide data. FRA requires most freight trackage to be inspected either once or twice per week, and maintains the Railroad Accident/Incident Reporting System, to which railroads must report all derailments, collision, and other accidents exceeding a specified cost and all injuries to persons

Research for Joint Corridor Operations and Roadway-Track Grade Crossings

Is indicated above, roadway crossings of shared-use corridors require research and development of signal systems that operate such as to replace the automated gates that stops the automobile traffic when trains approach the grade crossings. The objective is to reduce potential traffic delays that may result from the descent and ascent of automatic gates for crossing trains. Thinking on how to reduce such traffic delays has indicated that the potential replacement of the automatic gates system with a Constant Warning Time. This method is particularly applicable to freight rail operations. However, further research and development is needed.

Design of Drainage Facilities

Design of drainage for shared-use corridors, like traffic issues related to existing roadway-tracks grade crossings, has to consider factors originating outside of the ROW, while considering the existing freight facilities and proposed shared use. Some rail operators, such as Conrail, developed their own drainage design for freight operations. Currently, drainage design standards for new LRT projects in shared-use corridors are being prepared expressly for each project. Research is needed to identify the current drainage design practice of freight and the characteristics of existing drainage systems, to determine the risks and probability factors considered for joint use of existing corridors.

Development of Design Criteria

As stated before, there are no published unified design criteria for the design and construction of LRT systems in freight rail corridors. New LRT systems have been planned and designed based on discussions with the FRA and FTA for each specific proposed system in relationship to the existing freight ROW. The data available from the numerous shared-use corridors and the suggested research in the above sections can be used as a basis for developing a general standard document or guidelines acceptable by both agencies. Unified design criteria endorsed by both the FRA and FTA would bridge potential differences between the two uses of the shared-use corridors and would provide the planner and the engineer with the tool for planning and design of facilities and operations based on research.

SUMMARY AND CONCLUSIONS

LRT system use of existing freight corridors is anticipated to continue to grow due to the shortage of available mass transit ROWs in densely populated areas. While such corridors present a clear economic and land use advantages, they also present concerns and challenges. The challenges relate to safety concerns and consideration of existing facilities that were constructed tens of years ago under old design criteria, relatively sparse land development in the adjacent municipalities and the high frequency (6- to 12-min headways) usage of the corridors by new LRT systems as compared to relatively infrequent freight train operations.

The inventory prepared by the FRA is a first step additional data and collection of operation and maintenance records, equipment and facilities inspection records, derailment and accident records will be needed to serve as a basis formulation of design standards. It is recommended that the additional data and records and additional technical researching and design criteria be used in a joint effort by FRA and FTA to develop design manuals.

Research of investment in upgraded maintenance of facilities and potential reduction in probability/risk of derailment and accidents in comparison to investment in structures as crush walls is recommended for examining the potential replacement structural measures with safety achieved in well maintained systems. Research related to effective operations of roadway-track grade crossings and effective drainage design.

This paper is intended to be used as the first step in research and development and preparation of design manual and design criteria of LRT facilities and joint operations of LRT and freight with safety, as a center issue in mind.

Design manuals for joint-use corridors should address the following criteria:

- Track Spacing;
- Fencing;
- Vertical Separation;
- Crash Walls;
- Operation Speeds; and
- Drainage.

REFERENCES

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3. General Historical Map of the City of Hoboken, N.J., Robert C. Brelle, Hoboken, N.J., 1906.

DISCLAIMER

References to the Hudson–Bergen Light Rail Transit system in the paper do not necessarily reflect the opinions of NJ Transit, FRA, or the railroads companies.