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## Supplementing and Updating TCRP Report 52: Joint Operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads

*This digest summarizes the findings from TCRP Project A-17A, "Supplementing and Updating TCRP Report 52: Joint Operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads." This work was performed by Edwards and Kelcey, Inc. David Phraner served as the principal investigator.*

This digest supplements and updates *TCRP Report 52*, "Joint Operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads," published in May 1999. This digest updates information in *TCRP Report 52* to recognize the Federal Railroad Administration (FRA) and Federal Transit Administration (FTA) joint statement of policy concerning shared use issued in July 2000, provides supplemental information concerning the international experience with joint operation, and updates a discussion of the key issues and conclusions. As in the case of *TCRP Report 52*, this digest defines joint operation as commingled, simultaneous train operation on shared track by railroad trains (freight, passenger, or both) and rail transit vehicles that are not fully compliant with current FRA regulations.

## PREFACE: BACKGROUND AND SUMMARY OF *TCRP REPORT 52*

### Background

*TCRP Report 52,* "Joint Operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads," was originally published in May 1999. The report was intended to provide seminal research on joint operation issues between railroads and rail transit. For the purposes of this report, joint operation was defined as commingled, simultaneous train operation on shared track by railroad trains (i.e., freight, passenger, or both) and by rail transit vehicles that are not fully compliant with current FRA regulations. The report approached the subject comprehensively, including regulations, institutions, historical context, operations, infrastructures, and rolling stock aspects. The report also treated risk assessment and overseas experience with shared track. Also, in mid-1999, the FRA and the FTA jointly introduced a policy statement on shared track within the United States. The policy statement was finalized in 2000. Subsequently, overseas study missions, sponsored by the Transit Cooperative Research Program (TCRP), the FTA, and others were organized to visit key shared-track locations and learn from practices and technologies observed firsthand. Other shared-track activities included the formation of an American Public Transit Association (later the American Public *Transportation* Association, or APTA) working group, sessions at APTA and the Transportation Research Board (TRB) conferences, specialty conferences on joint use and shared track, and agenda items on TRB, APTA, and other committee meetings. All of these activities produced new information subsequent to the publishing of *TCRP Report 52*. These developments led to a decision to develop a document that supplemented and updated information presented in *TCRP Report 52*.

The following summary of *TCRP Report 52* is intended to provide continuity between the original report and this update.

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## Summary

*Rationale*

Rising transport congestion, increasing costs, and greater environmental sensitivity compel transportation practitioners to consider new ways of achieving more system capacity. Joint use of facilities is one means of maximizing use of transportation investments. However, physical, operational, and regulatory differences between rail users tend to preclude the potential economies offered by joint operation.

*Definitions*

"Rail transit," for the purposes of this research, includes *metropolitan-based* systems, such as light rail (i.e., streetcar derivative), rail rapid transit (i.e., subway and elevated-type urban railways), and diesel multiple unit (DMU) vehicles (i.e., rail buses that are bus- or light rail–derivative). Railroads are defined as part of a *nationally based* system with compatible physical and operating standards that permit full interchange of rolling stock, personnel, technology, and practice. "Joint use" is a broad term, covering various common usage facilities, including track sharing. "Shared track" includes simultaneous use on the same track.

*The Problem*

One of the most timely and controversial aspects of facility joint use is shared track between railroads (typically, heavy locomotive-hauled train consists) and rail transit (e.g., light rail cars). At issue is that none of the previous rail transit modes are considered compliant with FRA standards for railroad safety. Rail transit, therefore, faces a "steep burden of (safety) proof" to mix with railroad operation on common tracks. Exceptions are considered by petitioning the FRA for waivers.

Joint use of tracks among passenger and freight entities was once a long-standing tradition among individual railroads. Railroad management once provided comprehensive (i.e., both passenger and freight) services together on common tracks in all but the most congested environments. As railroads in North America were reorganized and deregulated, however, passenger and freight business tended to become separated both physically and institutionally. Public-sector passenger services and private-sector freight railroads now compete with each other for track space, and railroads grant trackage rights to one another only when it is in their common business interest to do so or when they are compelled to do so by regulation. The resulting competition for track space is made manifest in a track tenant-and-landlord relationship.

Commingling, or concurrent operation, of railroad trains and light rail transit (LRT) on common tracks introduces additional complication because these rail modes are regarded as incompatible by rail carriers and regulators. Safety, risk, and liability are popular reasons for keeping railroad and rail transit physically or temporally separated, whereas cost savings, safety, and public convenience are popular reasons for sharing track between rail transit and railroads. Historical domestic and overseas precedents, however, successfully demonstrate the validity of shared track when accompanied by regulatory safeguards, at least in places where shared track is commonly practiced. *The central dilemma of track sharing is that the standards accepted by railroad and those of rail transit are considered to be incompatible in four major joint-use characteristics:*

- Regulation,
- Operation,
- Physical plant, and
- Vehicle.

*Approach*

The previous four rail system characteristics make up the core research structure of this digest and its predecessor, *TCRP Report 52*. All joint-use issues fall within one or more of these four categories. From a comprehensive investigation of the four characteristics, the research team identified key issues governing joint use. These issues included

- Quantifying joint-use exposure to liability and risks;
- Identifying mitigation measures to reduce any joint-use risks to levels acceptable to rail carriers, regional decisionmakers, and regulators;
- Balancing requirements for rail system safety, capital cost savings, efficiency, and public convenience in a joint-use context; and
- Selectively transferring and applying overseas joint-use experience, practices, and technology.

Secondary issues were also identified, such as crashworthiness (i.e., the ability to sustain a crash) versus crash avoidance (i.e., the ability to prevent collisions). These issues provided a policy overlay to the four major joint-use features listed previously. Each of the four joint-use features was treated separately for the purposes of information gathering and other research exposition.

*Regulation*

Railroads are part of a common standard, regulated, interconnected national system of tracks, interchangeable rolling stock, and similar operating rules. Rail transit has none of these characteristics. Rail transit systems are separate metropolitan or state-based entities whose standards and rules (and even track gauges) can vary. Rail transit vehicles (except commuter rail vehicles) are considered non-compliant with federal railroad standards. Railroad tracks, therefore, may connect the metro areas, but not with rail transit systems within the metro areas. Railroads are regulated by the FRA for safety issues and by the Surface Transportation Board for other issues. States with rail transit are using statewide safety system program plans (SSPPs) to strengthen rail transit regulation. The SSPP effort is directed at all modes of rail transit and is organized by the carriers largely through APTA with the sanction of the FTA. Rail transit regulations may largely be performed regionally, but apply federal guidelines. Temporary waivers (for demonstrations of noncompliant equipment and special circumstances) and exceptions are granted by the FRA.

In North America, three light rail systems (in Salt Lake City, San Diego, and Baltimore) currently host railroad freight operations on their tracks, but the host light rail and tenant freight trains are separated temporally. Freight trains run only during night hours, when light rail service is curtailed. Often cited as "joint use," these three contemporary shared-track arrangements are not considered joint use for the purposes of this research because freight trains and light rail vehicles (LRVs) do not commingle, or operate concurrently, on the same track. Other shared-track projects are planned.

*Operation*

Joint use in North America can be viewed from two institutional conditions:

- **What is currently operationally achievable** (i.e., trackage rights, joint operating agreements, temporal separation, and temporary waivers) and
- **A future joint-use (including shared-track) operating ideal** (i.e., commingled operations and applying overseas practices and stringent risk assessments to make rail "new starts" affordable where they are considered otherwise infeasible).

Although there have been historical precedents for various operating practices on shared track, these practices have disappeared, along with the corporate culture and motivation that fostered them. There are, however, contemporary cooperative track-sharing operations that provide useful North American operating experience. Notable among these operations is the Northeast Operating Rules Advisory Committee (NORAC). Nine trunk freight and passenger operators and 27 associate member carriers adopted common operating rules that govern any member employee when the employee operates on another member's tracks.

Freight railroad concerns center on initiation of joint-use operations, liabilities, revenue implications, and the ability to expand on limited shared-track space if freight and rail transit businesses prosper and grow simultaneously.

*Physical Plant*

Freight railroad or any railroad and light rail have different performance and operating characteristics. The modes affect track and rail infrastructure in different ways. Beyond contrasting wear and tear, dimensional differences created by wayside transit structures (e.g., high-platform stations) can restrict a railroad's physical operating envelope. Technological solutions (e.g., gauntlet tracks for high-platform stations) exist to resolve these physical plant incompatibilities, but applying these solutions in the case of light rail and railroads is challenging. Some signal technologies under development, such as positive train control and positive train separation, hold promise as mitigation to reduce safety risk and accident exposure in future joint-use scenarios. Some overseas solutions can be applied in North America.

*Vehicle*

Contrasting railroad and rail transit vehicle design standards are the cause of the most prominent safety concerns by rail operators and regulators. LRVs are relatively homogeneous rail car types, but for the purposes of dealing with the family of DMU car types, it was necessary to propose three categories of DMU cars:

- **Category 1—**Railroad-derivative design, *FRA-compliant* rail cars (e.g., Budd RDC) capable of mixing with conventional railroad train movements and consists.
- **Category 2—**Light rail, railroad, or bus technology–derivative designs, *FRA noncompliant* for low-density railroad, isolated branch line, or regional rail new start applications, but prohibited from mixing with railroad operations in the United States. Current lightweight DMUs fall into this category.
- **Category 3—**Light rail–derivative design, *FRA-noncompliant* rail cars capable of operating on railroad track and streetcar track geometry with dual (i.e., diesel and electric) traction power. Though definitions vary, this category might be termed "diesel-electric-electric light rail vehicle" (DLRV) because it can perform in streetcar and railroad environments, but is currently prohibited from mixing with U.S. railroad movements without an FRA waiver.

The research team surveyed manufacturers of LRV cars and manufacturers of DMU cars (all three categories). From the survey responses, an inventory of current rail car models and types was assembled. None of the Category 2 and 3 cars were FRA compliant, and some of the Category 1 cars were provisionally compliant. The North American rail safety emphasis on *collision protection* (in contrast to European emphasis on *collision avoidance* and *impact attenuation*) came into focus when the research team reviewed the performance and physical characteristics of various car types. For example, railroad buffing (i.e., car body–compressive) strength for overseas railroads is in the 300,000- to 400,000-lb range, while North American railroad requirements are nearly twice that, at 800,000 lb. Typical light rail car buffing strength is far less than 200,000 lb. The basic remedies are not complementary. Making rail cars stronger to sustain collision forces (i.e., to ensure collision protection) creates a heavier car that is unable to stop in shorter distances, thereby sacrificing performance (i.e., sacrificing collision avoidance).

*Key Joint-Use Issues*

The major issue emerging from the data collection phase of the research concerned balancing public interests. Can public safety (i.e., reduced risk), public convenience (i.e., having more and better rail transit), and public cost (i.e., saving by using existing track rather than constructing parallel redundancy) be balanced? The research team addressed the analytical portion of the research by considering two broad types of remedies to the key issues:

- **Risk assessment process and guide** to estimate the risk of case-by-case, joint-use scenarios and then apply risk mitigation to reduce risk to acceptable levels and
- **European and Pacific Rim joint-use experience** and transferability of technology and practice to North American railroad and rail transit environments.

*Risk Assessment*

Risk assessment is an accepted practice in the United States and overseas in evaluating the feasibility of various undertakings, including joint use between railroad and rail transit and between railroad trains of different types. A federal regulatory framework is appropriate to ensure that any local analysis and decisions are valid (as done in Germany). Information from the German Ministry of Railways (i.e., from the Düren, Chemnitz, and Cologne proposals) and from the FRA (i.e., from the Northeast Corridor and Florida Overland Express proposals) revealed that fundamentally similar risk assessment processes are used by both foreign and domestic organizations to evaluate exposure of joint use. In the United States, high- and low-speed railroad joint operations are assessed for risk. Overseas, risk assessment is applied to railroad and light rail shared-track practices. Domestically, safety data on accidents, injuries, and fatalities were assembled from the National Transportation Safety Board, the FRA, and other sources. These data revealed an overall trend between railroad and rail transit toward increasing safety and favorable accident experience. This trend proved to be a "fortunate dilemma" for the research team, because the absence of accident experience limited the research team's ability to conduct data-dependent risk assessment.

In *TCRP Report 52,* a risk assessment guide was developed to help reduce possible misunderstanding of risk assessment for state and metropolitan transportation practitioners. The research team concluded that risk assessment is an *optional* device for practitioners wishing to introduce or expand rail transit. Risk assessment may be inappropriate to apply when joint use is infeasible for reasons other than safety risk or when there are no right-of-way assets available on which to apply shared-track practices.

*European Experience*

Although the debate will continue on how and whether Germany's or the Pacific Rim's joint-use practice can be applied to North America, research disclosed that

- Similar institutional and regulatory barriers to joint use existed overseas;
- These barriers were overcome or mitigated;
- The attitudes of railroad and transit management underwent a change;
- Risk assessment played a key role in regulatory change;
- Regulation of railroads and rail transit overall did not relax, but became a major determinant in joint-use achievements (unlike North America, Germany federally regulates its rail transit systems in addition to its railroads); and
- Metropolitan, "bottom-up" joint-use innovation influenced the speed and direction of shared-track developments.

The most innovative and advanced joint-use practices were found in Germany, specifically at the city of Karlsruhe. Three case studies were investigated, representing three different, modest-sized metropolitan areas in three distinct stages of joint-track use implementation. These case studies were updated and supplemented by additional case studies of Düren, Köln, and Zwickau. The three original studies are as follows.

- **Karlsruhe:** Joint-use growth, expansion, and diversification over a decade.
- **Saarbrücken:** Joint use in first years of operation and more applicable to North America.
- **Luxembourg:** Joint use in planning (implementation is now deferred).

Joint-use concepts are being investigated widely in Western Europe. At the time of the research project, several metropolitan areas had implemented or were about to embrace joint use. Eighteen joint operations in various nations were briefly profiled, and more than 20 other European cities in early planning stages of joint use were listed. All of the metro areas listed experienced changes in institutions (e.g., privatization), regulation (e.g., the European Commission transition), funding (e.g., regionalization of rail transport), and other environmental conditions that accompanied and helped bring about joint-use innovation in Europe.

*Pacific Rim Experience*

Japan is a major practitioner of joint use; in fact, Japan's joint-use practices are more extensive and diversified than

Germany's are. More than 160 operations were examined by the *TCRP Report 52* research team. From these operations, six joint-use case studies were selected for analysis. Each case study demonstrated different types of joint use, including

- Railroads extending through and integrating with rapid transit subways in central business districts (CBDs) to distribute their passengers;
- Rapid transit (i.e., subway) entities extending their reach over railroad lines;
- Combinations of the previous two types of joint use, with interurban railways starting and ending their trips in subways of neighboring metropolitan areas while running on their own tracks between these cities, or with rapid transit trains sharing tracks with the interurban trains at the periphery of the respective urban areas in reciprocal running;
- Third-sector (i.e., public-private venture) railway rail buses operating on Japan Rail (JR) tracks and a mix of rail buses, freight, and passenger railroad trains on third-sector railway tracks;
- Light rail and interurban operating jointly on streets in high- and low-platform modes as part of a system of comprehensive and varied rail services; and
- Local light rail operating with locomotive-hauled freights under common management.

Japan and the two other Pacific Rim examples profiled, Hong Kong and Seoul, demonstrate an ability to fulfill their rail transit plans by employing reciprocal (i.e., joint) running among railroads, interurbans, and rapid transit operations. In Japan, among the metropolitan areas covered, more than 789 *route* miles of rapid transit service expansion (over railroads) was achieved in the last 20 years. In the Seoul and Inchon metropolitan areas, almost 230 mi of rapid transit "subway" service expansion was accomplished using joint use with the national railroad as a tool for service expansion. The Japanese rail rapid transit service expansions would have been totally unaffordable, at an estimated \$79 billion (790 mi × \$100 million). The lesson learned goes beyond saving construction dollars with joint use; its real value is expediting rail projects that would otherwise never happen.

In Japan, joint use is a matter of business practice rather than regulation. Japanese federal regulators focus their attention on licensing and controlling potential monopolies. As a matter of routine, they do not regulate rail car performance and specifications. The distinction between rail modes in Japan has become blurred, largely because joint-use practices encourage standardization of rolling stock and operating practices over time. Some Japanese joint-use experience has already been applied in North America. Japanese *daisan*, or third-sector, ventures have a nearly North American equivalent in the joint venture and design, build, operate, and maintain (DBOM) turnkey and public-private enterprise currently being proposed in North America.

There is no direct Pacific Rim equivalent for Karlsruhe or the common other European joint-use case studies mentioned previously. This fact may be because Germany retained and developed its light rail systems to a higher degree than Japan did. In that respect alone, the Japanese experience may be more applicable in North America, where streetcar systems were largely dismantled in favor of motor coaches for metropolitan transit.

*Conclusions*

The principal conclusion from the *TCRP Report 52* research is that joint use has potential for implementation in North America, but under limited and controlled circumstances. More research into safety practices and technology is needed to refine the way shared track is applied in North America.

Critical circumstances can be defined and managed primarily by a risk assessment process within a regulatory context. As a tool, risk assessment measures the probabilities and exposure of various physical alternatives and operating plans. It also tests mitigation options to reduce risk to a tolerable level to satisfy regulators and joint operating partners. Accompanying risk assessment are other analysis techniques and a policy framework by federal and state regulatory entities. The planning structure to accomplish risk assessment is already in place with the state and federally sanctioned metropolitan planning organization (MPO) comprehensive planning process. The regulatory structure is coming into place with the renewal of state safety oversight of rail transit through the SSPP, with federal railroad safety rule making, and with shared-track policy statements.

More research is needed in the specifics of German regulation, operating practices, and use of risk assessment. Intensive further investigation is appropriate to learn Karlsruhe's technology and operating practices *as an ideal rather than a model*.

Saarbrücken, Düren, Kassel, Zwickau, and Cologne (Köln) offer more achievable examples of shared-track application for North America. Most of the physical aspects of German joint use are already well known through existing literature. The institutional and regulatory aspects, however, are more obscure. The German Railway Ministry provides useful examples of assembling and tabulating accident data in support of risk analysis. These techniques are fortified by safety data, which constitute another area deserving more attention. Risk analysis techniques need further testing and validation with actual case studies. There is more to learn from the Japanese application of third-sector business experience to a variety of ventures, with joint use of tracks being only one such venture.

Expectations for future research on shared-track practice vary. The research may be expected to be less generic and to specialize in areas of acute interest to rail system operators and regulators. Demonstrations to test research hypotheses may also become part of the research mix that advances knowledge and understanding of shared-track practice and technology.

## CHAPTER 1: INTRODUCTION

Over the past 20 years, regulatory, planning, and institutional circumstances have combined to increase the importance of and illuminate the issue of track sharing between railroads and rail transit.

Seven circumstances result in the gradual loss of surplus vacant or abandoned railroad right-of-way:

- There is increasing demand for rail travel service. In many areas of the United States, local communities are planning or developing LRT systems.
- LRT operations have been developing at an average rate of nearly two all-new systems per year over the past 20 years. The tally includes nearly 15 new LRT and 25 new Vintage Trolley systems. These initiatives use up former railroad right-of-way and tracks or other rights-of-way in the areas they serve.
- These rail transit "new starts" exhaust vacant right-of-way space, thereby creating demand for sharing track when the supply of vacant rights-of-way is fully depleted. Competition for track space increases on the remaining active railroad lines.
- There is potential for satisfying demand by using shared right-of-way or shared tracks when regulatory authority permits. As North American railroads merge and reorganize, branch lines are abandoned or sold to short line and regional railroads. Surplus track capacity is common among many of these light-density rail lines.
- Railroads and rail transit demonstrate improved safety records, but the infrequent rail accidents create clamor from the public, which presses for reform and regulatory remedy.
- Surplus railroad right-of-way and surplus track have a limited existence before they are lost to reverter clauses, bike and pedestrian trails, encroachments, or local non-use sentiments against resuming rail operations.
- All but one of the first-generation new LRT systems, such as San Diego, Baltimore, Edmonton, Calgary, and St. Louis, are expanding significantly. More new starts and system expansions are planned. Most of these expansions use, in part, existing railroad right-of-way or track to advance their expansion plans.

As opportunities to share rights-of-way diminish, rail transit operators and planners are re-examining the potential of sharing track. The FRA and FTA became concerned over the potential safety issues arising from the number of shared-track operations being planned around the United States and the level of interest being generated by shared-track proposals.

As a research-sector response to this interest, *TCRP Report 52* was published in May 1999.

At about the time that *TCRP Report 52* was published, the FRA and FTA issued a draft joint policy statement on shared use. This policy, in final form, is detailed in Chapter 2. Introduced in May 1999, the draft policy statement underwent an extended review and comment period. The FRA also issued a separate policy statement in November 1999 to detail its statutory jurisdiction and to explain the waiver process relating to shared track. About 50 comments and position papers were received on these draft policy statements. Final policy statements were issued on July 10, 2000 (note Federal Register Vol. 65, No. 132, pp. 42,529–42,553, FRA 49, Code of Federal Regulations [CFR] 209 and 211, FRA/FTA pp. 42,526–42,528). The final statements included a joint FRA and FTA policy document and an FRA policy statement describing federal safety concerns and the details of a waiver process for regulating shared-track proposals.

These final policy statements are not regarded by the FTA and FRA as new rulemaking. The policy is instead intended to interpret and detail existing FRA regulatory scope governing the "general railroad system" in North America. The detail and effect of these policy statements, specifically in the application, review, and granting of FRA waivers, are discussed in greater detail in Chapters 2, 3, and 5.

Much of the current and emerging rail system regulation is based on achieving and enhancing safety for the general public, customers, and employees. In promoting safety, the regulatory safety process may sometimes inhibit or even conflict with contemporary economic, technical, or operating objectives that provide greater rail transit travel opportunities. Proposals for joint operation between freight railroad or passenger railroad and lightweight, lower-cost transit rail vehicles are especially vulnerable to contrasting objectives between safety regulation and expanded or improved transit service. These factors come into consideration in planning new light rail or commuter rail transit proposals.

Formerly, rail transit and railroad regulatory scope encompassed both safety and business practices of carriers under the Interstate Commerce Commission (ICC). Since the 1981 "deregulation" and subsequent elimination of the ICC, emphasis has shifted to safety under the FRA, while business considerations (e.g., market entry, competition, rates, and service) have diminished somewhat under the Surface Transportation Board. Introducing prototypical or experimental lightweight rail car technology to the railroad environment is currently discouraged, although regulatory waivers can be obtained for FRA-noncompliant equipment. It is important, therefore, to evaluate the benefits and effects of current regulations while balancing conflicting public interests that confront joint operations on shared tracks or rights-of-way.

## Project Objective

The objective of this research was to supplement and update *TCRP Report 52* in light of new developments that have occurred since the report's publication, most notably the July 2000 issuance of the joint FRA and FTA policy regarding shared use.

A number of track-sharing activities and changes meriting research documentation have occurred since the publication of *TCRP Report 52*. These activities and changes include overseas study missions, track-sharing innovations and technology, new starts in North America and abroad, petitions for and granting of track-sharing waivers by the FRA, and the beginning of a more detailed joint-use research agenda. This digest includes information on these activities and developments.

## Digest Background

### *Focus and Scope*

This digest focuses on evolving issues and circumstances following the publication of *TCRP Report 52* in May 1999. Primary attention is given to the FRA and FTA final policy statements on shared track. Two major policy statements were issued. The first is a relatively short joint FRA and FTA statement on ways in which the two agencies will coordinate their relative safety jurisdictions. The second policy statement is a more extensive and detailed clarification of the FRA's policy. This policy clarification by the FRA details the FRA's position on its safety jurisdiction as applied to shared track and joint corridors. The scope of this digest includes shared track only. The FRA's policy statement also explains the waiver petition and review process.

Another development occurred subsequent to the publication of *TCRP Report 52:* Diesel multiple unit (DMU) rolling stock technology has advanced rapidly in the United States and overseas in the last 5 years. This advancement has somewhat expanded the scope of joint-use interest, from light rail electric vehicles sharing their tracks with freight trains to lightweight DMUs operating on railroad tracks. The track-sharing result is the same, and the same regulations apply, but the rolling stock technology and institutional arrangement may vary.

Shared-track regulation, policy making, and operating precedent generated issues that are summarized and updated in Chapter 4. Chapter 5 provides some conclusions and suggests topics for further research.

To provide continuity with *TCRP Report 52*, a few short elements, such as the summary and Table 1, are repeated in this digest. Short supplements to the original bibliography and glossary are added.

The joint-use rail issue is broad in scope and covers a range of joint-use opportunities. Table 1 shows the extensive range of the subject and provides a preliminary comparison of the degree of compatibility between rail transit rolling stock types and facility or modal types.

Joint railroad and LRT operations of the Salt Lake City, San Diego, and Baltimore LRT systems, though temporally separated and not commingled, are detailed in *TCRP Report 52*. Shared-track experience in North America is expanding, most recently with the first modern light DMU applications of rolling stock in New Jersey (Southern New Jersey Light Rail Transit) and Ontario (Ottawa-Carlton Transpo).

Against the backdrop of modal typology, the quest for seamless travel and research on integrated rail systems continues. The current issue to be confronted is the physical, operational, regulatory, and institutional integration of the rail modes. Within this issue, an emerging focus is the joint use of facilities, including tracks and interchange of rolling stock.

### *Emerging Advantages and Disadvantages of Joint Use*

From the perspective of the transit user and operator, joint-use operations are attractive for a number of reasons. Joint use

- Reduces or avoids costs in building, maintaining, or operating separate parallel tracks and infrastructure where there is sufficient capacity to share one set of tracks;
- Enables expansion of rail transit services and capacity without creating additional facilities, public takings, or environmental or social disruption;
- Encourages service integration, which would provide extended routes or reciprocal running and, thus, reduce passenger transfers between modes;
- Increases the feasibility for new starts in metro areas where rail transit is absent but desirable;
- Can be made consistent with other railroad business practices, such as development of cost centers, as in current U.S. and European experience; and
- Increases opportunities for incremental financing of rail transit on rail infrastructure that is underused or disused.

Despite the previous advantages, joint use has a downside: risk. Within the next few years, case-by-case risk assessment and waiver petitions to the FRA will govern joint-use protocols until safety and data precedents are established.

The U.S. highway accident fatality rate of 0.97 per 100 million passenger miles exceeds by a large margin the commuter rail fatality rate of 0.03 per 100 million passenger miles. The public is willing to accept a higher risk of accidents on highways; however, although rail is safer, the public expects to be protected by a regulatory system. Also, a single railroad incident could involve many more people than any highway incident likely would involve, and liability claims would be much greater.

**TABLE 1 Joint-use compatibility and scope**

| **Facility** | **ROLLING STOCK** | | | | |
|---|---|---|---|---|---|
| | **LRV** High-Floor | **LRV** Low-Floor | **DMU** Category 3 | **DMU** Category 2 | **DMU** Category 1 |
| **RR** Freight Branch | B,C | B,C,D | B,C,D | B,C,D | A,B |
| **RR** Freight Main | C,D | D,E,F | D,E, | D,E | A |
| **RR** Passenger Commuter | C,D | D,E | D,E | D,E | A |
| **RR** Freight and Commuter | C,D,E | D,E,F | D,E, | D,E | A |
| **RR** Passenger High-Speed | D,E | D,E | D,E | D,E | E |
| **LRT** Mixed Traffic | A | A | C | D(F) | D,E,F |
| **LRT** R-O-W Exclusive | A | A | A | C | D,F |
| **LRT** Grade Separated | A | A | A | A | C |

**LEGEND**

Degree of Compatibility (in descending order)

A. No Unmanageable Constraints (Fully Compatible)
B. Time Separation Permissible (Limited Temporal Compatibility)
C. Potential Design Remedy Applicable (Possible Design Compatibility)
D. Buffing Strength Mismatch (Regulatory Incompatibility)
E. Performance, Station Spacing, Functional Mismatch (Operational Incompatibility)
F. Track Geometry, Clearance Constraint (Irreversible Physical Incompatibility)

DMU Categories

Category 1: FRA-compliant (or near compliant), internal combustion, or turbine railroad car
Category 2: FRA-noncompliant, internal combustion light rail type car
Category 3: FRA-noncompliant, dual-power (diesel-electric-electric) light rail car

Notes:

- For purposes of this analysis, Category 2 and 3 DMUs are assumed to be of low-floor design.
- Comparative numerical scores in the matrix can be derived from assigning numbers 0–5 in place of A–F and adding the values in each matrix box.
- No regulatory policy or direction is implied in this scoping table.

( ) = a dependency on car design features
RR = railroad
LRT = light rail transit
R-O-W = right-of-way
LRV = light rail vehicle
DMU = diesel multiple unit

Table 1 shows that the scope of this research is between light DMUs and LRVs with railroad freight branch lines, railroad freight main lines, and railroad commuter and freight combined. The table also shows the compatibility among the FRA-noncompliant type vehicles, LRVs, and Category 2 and 3 light rail–derivative DMUs. (Category 2 and 3 DMUs are of the scale and weight similar to LRVs). The table also shows the degrees of compatibility among these modes.

For the purposes of Table 1, DMU cars are divided into three categories. These categories dispel the notion that DMU describes a generic rail mode. Railroad-derived DMU designs (Category 1) are more railroad compatible than are other designs of DMU adapted from LRV technology.

A decisive factor in regulatory compatibility may be the nature and ownership of the track to be shared. Current regulation of shared track does not appear to consider ownership of track or underlying real estate. Current shared-track operations (e.g., Salt Lake City, Baltimore, and San Diego) and the forthcoming shared track (e.g., Camden-Trenton, New Jersey) feature ownership by the transit operator. Each of these properties was purchased from a railroad prior to or as a condition of sharing track. Currently, there are no domestic examples of LRVs venturing onto railroad-owned trackage. This fact is due, in part, to the limit of branch line railroad electrification and the slow domestic assimilation of new lightweight DMU technology (which needs no electrification infrastructure) for rail transit.

## CHAPTER 2: SUMMARY OF FRA AND FTA JOINT POLICY STATEMENTS

The most significant event since the publishing of *TCRP Report 52* is the issuance of Federal Policy on Shared Track in draft (1999) and final (2000) versions. What has been commonly characterized as the "policy statement" was initiated as two distinct, but related, *draft* documents issued separately in the following sequence:

- May 24, 1999 (draft)—*Proposed Joint Statement of Agency Policy Concerning Shared Use of the General Railroad System by Conventional Railroads and Light Rail Transit Systems,* Federal Register, Vol. 64, No. 100, p. 28,238, May 25, 1999, issued by the FRA and FTA.
- November 1, 1999 (draft)—*Proposed Statement of Agency Policy Concerning Jurisdiction Over the Safety of Railroad Operations,* Federal Register, Vol. 64, No. 210, p. 59,046, November 1, 1999, issued by the FRA.

After a review period through February 18, 2000, comments were received and the *final* policy statements were published as follows:

- July 10, 2000 (final)—*Joint Statement of Policy Concerning Shared Use of the Tracks of the General Railroad System by Conventional Railroads and Light Rail Transit Systems,* Federal Register, Vol. 65, No. 132, p. 42,526, issued by the FRA and FTA.
- July 10, 2000 (final)—*Statement of Agency Policy Concerning Jurisdiction Over the Safety of Railroad Passenger Operations and Waivers Related to Shared Use of the Tracks of the General Railroad System by Light Rail and Conventional Equipment,* Federal Register, Vol. 65, No. 132, p. 42,529, issued by the FRA.

### General Description and Roles of the FRA and FTA

The purpose of this chapter is to explain the features and details of key shared-track elements of the two final policy statements. The texts of the two statements are coordinated and linked by common language and policy intent, but by their nature and intent, they have evolved into very different documents. From the draft into the final version, the joint FRA and FTA statement has remained predominantly a policy document. The FRA statement has evolved into a technical, detailed legal and regulatory guideline. The statements also express the policies of the FRA and FTA toward issues and regulatory areas other than shared track, but these issues and areas are not within the scope of this research. Joint corridor issues are among the related issues contained in the statements. Joint corridors are where rail transit and railroad may share the same right-of-way, but not the same track.

The contrasting regulatory roles of the FRA and FTA and the individual state rail safety oversight agencies are only summarized in this digest (they are treated in detail in *TCRP Report 52*). The regulation policy described relates exclusively to safety. Other forms of regulation applied to market access, rates, and public convenience are sometimes referenced, but not otherwise treated in these policy statements.

The FRA's statutory authority extends to safety regulation of the general railroad system (or interstate system of common carrier railroad lines) of the United States. More specifically, the FRA defines its jurisdiction very comprehensively as the entire railroad system except isolated urban rail transit elements. Nonsafety railroad regulation matters, such as rates and market entry, are now determined by the Surface Transportation Board and, prior to that, the ICC. The FRA coordinates with the National Transportation Safety Board in the latter's investigation of railroad accidents. The National Transportation Safety Board makes recommendations to the FRA for improving safety regulations to avoid future accidents.

The FTA has no direct regulatory role comparable to the FRA. Instead, the FTA has an overall responsibility over rail transit operators, such as light rail or rail rapid transit. For example, although the FTA has no field safety inspectors and does not conduct field safety audits, it exerts its regulatory responsibilities through a congressionally mandated state safety oversight system and plan required of each state in which rail transit is operated. Though their roles are disparate, the FRA and FTA have coordinated and redefined their respective roles regarding shared track, where their jurisdictions meet. These policy statements deal with the convergence of the two federal agencies on a single issue of importance to both.

The two agencies were not required to subject their policy statements to hearings or public review; however, the FTA and FRA jointly decided to make their draft policy statements available for public review. The documents in draft form were printed in the Federal Register as cited previously. The public review and comment period yielded significant response (about 50 submittals from the transportation sector and others directed at both draft statements), resulting in some changes to the policy content. The substance of the regulation- and jurisdiction-based policy, however, remained intact, as reflected in the final policy statements.

With these policy statements, as amended in their final form, treatment of shared-tack issues is rapidly changing from a less formalized review on a case-by-case basis to a more formal regulatory administration. The use of the waiver mechanism has been expanded and clarified for granting exceptions to normal regulatory conditions. Details of each shared-track policy statement follow.

### The Joint FRA and FTA Policy Statement

The purpose of this statement is to "coordinate the use of [the FRA and FTA's] respective safety authorities with regard to shared-track operations." Other statements of joint policy coordination include

- The assertion of FRA safety jurisdiction over the general railroad system in the United States (CFR 49, Part 209, Appendix A);
- The FTA's requiring states having rail transit that is not part of the general railroad system and not subject to FRA safety regulations to develop and approve a safety oversight program (CFR 49, Part 659);
- The resolution of the jurisdiction dilemma created by rail transit vehicles moving between these railroad and rail transit regulatory realms considered separate by contemporary regulators;
- The identification of major structural safety, weight, and size rail car incompatibility from mixing rail vehicle types occupying the same tracks at the same time;
- The acceptance of temporal separation as the most risk-free means to physically separate these disparate types of rolling stock;
- The emergence and increase of proposals to share track in the advancement of rail transit new starts;
- The acknowledgement of the improving safety record of rail systems, but raising concern over the probabilities of a "catastrophic" accident with attendant loss of life;
- The introduction of the concept of "steep burden of proof" imposed by the FRA on petitions for waivers for simultaneous track sharing (in contrast to temporally separated track sharing);
- The limitation of FRA jurisdiction from operation of rail transit operations outside the shared-use part of the rail transit system (such as in-street light rail trackage);
- The introduction of the FRA waiver process to regulate exceptions when shared track will be permitted accompanied by approved safety measures to reduce risk to equivalent or better probabilities;
- The citation of an informal October 1998 interagency agreement between the FRA and FTA to bring the FRA's safety expertise to bear on the safety issues of the commuter rail grant program administered by the FTA;
- The FTA's nonvoting participation on the FRA Safety Review Board to review and recommend action on petitioner's waivers;
- The expression of a "high degree of confidence" that time-based waivers (or temporal separation) will be granted by the FRA;
- The certification by petitioners that the state safety oversight plans and the federal safety regulations are coordinated and consistent in the matter of the petition; and
- The FRA and FTA's motivation to increase opportunities for improved and expanded passenger travel in metropolitan areas through expanded use of railroad lines in ways that continue to preserve the existing excellent safety records.

### FRA Clarification of Jurisdiction and Statement of Policy

In contrast to the previous joint statement, the final statement of FRA agency policy constitutes 25 Federal Register pages. Approximately one-half of the pages are devoted to public comments on the policy and the FRA's responses to these comments. The joint policy and FRA agency policy statements cross-reference one another. The FRA defines its separate policy statement as "describing its statutory jurisdiction over railroad passenger operations." The FRA does not regard its policy as a restriction because its rules already apply to these types of shared-track operations. The FRA statement also explains the waiver process. It defines the scope of its jurisdiction broadly, but defines the scope of its exceptions narrowly for the purposes of granting waivers.

The FRA clearly favors time separation for achieving physical separation of train movements of disparate types of equipment. In recently granted track-sharing waivers, the FRA appears to grant waivers readily but conditionally under time separation. The FRA is skeptical about domestic historical and overseas shared-track precedents for application in North America and says so in its policy statement. The FRA is also skeptical of granting waivers on the basis of commingled or simultaneous operation unless the proposal is accompanied by a proven equivalent safety operating plan or FRA-compliant rolling stock. The FRA will regulate only the operationally shared-track portions of shared-track systems. In the process of defining its regulatory or "statutory jurisdiction," the FRA details other elements of its joint-use policy besides shared track. Shared- or joint-use corridors and related risk to trespassers, reporting requirements, and highway grade crossings are among the indirectly related subjects that the FRA addresses, but are not included in this research.

The FRA's safety obligations form the central rationale for application of its jurisdiction to rail transit. Safety is expressed in risk, or the probabilities of collision, injury, or fatality. Both policy statements recognize that the safety risk can be minimized or eliminated by imposing temporal separation requirements on the rail operators. For the purposes of this research, "temporal separation" is defined in *TCRP Report 52* as "time separation into lengthy blocks of time where tracks are dedicated to the use of one or the other (but not both) of the joint users exclusively." Further definition and discussion on "temporal separation" is provided in the section dealing with shared-track issues of this report.

If safety is the policy rationale and temporal separation is the preferred remedy for shared track, then the waiver process is instrumental for overseeing regulatory compliance. All rail transit and railroad shared-track circumstances require a waiver, even when temporal separation is an element of the operating and safety plan of the petitioning operator. The FRA waiver process predated the shared-track policy statement. The waiver provides a good example of the FRA's defining its existing regulatory powers and jurisdiction, even though the waiver, in the case of shared track, is arguably being applied in a new way. Granting a waiver does not mean that the FRA is relinquishing its statutory jurisdiction. The waiver will stipulate what is waived, and other aspects of FRA regulatory reach remain in effect. The waiver process serves several purposes:

- To formally notify the FRA about proposals by rail operators to execute shared-track operations;
- To review and issue a decision on the specific case-by-case track sharing proposed;
- To optionally impose safety conditions on proposed track-sharing arrangements to reduce risk;
- To periodically review whether the petitioner is in compliance with the original conditions for track sharing imposed by the FRA;
- To modify, withdraw, or nullify waiver conditions at any time, if conditions are violated;
- To enable revisiting of individual track-sharing conditions when the FRA believes that conditions of track sharing need to be adjusted;
- To renew the waiver approval (waivers are granted for a specific period and, therefore, are considered temporary and needing periodic renewal);
- To link FRA jurisdiction with the state oversight agency regulating rail transit safety and to avoid duplication and additional layers of regulation by deferring to the state oversight agency to function according to the plan and federal regulatory overlay (rather than periodically inspect to ensure operator compliance, the FRA will coordinate with the state agency on a periodic basis);
- To monitor and control the anticipated growth in numbers and types of track-sharing arrangements between rail transit and railroads; and
- To consider whether the policy needs to be revised, strengthened, or augmented (e.g., the FRA amended its policy definitions after the comment period and decided to codify its policy "for purposes of easy reference" in the CFR; therefore, the FRA added an appendix to existing regulations to clarify the FRA's jurisdiction, including an amended Appendix A in CFR Part 211 on rules of practice regarding waivers applied to shared trackage).

Key to understanding the use of the waiver process, as set forth in the FRA's policy statement, are the statements of policy citing basic conditions considered in granting a waiver petition:

- Because of grave concerns about operating two incompatible types of equipment simultaneously on the same track and other considerations, the FRA may permit simultaneous shared track, but only when the petitioner meets a steep burden of demonstrating that an alternative safety measure will reduce risk of collision.
- Both the FRA and FTA are highly confident that the FRA will provide the waivers that rail transit carriers need to operate on a time-separated basis.

The chances of obtaining a waiver for true simultaneous shared track are sharply reduced over temporal separation. The interpretation of the term "waiver" varies within the transit and railroad industry. Some practitioners declared in public comments that the waiver may connote some pre-existing rule violation or that a blanket-type waiver be issued to adopting standard safety practices or equipment. Other practitioners believed that the FRA need not impose its jurisdiction when temporal separation and compliance with SSPPs are demonstrated. The waiver method of regulating by exception is clearly a debate and is dealt with in the issues chapter.

At the conclusion of its policy statement, the FRA issued guidance in tabular form for possible waiver petitioners (see Table 2). Entitled "Possible Waivers for Light Rail Operations on the General Railroad System Based on Separation in Time from Conventional Operations," this table provides useful summary guidance in taking the first steps of preparing a petition for waiver, assuming temporal separation. In the table, the FRA defines which issues it will defer to state oversight, when compliance will be encouraged, what falls

**TABLE 2 Possible waivers for light rail operations on the general railroad system based on separation in time from conventional operations**

| Title 49 CFR part | Subject of rule | Likely treatment | Comments |
|---|---|---|---|
| **Track, Structures and Signals** | | | |
| 213 | Track safety standards | Comply (assuming light rail operator or its contractor has been assigned responsibility for it). | If the conventional RR owns the track, light rail will have to observe speed limits for class of track. |
| 233, 235, 236 | Signal and train control | Comply (assuming light rail operator or its contractor has responsibility for signal maintenance). | If conventional RR maintains signals, light rail will have to abide by operational limitations and report signal failures. |
| 234 | Grade crossing signals | Comply (assuming light rail operator or its contractor has responsibility for crossing devices). | If conventional RR maintains devices, light rail will have to comply with sections concerning crossing accidents, activation failures, and false activations. |
| 213, Appendix C | Bridge safety policy | Not a rule. Compliance voluntary | |
| **Motive Power and Equipment** | | | |
| 210 | Noise emission | Waive | State safety oversight. |
| 215 | Freight car safety standards | Waive | State safety oversight. |
| 221 | Rear end marking devices | Waive | State safety oversight. |
| 223 | Safety glazing standards | Waive | State safety oversight. |
| 229 | Locomotive safety standards | Waive, except for arrangement of auxiliary lights, which is important for grade crossing safety. | State safety oversight. |
| 231* | Safety appliance standards | Waive | State safety oversight; see note below on statutory requirements. |
| 238 | Passenger equipment standards | Waive | State safety oversight. |
| **Operating Practices** | | | |
| 214 | Bridge worker | Waive | OSHA standards. |
| 214 | Roadway worker safety | Comply | |
| 217 | Operating rules | Waive | State safety oversight. |
| 218 | Operating practices | Waive, except for prohibition on tampering with safety devices related to signal system, and blue signal rules on shared track. | State safety oversight. |
| 219 | | | |
| 220 | Alcohol and drug | Waive if FTA rule otherwise applies | FTA rule may apply. |
| | Radio communications | Waive, except to extent communications with freight trains and roadway workers are necessary. | State safety oversight. |
| 225 | Accident reporting and investigation | Comply with regard to train accidents and crossing accidents; waive as to injuries; FRA accident investigation authority not subject to waiver. | Employee injuries would be reported under FTA or OSHA rules. |
| 228** | Hours of service recordkeeping | Waive (in concert with waiver of statute); waiver not likely for personnel who dispatch conventional RR or maintain signal system on shared track use. | See note below on possible waiver of statutory requirements. |
| 239 | Passenger train emergency preparedness | Waive | State safety oversight. |
| 240 | Engineer certification | Waive | State safety oversight. |

* *Safety Appliance Statute.* Certain safety appliance requirements (e.g., automatic couplers) are statutory and can only be waived under the conditions set forth in 49 U.S.C. 20306, which permits exemptions if applications of the requirements would "preclude the development or implementation of more efficient railroad transportation equipment or other transportation innovations." If consistent with employee safety, FRA could probably rely on this provision to address most light rail equipment that could not meet the standards.

** *Hours of Service Statute.* Currently, 49 U.S.C. 21108 permits FRA to waive substantive provisions of the hours of service laws based upon a joint petition by the railroad and affected labor organizations, after notice and an opportunity for a hearing. This is a "pilot project" provision, so waivers are limited to 2 years but may be extended for additional 2-year periods after notice and opportunity for comment.

OSHA = Occupational Safety and Health Administration outside the jurisdictional boundary, and when waivers are likely to be granted if all other requirements are fulfilled.

## CHAPTER 3: SUPPLEMENTAL INFORMATION SINCE *TCRP REPORT 52*

Although the most significant shared-track event occurring after *TCRP Report 52* is the issuance of the FRA and FTA final policy statements on shared track as reported in Chapter 2, other activities also merit recording in this shared-track update. This chapter reports other events and circumstances supplementing the information in the first four chapters of *TCRP Report 52*. This chapter is divided into three main parts that correspond with specific chapters in the original report and that record the three major categories of shared-track activity since *TCRP Report 52*:

- Additional information on Karlsruhe and other track-sharing locations (see Chapter 7 of *TCRP Report 52*),
- Transit railcar and technology development (see Chapter 4 of *TCRP Report 52*), and
- Other information on institutions, operations, and infrastructure (including shared-track waiver petitions, overseas study missions or technical tours, and conferences and working groups developed to address application of shared track in North America—see Chapters 1, 2, and 3 of *TCRP Report 52*).

### Additional Information on Karlsruhe and Other Track-Sharing Locations

Several overseas study missions and tours directed at the shared-track issues involved visiting Karlsruhe because Karlsruhe is the most impressively sophisticated and most diverse example of shared track among contemporary rail systems anywhere. Karlsruhe, under the leadership of its general manager, Dr. Dieter Ludwig, reintroduced track sharing between railroads and rail transit and LRT on a large scale. Karlsruhe track-sharing advancements are extensively reported in the trade press, in study tour reports, and in *TCRP Report 52*.

There is a tendency, therefore, for visiting transit or railroad professionals to overlook more modest track-sharing operations elsewhere and cite Karlsruhe as *the* model for application in North America. More probing investigation indicates that although Karlsruhe is a high ideal for track sharing, there are other more modest and more applicable models from which to learn shared-track practice and technology. *TCRP Report 52* focused most of the European experience on Karlsruhe to heighten awareness of the pioneering operation and to demonstrate the highest forms of track sharing. However, when the excitement subsides in observing and studying Karlsruhe's LRT-based S-Bahn, thoughts turn to practical applications and other shared-track systems closer to the North American experience.

*Background*

While the *TCRP Report 52* research was underway, the FTA and FRA were cooperating on the joint policy statement previously described to better define the federal regulatory role in existing domestic rail transit new starts that relied on shared track and other joint use of rail facilities. That draft policy statement was issued in early 1999 and was modified by the FTA and FRA, using input received during the official comment period ending in February 2000. During this same period, overseas study measures on track sharing were planned and executed.

APTA formed the Joint Use Working Group, which responded to the FTA and FRA policy initiative. APTA also sponsored the Shared Track International Symposium in July 2000. These activities focused attention on foreign track-sharing innovations and their potential application in North America.

Primary case study locations included Saarbrücken, Düren, Köln, Kassel, Zwickau, and other more recent and more applicable models. Why are these joint-use examples, which are less known in North America than Karlsruhe is, important? Karlsruhe is acknowledged to provide the most sophisticated and advanced examples of shared-track practice between railroads and light rail. It does not, however, provide a directly transferable model to the North American environment for the following reasons:

- Karlsruhe had a pre-existing, highly developed integrated streetcar and electric interurban (LRT-based S-Bahn) network. Those conditions are absent from rail new start–aspiring North American cities, particularly from cities with populations below that of Karlsruhe (i.e., below 270,000).
- Karlsruhe incrementally expanded its LRT S-Bahn system using a novel shared-track capital program strategy based on available pre-existing tram and railroad infrastructure. Karlsruhe did so after exhausting funding and possibilities for expanding its tram network by conventional means in streets or new right-of-way. These circumstances are rare in medium-size and smaller cities in North America.
- Karlsruhe (and in fact all of Germany) has a large percentage (nearly 50 percent) of its main and secondary railroad lines electrified. All railroad corridors serving Karlsruhe are electrified. This condition does not characterize the smaller German case study cities (i.e., Düren and Zwickau) and North American cities outside the Northeast Corridor.
- Related to the scarcity of North American main line railroad electrification is the potential reintroduction of DMU rail car and rail bus technology to North America. These rail cars are similar to LRVs in appearance and performance, except that they can operate independently of wayside traction power infrastructure. This characteristic constitutes an important option for small North

American cities. That option can be better understood by researching the Western European experience as the highest state of the art and widest range of applications of this technology. New Jersey Transit's Southern New Jersey Light Rail System is among the first contemporary uses of the light DMU technology as a surrogate for conventional electrified light rail.

- The North American new-start phenomenon using shared track is better demonstrated by comparably modest "start from scratch" rail transit projects in Germany. These projects include, most notably, Düren, Saarbrücken, and Zwickau. Similar to medium-sized North American cities, these cities, except Zwickau, dismantled their obsolete trolley systems.

Karlsruhe, in spite of not being a readily transferable model to North America, is an instructive case study because its system components do the following:

- Represent the most advanced example of shared-track state of the art, whose evolution provides selective lessons in expanding light rail systems incrementally using surplus capacity on railroad track.
- Provide selective lessons and precedents in institutional arrangements and regulatory innovation that encourage, rather than suppress, hosting shared-track arrangements.
- Demonstrate operating practice extremes by dispatching tram and mixed LRT and train traffic through peak-volume points. (These traffic scenarios are "worst case" for scheduling and dispatching very high train volumes and diverse mixes of rolling stock and consists. These scenarios confront the argument that "it can't work here" with a counterpoint that "less traffic and diverse mixture scenarios might work, accompanied by equivalent safeguards in North America.")
- Confirm that the German train control technology and control centers in joint use employ contemporary, conventional, proven, and transferable technologies, combined with rigid operating discipline to maintain a satisfactory safety record.
- Exemplify the result of the strong political leadership and commitment necessary to accomplish joint-use (or any rail new-start) projects.

For all of these reasons, the research team visited Germany. The visit focused on inspecting Karlsruhe peak-period train mix points and train control centers, covering the entire Saarbahn system, and visiting the Dürener Kreisbahn. Some supplementary material was also collected on the application of lightweight DMU, light rail–derived technology used on Zwickau's Vogtlandbahn, and a very brief visit and inspection of the Kölner Verkehrs–Betriebe AG (KVB) headquarters in Köln.

*Karlsruhe Revisited*

Much can be researched and reported on the pioneering shared-track operation and other innovations in Karlsruhe. Two aspects of the Karlsruhe phenomenon are of particular interest:

- The quantification of a representative number and mix of train and LRV movements past the heaviest traffic point on the shared-track system. (This quantification would assess the shared-track operations performance at the highest end of the train volume spectrum. Train volumes over shared track are also quantified in other case study cities in Chapters 3 and 4 of this digest.)
- Information on the nature and technical sophistication of the train control centers and dispatching practices on the shared-track system.

Although both of these aspects were studied during the tour of Karlsruhe, a more detailed investigation is needed by other researchers in subsequent visits. Trains were observed and logged at a peak-traffic location for an hour starting at noon. These observations are reported in the FTA and FRA "Shared Track Operations in Karlsruhe" Final Report (September 2000) Appendix B. The observations are not duplicated in this update, but the report is recommended reading. A short summary of findings follows.

The general peak-train volume point for shared track currently is at Rastatt on the line to Baden Baden. The specific peak-train volume point is at the Karlsruhe Hauptbahnhof (the main train station), where trains from eight railroad corridors (six of which share track with LRVs) feed into both sides of the "through track" configured main railroad terminal. The terminal is not, however, a good throughput measurement of joint use for demonstrating train volume and train mix past a single point. The Karlsruhe station is unsuitable for this research need because

- The Karlsruhe main station does not resemble a situation presently envisioned in North American shared-track plans;
- The station operation is more a terminal management exercise than a through-line dispatching routine;
- Too many trains originate or terminate at the station, and so the station is not a good representation of potential throughput train volume;
- Scheduled dwell time for trains on the station tracks varies by train type;
- There are mandatory low train speeds within the yard or station limits;
- Freight trains are being bypassed around the terminal;
- All trains stop and are at rest within the station; and
- Operations are spread over ten tracks in the station.

Deutsche Bundesbahn (DB) publishes and distributes to the public a timetable book for each major terminal in Germany. This book shows all arriving and departing trains by time, number, and class.

Based on observations, a four-to-one ratio of passenger-to-freight train movements is a reasonable estimate for the number of freight trains on the Karlsruhe-Baden Baden main line.

When Baden Baden–bound trains depart the Karlsruhe main station, they proceed southwest over two parallel but separate double-track main lines. Just north of Rastatt Station, these two lines converge, concentrating southbound train movements at Rastatt's station. Therefore, all trains between Karlsruhe and Baden Baden pass Rastatt on two express tracks and two local tracks just south of the point of convergence. LRVs and lesser-class, locomotive-hauled trains stop at Rastatt, while freights and higher-class express passenger trains pass through the station at track speed on the center express tracks. At Rastatt, the following characteristics of train movements were observed:

- Diverse mix of train types and consists (e.g., freight, passenger, and LRV),
- High throughput train volume (16 trains in 1 h, 9 trains in 0.5 h),
- Simultaneous stop and nonstop functions,
- Trains routed against predominant traffic flow,
- Reverse-signaled tracks and operations,
- The presence of a major junction nearby, and
- Very short intervals between trains (as little as 3 min between LRV and following freight on the same track).

Operations at Rastatt demonstrate shared track at the very highest level of operating discipline and performance, as shown in a log of train movements at Rastatt.

In summary, the observation disclosed 16 trains passing in an hour, 9 of which were scheduled northbound in the half-hour interval between 12:30 and 13:00. All except two trains during this 30-min period used Track 3, and one of the two southbound trains crossed over against traffic on Track 4.

The time interval between passing trains on the northbound track is noteworthy. Specifically, a northbound conventional intercity train is followed 1 min later by a high-speed Intercity Express (ICE) train, followed 10 min later by a Euro International Express, followed 4 min later by an LRV making a station stop, followed 3 min later by an express freight, followed 4 min later by another freight—all sharing the same track.

Further observations were made on Karlsruhe's LRV and tram system to determine peak-load points off the railroad joint tracks. Observations were made of tram and LRV movement capacity and performance on the street in mixed traffic and the effect of introducing LRV traffic from the high-capacity rail system into the low-capacity, in-street tram trackage. The reason for this effort indirectly relates to shared track. An issue arises about managing the growth in LRV movements in mixed-traffic conditions during peak commuting and pedestrian periods. Whatever increases in ridership that a suburban S-Bahn service attracts on the shared-track portion of its route will eventually be distributed through the CBD on tram track embedded in a street and shared with mixed vehicular traffic.

Karlsruhe's Kaiserstrasse provides an excellent example of the dilemma caused by modal shift of commuters from the railroad-reserved tracks to the in-street tram tracks within the congested center city. Formerly, these suburban commuters would have taken commuter trains to the main railroad station and transferred there to local trams. Now, these commuters use LRVs from their home directly to the CBD. The result is lower occupancy LRVs taking up track space on CBD tram tracks. These riders were formerly delivered to CBD destinations in high-occupancy city trams from the railroad station.

Only S-Bahn lines S-3 and S-31 to Bruchsal currently serve the main train station and do not routinely venture on Karlsruhe streets and Kaiserstrasse specifically. Lines S-3 and S-31 are direct substitutes of light rail rolling stock for railroad train consists as a matter of economy. Passengers on these two lines must transfer to local tram routes at the station to reach their ultimate CBD destinations. The other S-Bahn lines funnel into Kaiserstrasse through three key track connections (Abtalbahnhof to the southwest, Knielingen to the west, and Durlach to the east). As described previously, these three connections are the transition points in train control, regulation, traction voltage, and track ownership between railroad and light rail systems. The success of the Karlsruhe Verkehrsverbund's (KVV's) S-Bahn in attracting new riders and diverting others from competing modes has created an increasing congestion problem for traffic engineers and rail transit operators. Kaiserstrasse is a very congested local travel corridor compelled to host interregional as well as local trips.

Compounding the problem is the KVV's evolving operating policy of through routing S-Bahn services. A few trips terminate on tram loops and sidings at or near the CBD, but most enter the city, circulate within the CBD, and exit the other side of town. The Heilbronn–Baden Baden S-4 route is the longest (104 km) of these through routes (2 h running time from end to end). Though S-4 headways are modest, the line contributes to downtown congestion.

As described in Chapter 7 of *TCRP Report 52*, two referendums on constructing a subway under Kaiserstrasse for the S-Bahn light rail services have been defeated. A representative of the KVV, when asked about this defeat in a briefing, indicated that people prefer to ride on the surface and relate to the retail and other attractions along the busy thoroughfare. Although the Kaiserstrasse corridor through the CBD is not exclusively for transit vehicles, it is increasingly dominated by rail transit and is considered to have evolved into a reserved transit and pedestrianway for a portion of its route.

Because of this relationship between the shared railroad track catchment area outside the city and shared street traffic in the distribution area, an informal observation of peak-load point in downtown Karlsruhe was conducted. On an April Saturday, observations were made at Marktplaz and Kaiserstrasse. A 5-min period between 11:00 and 11:05 a.m. was selected to represent high, though not necessarily peak, volume. This location is a "T" intersection on the tram system, with east-west tram routes and S-Bahn routes blending with rail car movements from the main train station. Nine cars passed through the intersection within the 5-min duration of the observation. These movements included merging, diverging, and through moves using operator-activated electric switches. As a portion of the open-air market was active that day, pedestrian and small commercial truck movements were heavy. All track at this location is embedded in street paving with pedestrians, motor vehicles, and rail traffic competing for street space. Traffic is sorted by different paving textures, painted lines, and traffic signals.

A conclusion from this observation is that the magnitude of popularity of shared track found outside Karlsruhe creates congestion on public thoroughfares inside Karlsruhe. This conclusion may apply to North American examples of light rail when suburban branch lines are added, but all lines must funnel through downtown on a single rail corridor. If the single rail corridor through the CBD is in the street shared with vehicular traffic, the dilemma is intensified.

In contrast, at Saarbrücken (with its single LRT line still incomplete at its northern end), LRV-induced congestion in the CBD is rare. Substantial portions of the Saarbahn route downtown were created by reserving one-half to two-thirds of a street surface for light rail. Although this creation alone reduces general traffic capacity, the real test will come when the Saarbahn services grow in patronage, area coverage, and route diversity and all traffic funnels though a single downtown traffic corridor.

In Düren, this type of on-street traffic management and control problem is absent entirely because Dürener Kreisbahn (DKB) diesel LRVs do not operate on city streets. DKB uses railroad infrastructure exclusively. This exclusive use of railroad infrastructure does not exist in Zwickau, where the difference in track gauges between the meter-gauge tram and standard railroad (1,435 mm) prevents interchange of equipment unless extensive dual-gauge track is constructed and the next generation of Zwickau's DMUs can negotiate streetcar track geometry. The lesson learned is that practitioners tend to overlook the street-side element of the shared-corridor light rail spectrum.

The Hardtbahn and Abtalbahn interurban railways in Karlsruhe are built on two former railroad routes now designated S-Bahn routes S-1 and S-11. The railways are combined end-to-end through the CBD to form a long (62-km) corridor with 54 station stops and 53 grade crossings between Ittersbach and Bad Herrenalb on the south and Hochstetten on the north. The railways' origins and evolution are distinct.

The northern route, or former Hardtbahn, was operated exclusively for freight by DB. Vekehrsbetriebe Karlsruhe (VBK) purchased the line, strung wire, extended track, and converted the line to light rail standards during a period commencing in 1978 and completed the route to Hochstetten in 1989. DB continued to serve as the freight operator to Neureut. The freight track connection and continued presence of freight service invoked Eisenbahn-Bau-und Betriebsordung (EBO) regulations. Abtalbahn LRVs, therefore, were equipped with air whistles, Induktive Signalsicherung (INDUSI) train protection, train control from a central dispatcher for passing sidings and single-track sections, and cross-trained LRV operators. For freight purposes, the Hardtbahn may be considered a low-density short line because it handles less than one freight train a day (340 trains annually).

Earlier, the southern route, or Abtalbahn, was an independent meter-gauge steam and electric interurban featuring mixed freight and passenger trains over common tracks. VBK purchased the privately owned line and, between 1958 and 1966, converted the line from meter gauge to standard gauge. A freight-track connection was established at Ettlingen West for interchange with DB. Freight-train movements on the Abtalbahn are more active, with more than 1,100 annual movements. Annual LRV movements on the entire Hardtbahn and Abtalbahn (i.e., S-1 and S-11) route system total more than 139,000 scheduled LRV trains.

### *Train Control, Dispatching, and Control Centers*

Three distinct applications of train-control practice are applied in Karlsruhe:

- On-the-railroad tracks,
- On-the-S-Bahn interurban tracks, and
- On-street tram tracks.

These train control systems are described in Appendix B of the FTA Study Mission Report, "Shared Track Operations in Karlsruhe."

### *Why Saarbrücken's Saarbahn Model is Instructive*

Since *TCRP Report 52*, study tours and other research have produced additional insights into Saarbrücken shared-track operations. Consider the case of a small industrial city that abandoned its streetcar system entirely and continued its local transit service with buses. The city management is trying to cope with congestion, air quality deficiencies, the city's economic transition to a mix of technical and educational institutions, and the destabilization of blue-collar jobs, all while grappling with an eroding tax base. The city leadership wants to accomplish a visible, affordable, and functional public works project. They are candidates for a rail new-start initiative. This scenario could describe many North

American cities, and it does describe Saarbrücken and the Saarland region. For this reason, the Saarbahn's achievement is important and, in some respects, eclipses the larger and more impressive Karlsruhe model.

The "Saarbahn" is the popular name for Stadtbahn Saar light rail operation, Germany's newest shared-track light rail. The Saarbahn is significant for North American application because, like most U.S. cities, Saarbrücken dismantled its trolley system entirely in the 1960s. Spawning and nurturing the Saarbahn was a new start, starting from scratch. Unlike in Karlsruhe, where the city built incrementally on an active tram system and an electric interurban, in Saarbrücken the entire trolley infrastructure was gone. Saarbrücken is, however, the center of a tight radial pattern of railroad corridors.

The Saarbahn is a good case study for North America because of the speed with which it was planned, designed, and built (i.e., 5 years from start of planning to first revenue service). In February 1992, the local funding commitment was made to advance the project. Planning began in April 1992. Purchasing began in 1993. Federal and regional funding consents began in June 1995. In October 1997, the Saarbahn's "initial operating segment" went into revenue service. The reasons for this speedy performance, as cited by people who built the system, include political commitment, strong centralized project management and control, an equity stake among contractors and management, the fact that nearly 60 percent of the first construction phase (i.e., Sarreguemines, Saarbrücken, and Lebach) is on existing DB and Socièté Nationale des Chemins de Fer Francais (SNCF) railroad infrastructure, and the fact that project planning and design phases were expedited.

Financing the startup of the Saarbahn was cooperative. State (i.e., land) capital contribution for the project was initially DM 225 million, while the federal government's contribution was initially DM 214 million. The remainder of the cost was covered by the builder-owner and operator, Stadtbahn Saar GmbH. In terms of total cost, the funding shares were as follows: federal 38 percent, regional or local 40 percent, and the company 22 percent.

The Saarland model of combining complementary businesses (but under the mantle of the public sector) has precedent elsewhere. In other German cities, the Stadtwerk is still popular. All of the shared-track metropolitan areas in Germany have a Stadtwerk-type institution with a rail transit component in various forms. In Japan, this arrangement is called the third sector; in the United States, it is called "public–private partnerships." Another similarity between North American innovative business practice and Saarland is the DBOM technique. Private capital and sweat equity, though not referred to as such in Germany, are ingredients in the Saarbahn's success.

The institutional arrangement for the Saarbahn is instructive, as it is similar to Stadtwerk institutions elsewhere in Germany. Saarbrücken's public utilities and transport are combined under Verkehrsverbund Saarland (VVS) Group. This arrangement is similar to the private utility syndicates of the United States in the early twentieth century. With the U.S. syndicates, a single ownership or holding company organized economic development, real estate, gas, electricity, and streetcars. The businesses were complementary, and cross subsidies kept the financially weaker elements solvent. The synergy among these enterprises was important, even though some of the businesses were chronically weak. So the situation is in the Saarland, where the public utility cross-subsidizes the transport. In discussions with staff working on the design of extensions, it was mentioned that the dismantling of the holding company and privatization of its components is under consideration. The fate of transport enterprises separated from the Stadwerk arrangement is ominous because of the same circumstances following the enactment of the anti-trust Public Utilities Act of 1935, which separated the streetcar companies from their parent electric utilities.

**Rolling stock and design decisions.** The Saarbahn is different from Karlsruhe in some other ways. The Saarbahn's light rail cars are considered somewhat more advanced than the first generation S-Bahn cars for Karlsruhe. These Karlsruhe cars are a relatively standard design first developed by Siemens Duewag as the model B for Köln. In Köln, the model Bs are used in several applications, including the two former Köln-Bonn Eisenbahn interurban Lines 16 and 18. Of these, Line 18 has heavy freight train traffic. Saarbahn's cars were custom designed for new starts featuring shared track. They were built to be operated on the DB railroad lines, not to be an adaptation of a design for another primary purpose. The difference between the Saarbahn and Karlsruhe S-Bahn cars is subtle, but important, as it relates to the contrasting standards of the track. An S-Bahn operator may order new series LRVs to overcome a design flaw or disadvantage of the series car it replaces, but a design deficiency based on the track cannot be remedied except by replacing all of the track.

The disadvantage of having a tram system like Karlsruhe's as a base from which to build is that the tram design standards are fixed. This disadvantage is another lesson applicable to North America. One of Karlsruhe's dilemmas was to reconcile the tram rail wheel and flange profiles with those of the DB railroad track. Tram wheel treads are narrower, and the flange profile shallower, than railroad counterparts. Karlsruhe solved the problem with a compromise wheel profile. In doing so, however, KVV was compelled to accept restrictions on the use of its LRVs on certain DB track.

In contrast, the Saarbahn selected railroad profile rail for its track and railroad profile wheels and flanges for its LRVs. The Saarbahn was not limited to a streetcar standard, like in Karlsruhe, or to a meter-gauge local system, like in Zwickau. The disadvantage of adopting the railroad rail standard is that the wider flangeway on street trackage on the Saarbahn has a greater tendency to cause pedestrian tripping in the pedestrian/transit zones downtown. A major advantage to using the railroad standard is that Saarbahn LRVs can go anywhere on DB and are unconditionally EBO certified. The 28 Bombardier-designed, dual-voltage LRVs for the Saarbahn have come to be known as "tram-trains."

There are less apparent shared-track benefits. Being able to go anywhere DB rail and catenary go is one subtle advantage. Other benefits of shared track using railroad-compatible wheels and track is the ability to respond to emergencies, temporary routings, evacuations, and special events using the railroad network. In North America, this shared-track opportunity would be a rarity, as it would apply only to DMUs that are independent of overhead catenary and wayside power.

The project's principal investigator visited Saarbrücken during the annual Saarmesse, or exposition. This exposition highlighted yet another shared-track opportunity often overlooked. The exposition grounds are on the south side of the Saar River, remote from the existing LRT and CBD. Three major events are held there annually. The Saarbahn's LRVs serve the Saarmesse during these limited periods because of the proximity of a railroad branch line at the exposition grounds and because of the connection between railroad and light rail tracks. The only incremental cost for serving the exposition with light rail is the fee for using railroad track, which DB assesses. The infrastructure is already in place, and the LRVs are certified to use the tracks. An additional intriguing aspect of this infrequent rail transit service is the lack of means to reverse direction at the Saarmesse exposition platform (there is no station on this freight line). A track crossover to reverse trains is available another 4–5 km up the line. The LRVs simply advance to the next railroad yard in the next town to reverse direction. In the process, the rail cars pick up more revenue passengers at a town that has no light rail service except during Saarmesse. This operation was made possible through the forethought of the Saarbahn designers and decisionmakers.

While under construction, the segment of new Saarbahn track between Ludwigstrasse and Cottbuser Platz stations required the replacement of a large vehicular bridge across a network of DB railroad tracks. The incremental cost of building a track connection between the Saarbahn and DB as an element of the bridge construction was relatively modest, even though no regular S-Bahn LRT service was anticipated at the time.

This track connection will eventually serve DB lines to Forbach, a French suburb, and other rail corridors being planned for the Saarbahn's expansion. But for now, the connection and the DB tracks to and beyond the exposition are used only for three periods a year. This opportunity to serve Saarmesse demonstrates how incremental rail transit service expansion can be implemented, even temporarily, at very affordable prices.

**Saarbahn statistics.** Saarbahn's success is revealed in its statistics. Total estimated capital cost for the first phase is DM 600 million, or DM 13.6 million per kilometer. That cost includes tracks, power, workshop, 28 LRVs, and other "premises." Translated into U.S. dollars and miles, the equivalent for this package is less than $11 million per mile. Previously, operation ended at Cottbuser Platz, 3 km west of Stadt Zentrum ("town center"). The segment of track to the Rastpfuhl neighborhood opened for service in October 2000. Service is expected to commence on the next segment at Riegelsburg Rathaus ("town hall") in October 2001. Construction on this segment has been difficult because the segment is in a semi-reservation in the middle of a busy arterial avenue (Lebacher Strasse) and because this route traverses a somewhat more affluent part of the city. Some resistance has been encountered to construction and its impacts. Once beyond Riegelsburg, the alignment follows a disused former DB railroad line to the terminal point at Lebach. Construction on this last segment will advance rapidly. This surplus railroad line to Lebach was purchased by the Saarbahn.

**The first-phase system.** When thus completed, the first-phase line will begin on a German railroad at Lebach and transition to in-street reservation, then to in-street trackage in mixed traffic, then to a pedestrian transit zone downtown, then back to mixed traffic, then to reservation in the middle or side of the street, then to an active DB railroad, then to Brebach, then into France on SNCF tracks, then finally to Sarreguemines. A 1-km extension of DB catenary into France prevents having to use a 3-V car at this point. At least one voltage-transition point exists. Cars automatically make the transition by coasting under a segment of de-energized catenary.

Train control is confined to the southern part of the route between Romerkastell and Sarreguemines. The segment is operated on DB trackage. A small control center is installed in the very modest Brebach station controlling only this segment. Line-of-sight and interlocked signals on a short single-track, in-street segment control train movements. Unlike the system in Karlsruhe, the current light rail service between Brebach and Sarreguemines is not challenged by the presence of frequent railroad train service. In a sense, this condition resembles more closely the typical railroad secondary branch line found in North America. The line between Brebach and Sarreguemines has only one long-distance passenger train daily. Local freight and switching is active because of several lineside industries shipping on the railroad. At least two of these industries were observed operating their own switching locomotives.

The track to Saarmesse, in contrast, is a busier line segment. It is on the main line to Metz and Verdun (in France), hosting about 30 passenger trains daily. Although the Saarmesse light rail service is on this busy route for only 2–3 km, a portion of the route is at the convergence of several lines feeding the main train station.

The success of the service to Sarreguemines has resulted in a clamor for service elsewhere into France. The railroad line to Forbach (in France) is a priority. Accordingly, the

Saarbahn has exercised an option on additional LRVs, one of which will be a 3-V prototype. France's railroad standard voltage is 25 kvAC 50 cycle, while Germany's is 15 kvAC 16-2/3 cycles. The Saarbahn's own LRT voltage is 750 vDC, which makes traction voltage an important criterion in Saarland's regional light rail planning. An ambitious plan exists to expand along five additional rail corridors, including Saarlouis, Neuenkirchen (which had its own light rail system into the l960s), Zweibrücken, Homburg, and Metz. The railroad lines in these corridors are divided into three key categories: electrified (for electric LRVs), non-electrified (for DMUs), and abandoned or disused (for reclamation).

Other cities near the Saarland are considering light rail and DMU operations based on shared-track concepts pioneered by the five different shared-track models discussed in this digest. Strasbourg anticipates expanding its existing light rail system using the Karlsruhe model for shared track. Kaiserslautern, in the adjacent state of Rheinland-Pfalz, is also considering a new start, but wishes to avoid the expense of catenary and power-traction systems, so it will follow the Zwickau or Düren models using light rail–derivative DMUs. Mulhouse, which abandoned its streetcars earlier, is also considering shared track, possibly using the Saarbahn model.

An SNCF official developing joint-use plans in France indicated that there were three major requirements to developing a shared-track network. These three criteria are common to North American requirements:

- The area must have railroad lines well located to attract patronage,
- The rail lines must have surplus capacity, and
- The area must have or be planning a light rail network.

When the first construction phase is completed, the Saarbahn anticipates three additional development stages envisioned to create a 72-km route network, of which over half (40 km) will be on railroad track. Saarbahn will then have graduated to the Karlsruhe model, expanding its existing light rail system.

*Düren, Zwickau, and Köln Case Studies*

These three case studies in different German cities are treated individually in this digest, but were described as a group only briefly in *TCRP Report 52*. All three studies provide useful lessons for application to North America. The Zwickau and Düren models are similar, using the same Regio-Sprinter DMU, though Zwickau has recently purchased second-generation DMUs. There are, however, some critically important differences between them for North American application.

Though Karlsruhe appears to get the credit for innovating shared track, Köln's system predates Karlsruhe. Köln's regional shared-track operation, though modest, is institutionally complex and operationally unique enough to merit note in this update. Köln's primary lesson is in its institutional model. The Karlsruhe model remains more refined and complex.

The research team did not visit Zwickau and covered only portions of the Köln system, but none of the shared-track KVB S-Bahn Routes 16 or 18 to Bonn. Secondary sources included Siemens, Rail Consult, the Dürener Kreisbahn (DKB), KVB, KVV, and the Federal Transport Ministry.

*The DKB (a.k.a. "Rurtalbahn") Model*

**Düren relevance.** Düren is located on the main freight and passenger rail corridor connecting Köln with Aachen, Brussels, and Paris. This rail corridor is one of the earliest in Western Europe. Düren's main train station dates back to 1841. Here, several branch lines diverge from the main DB line. Düren is part of the Köln land, and frequent regional service connects it with downtown Köln. The area served within the Kreis is just less than 1,000 sq km, with a population of 263,000.

Other county institutions in Germany besides Düren have purchased and operated (or contracted operation of) local non-electrified railroad branch lines. Railroad branch line investment is common and considered an economic development initiative, whether in Düren or in other areas of Germany and whether by councils of government or county improvement authorities in North America. These initiatives are usually motivated by a threatened loss of rail freight service and a resulting threatened loss of blue-collar jobs.

What is uncommon and innovative in Düren and, therefore, of interest to U.S. practitioners is the county's use of passenger service on a railroad branch line: the county used a new generation of light rail–derivative rail car with no electrification dependency. The attraction for transit practitioners is the innovative use of EBO-noncompliant DMU railcars and the retention of rail freight service—all operated under common management. The county-owned, county-operated bus company and Stadtwerk expanded to include passenger and freight service operation on the same track.

**DKB system description.** The origin of this initiative is useful for North American transit professionals to understand. Düren had a small streetcar system, which was abandoned in the 1960s. None of the tram infrastructure remains, and none of the present DKB initiatives use streetcar-type track or any in-street track. The county operated a very small freight-switching operation prior to 1993. On May 25, 1993, threatened with loss of branch line service on the former DB branches, DKB purchased these non-electrified railroad alignments to Jülich and Linnich to the north and to Heimbach to the south. The privatization of DB had compelled the national railroad to shed unprofitable branch lines. Inspection of the southern portion of the Jülich line indicated substantial investment in upgrading track and other rail infrastructure. This program of improvements is being phased over a number of years, and little evidence of the old DB infrastructure is present. Though not verified by the research team's personal inspection, the line north of Jülich is planned for rehabilitation to Linnich for expanded DMU service. The line further north to Baal is planned to be restored (its track was dismantled previously by DB). The present active DKB single-track line, with passing sidings, has 56 grade crossings, which are monitored by dispatchers at DKB's new headquarters.

DKB also operates rail services under contract with DB. Its DMU railcars are leased offline to DB for off-peak periods, substituting for higher-capacity, locomotive-hauled (and more expensive to operate) train consists. This arrangement has existed since 1996. In all, DKB operates about 70 km of route, about 60 km of which has DMU-hauled passenger service. This operation does not include the previously mentioned 42-km route operated off peak for DB. DKB's combined county bus and rail services carry more than 12 million passengers annually. Freight traffic is stable or declining modestly at about 120,000 tons annually. Only about 30 staff are needed for the rail operation. The south line (Line 484) operates on a 30-min base headway to Untermaubach-Schlagstein and 60 min beyond to Heimbach. The north line operates a base of 60 min over its entire length.

The decision to purchase light DMU rail cars by DKB is probably the most significant decision of interest and application to the North American new-start experience. In spite of previous streetcar, rail freight, and bus-operating experience, the rehabilitation and restoration of passenger service on the Heimbach and Jülich branches would, in the United States, be considered a new start. In Germany, without a new-start federal policy and with a privatization and decentralization environment, the adoption of local branch lines and their restoration for passenger services by local authorities, like DKB, is considered desirable and federally supportable. The means to accomplish this objective, however, are not considered if traditional railroad-based institutions, labor practices, and rolling stock options are used.

The choice of rolling stock, in this case the Siemens Regio-Sprinter DMU, dictates a new approach in operating and management practice operating diesel-propelled light rail–type vehicles, featuring

- Low floors;
- One-person operation;
- Transit-type, proof-of-payment fare collection;
- Coordinated joint maintenance with and of the bus system (basically, joint maintenance bays, tooling, common propulsion systems, and personnel);
- Operation on a railroad branch line with concurrent local freight service;
- Sharing for a short segment of a high-density main line (220 daily trains) at Düren (originally, these train movements were in revenue service when both branches were through-routed; now, the sharing is only for positioning equipment);
- Certification of the Regio-Sprinter for use on railroad lines using EBO-equivalent safety proofs (this certification will be further detailed in the section on Zwickau); and
- No requirement for electrification.

These passenger transportation reforms are major when considered from a European or North American perspective. They are fundamental to the choice of rolling stock.

DKB was the first notable use of the Regio-Sprinter and the first application of a light rail–type car in railroad passenger service beginning in 1995. Prior to the arrival of the Regio-Sprinters, DKB owned and operated Maschinenfabrik Augsburg-Nuernberg (MAN) Schienenbus when DKB took over the branch lines in 1993. Two remaining out-of-service Schienenbus units were observed to still be on the property and were for sale (in addition to one of the two freight locomotives). DKB was, therefore, experienced in operating lightweight rail equipment. As the first operator of Regio-Sprinters, DKB owns serial number 001, the first Siemens production model. This unit was borrowed to tour the United States and Canada in 1997.

DMUs generally cost less capital per seat than dual-voltage LRVs do. For the Regio-Sprinter, the per-seat cost is less than half that of the dual-voltage Karlsruhe GT8 car and two-thirds that of a dual-voltage Saarbrücken car. Among the lowest capital cost per seat is the Deutsche Waggonbau AG (DWA) "Dosto-Schienenbus," at a quarter of the cost of the Karlsruhe GT8 and a little over half the per-seat cost of the Regio-Sprinter. Explanation of current DMU models and nomenclature follows.

Total comparative 1995 capital costs were about DM 4.5 million for the GT8, DM 1.6 million for the Regio-Sprinter, and DM 1.1 million for the Dosto-Schienenbus. All of these costs have risen, but the relationship among various car costs have remained relatively constant. Operating costs for the DMU is claimed to be slightly lower than for the dual-voltage LRV, at DM 8 per kilometer versus DM 10 per kilometer, respectively. Track-user charges vary because the infrastructure element of DB has been privatized. The KVB was paying 5–8 DM per kilometer. According to the KVV, the dual-voltage feature adds about 15 percent to the capital cost of a standard single-voltage LRV. The 1995 cost per kilometer of electrification in Germany was more than DM 0.5 million. Eighty-five percent of the cost of electrification will be borne by the land. Electrification, therefore, becomes a viable option for the rail operator if public officials can be convinced of its value. With 30- and 60-min headways, and lack of pre-existing electrification on its branch lines, the rationale for DKB's choice of the Regio-Sprinter in 1995 (or any modern light rail– or bus-derived DMU now) becomes apparent and applicable for lower-density North American new-start proposals.

The significance of track sharing for DKB has diminished since the arrival of the Regio-Sprinters. Freight service at one train a day has remained constant, though DMU service has expanded in frequency and coverage. The segment with the highest risk of collisions between trains has been removed from revenue service. This segment is located where the DMUs cross the busy Köhn-Brussels main line, sharing track for a short segment in revenue service at Düren Bahnhof. DB's Köln-Aachen main line separates DKB's two operating segments. Tracks were added to enable DKB "trains" to share main-line track for a short segment. During a short period, DKB trains performed this move in revenue service. Now, the service is divided into the two separate branches, but non-revenue equipment moves still interface with main-line tracks.

For DKB, the risk probabilities have diminished because of the splitting of operations into two services and because of the constant freight train volume. Non-revenue equipment moves, such as the DKB at the Düren Bahnhof, are specifically excused from certain requirements. The "basic study" and its successor risk analyses remain as a benchmark in shared-track regulation. Curiously, Karlsruhe was not among the specific case studies included in published risk analyses.

*The Zwickau Vogtlandbahn (a.k.a. "Regentalbahn") Model*

Zwickau is located in the former East German zone near the border with the present Czech Republic. The Zwickau model is similar to Düren only in the selection of the Siemens Regio-Sprinter. The shared-track concept is considerably more refined in the Zwickau model than in the Düren model, even more refined than in the Karlsruhe model in some respects. These differences and refinements make Zwickau a candidate for North American study and selective application.

Zwickau was the first city, other than Karlsruhe, to achieve what Karlsruhe accomplished in integrating tram and railroad service by invoking the shared-track concept. Zwickau did so with DMU rail cars rather than dual-voltage LRVs. This difference is significant for North American shared-track interest. Major obstacles existed to integrating the two rail modes. The lack of electrification on the lines served by Zwickau's Regentalbahn required management to select a light rail–derivative DMU. The existing meter-gauge tram system in Zwickau prevented direct interchange of equipment between the trams and standard-gauge DMUs. The restricted curvature capability prevents the Regio-Sprinters from negotiating tram track, even if they could fit on the track. Alternatives were considered, but the expense of installing third rail on the standard-gauge railroad track for the meter-gauge trams was dismissed early. Conversion of the meter-gauge system was clearly impractical. The solution that was developed advanced the state of rail transit planning and engineering in many ways:

- Dual-gauge gauntlet track was laid in a street, which required reconstruction and expansion of the tram system.
- Gauntlet track was installed for 1.3 km with a minimum 120-m turning radius in view of the Regio-Sprinter's limitations. This installation meant that the alignment of the street selected for the dual service had to be relatively tangent (see Figure 1).
- A separate diverging-track downtown "Zentrum" stub terminal was installed to permit the DMUs to layover and change ends without interfering with tram traffic.
- The "devil strip" between track centers was of generous dimension to permit passage abreast of the wider standard-gauge cars.
- Regio-Sprinters were ordered to be equipped with tram-type devices for operating in the street. These devices included warning "trolley" bell; tail and brake light signals; 35-km-per-hour, on-street control enforcement; transponders to activate signals for transit priority and track switches; interlocking outside mirrors; and a brake system designed in accordance with BOStrab requirements (i.e., two retarders, track brake, and disk brakes).
- Other features were added to the Zwickau's Regio-Sprinters to improve their performance, flexibility, and adaptation to local conditions:

  — Snowplows were added to car ends.
  — A transit-type, self-centering transit coupler was installed rather than side buffers (this feature has since become standard for most new-generation German DMUs).
  — Cars can be multiplied up to four units.
  — Output of the two MAN prime movers (i.e., engines) has been increased by 15 percent.
  — Emission control has been improved to correspond to Euro II.
  — Fuel tanks are heated.
  — Electrical equipment formerly installed on the roof has been moved inside the car body.
  — Interior space has been revised to meet local needs.
  — The 70-percent, low-floor feature was preserved.

**The Vogtlandbahn system.** This railway operates an extensive system of regional routes within the land (i.e., state) of Saxony. Since October 1996, eight new Regio-Sprinter DMUs have been on the 97-km Zwickau-Bad Brambach Route. The cars had been delivered earlier that summer, but could not be placed in service, pending the cars' acceptance as EBO compliant. Three other subsequent services (Zwickau-Klingenthal 69 km, Reichenbach-Falkenstein 68 km, and Plauen-Scheiz West 33 km) provide 60- to 120-min headways, with a total of 18 revenue DMUs. This provision results in a network of 267 km, but some of the services overlap in such a way that some intervening locations may have more frequent service. Cars are coupled and uncoupled in service as trains are formed. Service


*Figure 1. Siemens's Regio-Sprinter on dual-gauge track in Zwickau on Vogtlandbahn.*

extensions are planned, including across the border into the Czech Republic.

**Certifying the DMUs for EBO.** Vogtlandbahn DMUs had already been equipped with inductive train protection and radio communications. To achieve comparable safety to the EBO requirements of 1500 kN of longitudinal force (i.e., buffing strength), superior braking performance had to be demonstrated. It was critical that the proofs be made in a timely manner to enable the eight new cars be put into service. The objective would be either to reduce the speed of the vehicle to more tolerable impact forces or to avoid collision entirely. It was proven that the cars have twice the maximum braking rate as that of standard vehicles. It was demonstrated that there was no increase in danger to passengers and operator in comparison to comparable vehicles at speeds of up to 11.5 km per hour. It was further demonstrated that there is no substantially greater risk for passengers at speeds up to 30 km per hour as a result of deformation of the vehicle body (i.e., crush zones).

Numerous crash simulations and calculations were performed to test and retest the safety data. The validity of the tests were themselves tested, using the same criteria employed in the automobile industry. A clarification on the avoidance of over-buffing was also included. Crash simulations showed that the plastic deformations of the Regio-Sprinter disperse with a high degree of stability. In other words, the car body structure maintains integrity (i.e., there is no uncontrolled breaking apart) as the car deforms and reduces accelerations for the occupants of the vehicle.

All proofs were submitted by the manufacturer to the University of Hannover for independent scrutiny by the Institute for Rail Vehicles and Mechanical Railway Installations. Recommendations were forwarded to the ministry; acceptance was granted on October 9, 1996; and the cars commenced service. They have been operated without significant incident since then.

In summary, Zwickau is the first example of LRV-derived DMU cars operating in the diesel mode in streets with mixed vehicular traffic on a local tram route and operating in mixed passenger and freight trains on a conventional railroad. Although this example is the best contemporary one of lightweight DMU integration with railroads and light rail simultaneously, it does not yet achieve the ultimate ideal of a dual-power LRV capable of first operating in the street in the electric mode while drawing power from overhead wire and then transitioning to diesel-electric power on non-electrified railroad. This feature is available on the Saarbrücken model LRV, but is not installed on the present Saarbrücken cars.

Sapporo (Japan) former diesel-electric LRV and Galveston's Vintage Trolley "wireless" diesel-electric cars represent very few examples of on-board–generated, power-electric streetcars. New Jersey Transit's South New Jersey

LRT between Camden and Trenton comes closer to an ideal with DMUs adapted to street running. The similarity of circumstances with South New Jersey LRT and the absence of railroad electrification demonstrate the applicability of the Zwickau case to North America.

Zwickau opened its dual-function service with a fleet of Siemens Regio-Sprinters after obtaining certification from the Transport Ministry, which acknowledged equivalent safety though the cars did not achieve the 1,500-kN compressive strength requirements. A second generation of DMUs, the Siemens "Desiro," is now introduced on the Vogtlandbahn in Zwickau and meets the 1,500-kN requirement.

*The Köln Verkers-Betriebe Model*

Köln, with a city population of 1 million and a regional population of 3.3 million, is the center of a radial pattern of modern S-Bahn and tram lines with two circumferential belt lines forming a complex network. Since 1987, this network has been under the control of a single regional transit agency, Verkehrsverbund Rhein-Sieg GmbH (VRS). Köln Verkehrs-Betriebe AG (KVB) is the tram and pre metro S-Bahn affiliate of VRS. This VRS oversight organization coordinates and integrates road and public transit over a 5,100-sq-km area. VRS is comparable to the KVV in Karlsruhe with its tram (VBK), S-Bahn (Abtalbahn) and regional rail (DB) rail transit affiliates. This type of oversight agency is a common institutional device in German metropolitan areas. Such agencies were formed to coordinate management and fares and to integrate many diverse public and private transport services. VRS coordinates six operators, one of which contracts with DB to provide DMU-based, S-Bahn commuter service over three commuter corridors using 35 new purpose-built Bombardier "Talents" (see Figure 2).

Köln's innovative shared-track arrangement preceded that of Karlsruhe, arguably by several decades. A predecessor interurban railway, Köln-Bonner Eisenbahn, hosted both passenger and freight business on its reserved alignment between Köln and Bonn. Köln-Bonner Eisenbahn merged into KVB in 1992. There are two parallel routes (Routes 16 and 18) between these two cities, both of which are now operated by KVB. Lines 16 and 18 integrate their LRV train movements with freight trains on railroad tracks near their mid-point and with city trams in streets at their end points. Track connections with the national railroad system exist at several points. Both lines are approximately 40 km long with 40–50 transit stops on each route. Each route operates a little more than 39,000 scheduled S-Bahn LRV trains annually. Although both routes handle freight trains over a portion of their tracks, Route 18 handles 25 times (i.e., 15,000 movements) the annual freight train movements of Route 16 and has twice the number of grade crossings (i.e., 33). Therefore, this digest focused on KVB Route 18. Route 18, formerly owned by Köln-Bonner Eisenbahn, has sections of single track (but not in the shared-track segments) that are being doubled in a decade-long upgrade of both interurban routes. Both interurban alignments traverse industrial, suburban, residential, and agricultural areas near the Rhine River Port of Köln, which is served by its own short-line (i.e., Kleinbahn) freight railroad.

This freight railroad integrates with DB freight and passenger and KVB light rail by being a tenant on their respective tracks. The freight services are local in nature and operated with diesel locomotives. Reconciling different voltages on the Köln-Bonn interurban lines, therefore, is not the dilemma in Köln as found in other shared-track case studies.

Consistent with North American interest in train volumes and composition of the mix on shared track, more detailed information was assembled for KVB Route 18. Little had changed for the purpose of this digest's analysis, except that the ratio of freight trains to LRVs is changing. At the heaviest traffic point, which was a short segment in Brühl (a.k.a., Vochem), the KVB tracks host 36 daily freight trains and 134 daily LRVs.

What makes this operation unique is the nature of the freight service, which depends heavily on low-speed switching, or "shunting." A Federal Transport Ministry–sponsored risk assessment determined that this type of train movement is vulnerable to risk of sideswipes (Germans call these sideswipes "flanking"-type collisions).

Köln's shared-track viability and complex operating circumstances become more comprehensible in light of the relationships between the freight and transit rail operators that share track. The freight carrier, "Häfen and Güteverkehr Köln AG" (HGK, which was Köln Harbors and Freight Transport Company Railroad prior to the 1992 merger) and the light rail operator VBK are commonly owned, but separately managed. VBK and HGK have interlocking directorates. The lesson learned is that shared track appears to become more viable when operator interests are in common and/or when the railroad and rail transit operators are commonly owned or are both part of the coordinating and service integrating Stadtwerk-type institutions.

These institutional arrangements exemplified by Köln are, with some variation, common in other large German cities. Shared-track agreements seem to flourish in an environment where

- Management is decentralized,
- Operations are coordinated and integrated by a regional oversight agency,
- Synergy between public utilities and transport is encouraged institutionally,
- Leadership can influence policy across transport modal lines,
- Public and private transport enterprises coexist, and
- The interests of both railroad and rail transit operators are fulfilled.

Finally, perhaps the most unusual aspect of the KVB shared-track operation is the use of the line for driver training. No accidents of note have been recorded over the life of the joint-use, shared-track arrangement.

*Other Recent Innovations in Track Sharing*

Two other shared-track or joint-use innovations are maturing on the Deutsche Bahn AG (DBAG) former national railways and on the local Dresden light rail system (i.e., the Dresdner Verkehrsbetriebe [DBV]).

**DBAG model.** DBAG contract services are expanding. Lightweight, semilow floor DMUs are replacing commuter and secondary passenger trains. After the merger, reorganization and regionalization of German east and west federal railroads, then DBAG, the semi-private successor operator, was eligible to compete for operating contracts against other private operators. A DBAG operating affiliate has been successful in securing contracts from regional transit organizations responsible for operating commuter and branch line passenger railroad service on lines formerly owned and operated by DB. To effectively compete for these contracts, DBAG has purchased a large but diverse fleet of light rail–derived DMUs, such as the Talent, Desiro, GTW 2/6, Coradia-LINT, and others. More than 500 of these modern cars have been produced and are in operation by DBAG and others on secondary railroad services. These cars are operated as one-person LRVs, except they are non-electrified and use surplus track capacity on main line and secondary railroads. This operation is the equivalent of being able to convert a branch line railroad with FRA Class 3 track to a light rail service without having to erect catenary.

Most of the resulting DMU services approach the fulfillment of North American affordable rail new start needs. These DMU-based services are labor, equipment, and infrastructure efficient. They are implemented rapidly and deployed flexibly to meet changing travel demand using railroad track space. As these cars are designed exclusively for railroad track geometry, they typically cannot negotiate light rail track curvatures. Because of their light weight, low floor, modular design, and 1500-kN (i.e., 337,000-ft-per-pound) buffing strength, they are DBAG or EBO compliant, but not FRA compliant. These cars could, however, form the basis of a North American railroad branch line conversion to DMU light rail while retaining railroad freight service in temporal separation through waiver petition under the new FRA and FTA policy guidelines. Essentially, the South New Jersey LRT and Ottawa-Carlton DMU initiatives constitute this basis.

**The Dresden model.** In Dresden, Germany, a novel arrangement for hauling freight on a light rail system has proven successful. Some of the tram tracks through the heart of Dresden are now carrying cargo in addition to passengers. The freight streetcars, called "CarGo Trams," represent a novel solution to the problem of finding a way to supplying the new downtown Dresden factory of Germany's biggest automaker, Volkswagen AG, without worsening the city's already severe traffic jams through increased truck volume.

The trams, specially refashioned to carry cargo rather than passengers, deliver auto parts and other just-in-time freight to the downtown Dresden plant from a distribution center west of the city, which warehouses the parts brought from other factories by train or truck.

Dresden's transportation authority, the Dresdner Verkehrsbetriebe, is operating the new CarGo Trams and hopes to export the concept to other European cities that are trying to encourage central-city industrial development without causing traffic congestion.

## Transit Railcar and Technology Development

While comprehensive shared-track research was underway and *TCRP Report 52* was in preparation, a new generation of light rail cars was in design and application in Western Europe. *TCRP Report 52* listed the first of these type of units, including the Regio-Sprinter, Regio-Shuttle, Talent, GTW 2/6, and others. Since that time, the Regio-Sprinter has completed its tour of North America and two DMU models (ADtranz GTW 2/6 and Bombardier Talent [see Figures 2 and 3] have been selected for first applications in North America in time-separated, shared-track arrangements in New Jersey and in Ontario, respectively. More complete information on these DMUs and additional DMU models is now available. The low-floor and other conventional electrically powered LRV designs continue to be refined, but without significant railroad electrification in the United States, the application of conventional electrically propelled LRV models in track sharing is limited. In contrast, DMUs, as "wireless" LRVs without dependence on wayside power infrastructure, have a less complex and much broader application on this continent. For all these reasons, emphasis in this update concentrates on DMU rail car technology advancements since *TCRP Report 52*.

Adapting shared-use practice and technology to North American circumstances goes beyond operations, infrastructure, and regulation. Rolling stock is a necessary determinant in converting overseas lessons to domestic practice. This portion of the update explains how "diesel" and electric light rail rolling stock design can compensate for possible North American deficiencies in local operations, regulation, or infrastructure. Most of this information is based on data collected during the research team's tour of shared-track case studies at Saarbrücken, Düren, Karlsruhe, and Köln.

Most of the world's current passenger rail car innovation and design diversity originates in Western Europe. Vital lessons can be learned from European experience in rail car design. An important factor for North American decisionmakers in adapting shared use is overseas innovation in LRVs, specifically development of a new generation of LRV and bus-derived, diesel-propelled, low-floor DMU cars.


*Figure 2. Bombardier-Talbot Talent, DB Type 644 three-unit, diesel-electric drive, optional floor heights, mechanical drives, and modular configurations available.*

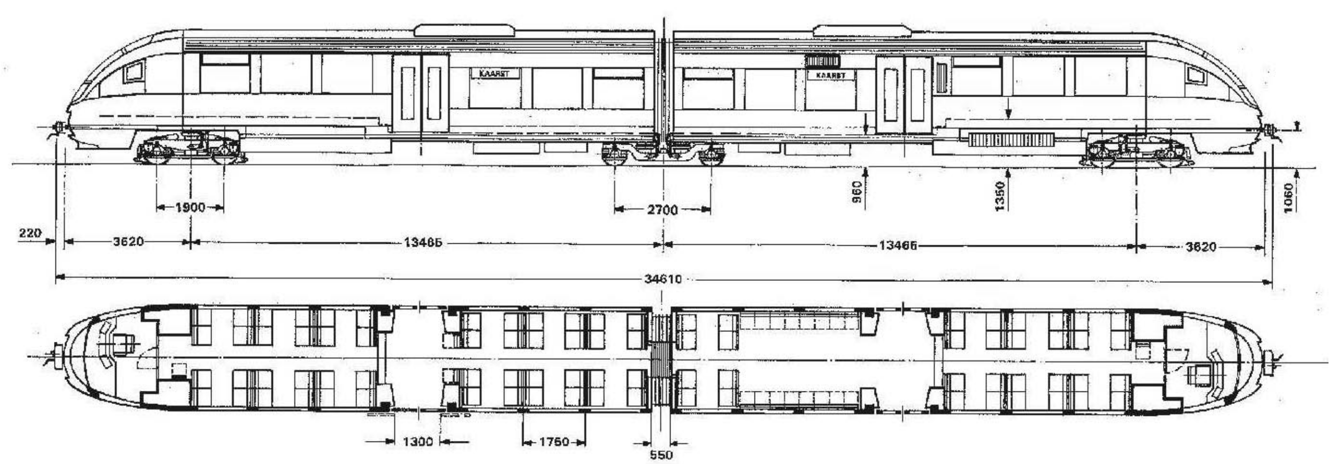


*Figure 3. Bombardier-Talbot Talent two-unit Regiobahn representing family of modular rail cars.*

Even with the recent catenary extension of the Northeast Corridor, there is less than 1,000 km of main-line railroad electrification now in the United States—less than a quarter century ago. In contrast, electrification is far more extensive and expanding in Western Europe on their nationalized and private railroad systems. In Germany, DB operates 38,384 km of standard-gauge railroad, 18,652 km of which is electrified. Whereas less than 1 percent of North American railroad mileage is electrified, more than 46 percent of the nationalized German railroad is electrified. A similar high percentage of electrified track miles exists in other Western European countries. There is, therefore, a high probability that larger German (and French and Benelux) cities proposing or expanding LRT and tram systems will have at least one electrified railroad corridor with which to connect. Karlsruhe and Saarbrücken are instructive models on how to extend electric light rail over electric railroad infrastructure. Karlsruhe has demonstrated the wisdom of sharing not only railroad track, but also the host railroad's traction power, signals, and other elements of infrastructure. The absence of this ancillary railroad power, signal, and other reclaimable infrastructure is sometimes overlooked in considering application of the Karlsruhe and similar Western European models to the North American rail transit environment.

Strict adherence to the Karlsruhe model, therefore, assumes the presence of adjacent electrified railroad network and a means to transition between traction power networks and tracks. One of the first initiatives Karlsruhe undertook in its shared-track strategy was to develop a dual-voltage (i.e., 750vDC/15kvAC, 16-2/3 Hz) LRV. Creating the dual-voltage LRV was accomplished by sandwiching a third or mid-car unit equipped with AC conversion electronics into a prototype two-unit articulated LRV. This model of dual-voltage (or potentially tri-voltage) LRV is being applied elsewhere in Western Europe where abundant electrified railroad networks exist. Absent railroad electrification, this similar approach may be applied in North America, but using diesel or alternative fuel technology.

The Düren and Zwickau models and, to a lesser extent, the Saarbrücken model may be considered more applicable to most circumstances found in North America. The lack of electrification in North America can be compensated for by substituting a self-propelled light rail car capable of operating independently of catenary or third rail. This substitution was made in Düren and Zwickau and proposed in "wireless" shared-track planning elsewhere.

DMU, like rail diesel car, has become a generic term to describe a passenger rail car that can operate coupled in multiples, forming trains of two or more cars and powered by one or more on-board internal combustion prime movers. All cars in the consist are operated from a single cab or set of driver controls. The Budd-built rail diesel car was popularized in North America by pre-Amtrak railroad management. More than 400 of these self-propelled and then-FRA-compliant cars were produced for domestic and overseas markets. The major railroads, buyers of the rail diesel cars, were previously compelled to operate uneconomic locomotive-hauled passenger trains. The railroads applied economic measures by using rail diesel cars primarily on low-density rail lines or relatively low-passenger train assignments on main lines. Two U.S. railroads used the rail diesel car extensively in daily commutation service. Cost savings were achieved in train, engine, and ground crews; fuel; and other deployment expenses. The rail diesel car uses two relatively small-displacement engines (the Detroit Diesel 6-110 series that are not bus engines, as commonly thought). These two-stroke General Motors Detroit Diesel engines are linked to Allison torque converter transmissions. The drive shafts from both engines, slung beneath the car body through cardan shafts and universal joints, drove the inner axles of both trucks. The rail diesel car drive-train arrangement is similar to at least three of the newest DMUs now being marketed worldwide.

In Germany, the "Schienenbus," until recently, performed functions similar to those of the rail diesel car. The Schienenbus (see Figure 4) is a hybrid vehicle with a bus body and bus-and-truck engine mounted on a two-axle rail chassis equipped with flanged wheels. The Schienenbus was developed in the 1930s to fulfill the need for an inexpensive rail vehicle built to standard specifications on Germany's Reichsbahn (the predecessor to DB). Rail buses were also popular among North American short line (and some main line) railroad operators from 1920 to 1940. These rail managements were also motivated to use these curious hybrids to reduce operating costs on marginal passenger services. The newest generation of light, low-floor DMUs reflects a return to the earlier tradition of borrowing from bus, truck, and streetcar technology for economical railroad passenger rolling stock.

A number of serious accidents in Germany in the late 1970s involving Schienenbus resulted in the development and specification of larger, more robustly designed rail diesel cars. Although these cars were more similar in size to the U.S.-produced rail diesel cars, they would not have complied with current FRA requirements. These rail diesel car–type of car, like their North American cousin rail diesel cars, are largely railroad-derivative designs. Their buffing strength is in the 335,000 foot-pound range (i.e., 1500 kN), and these cars are compliant with EBO regulations. The Siemens VT-628 series (see Figure 5) exemplifies the contemporary German rail diesel car. More than 1,000 of this type of car replaced the Schienenbus and locomotive-hauled train consists where possible on branch-line and main-line assignments during the 1980s and 1990s. The Schienenbus has virtually disappeared from regular revenue service, but its rail diesel car successors are prevalent. A new generation of DMUs, third in succession after the Schienenbus, are now being ordered by the hundreds. Appendix A summarizes the diversity in new-generation DMUs and the variety of modular design combinations.

These third-generation, self-propelled cars are replacing whatever Schienenbusse remain and the rail diesel cars on selected assignments. Appendix B lists more than 1,000 of these cars on order or in service in the last 5 years since they were introduced. Most of these cars (but not all) are EBO compliant in buffing strength. Those that were deficient in this regard have gradually been achieving EBO-equivalent–compliant status by compensating for buffing strength with active safety measures acceptable to the Transport Ministry. Discussion with Siemens, for example, indicated that it had achieved equivalent safety status for its popular Regio-Sprinter DMU. These newest DMU cars draw heavily from light rail and bus technology, blending them

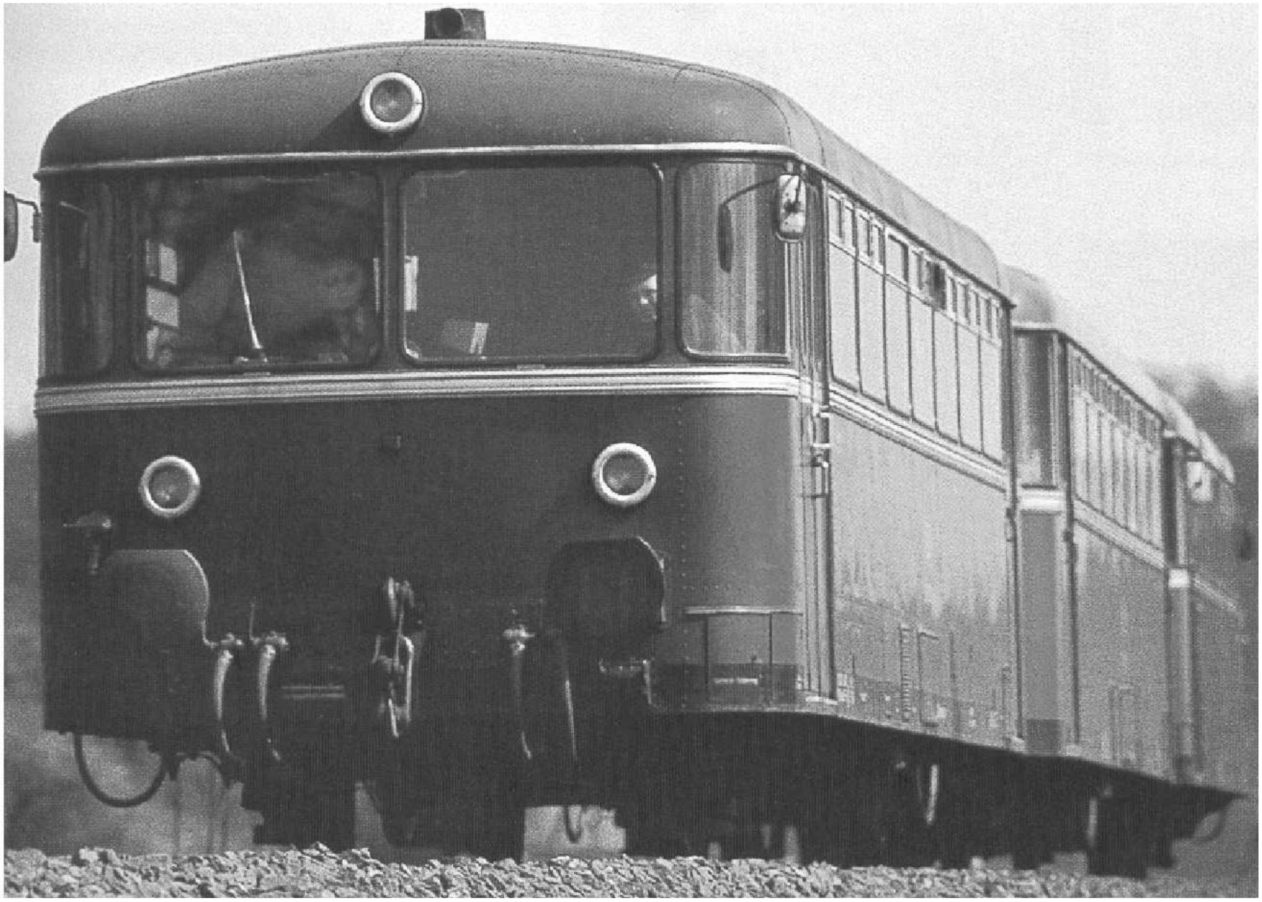

*Figure 4. MAN Schinenbusse early bus-derived traditional German DB rail bus.*

*Figure 5. Siemens's VT-628 rail diesel car and similar self-propelled units comparable to the Budd RDC.*

with rail car design and operating experience to produce a new breed of rail car in many forms and for many applications, including North America.

Professionals disagree on the definitions and terms describing these innovative rail cars. The cars are sometimes referred to as DLRVs, though at least one model is available also as a conventional all-electric LRV. The true DLRV concept is explained later in this chapter. DMU is used in this digest to describe the genre.

Two proposals are in advanced implementation: New Jersey Transit's "Southern New Jersey LRT" and Ottawa-Carlton's "Mass Transit North America" projects. A further description of applications for these types of car follows.

Basically, the electric-traction DMU can be designed to do nearly anything a conventional electric LRV can do without the benefit of wayside power or electrification. The resulting DLRV is not a direct equivalent of an all-electric LRV in environmental, operating, and financial performance. Those differences in performance, such as noise, emissions, acceleration, and longevity, require further research, present worth analysis, and other quantification.

What do the DLRVs and DMUs mean in terms of rail transit service delivery in North America? The dual-power, DLRV-type car can be deployed to extend existing electric LRT services by using surplus or disused railroad branch lines or sharing track that can be connected with the outer terminals of existing LRT systems. Service can be expanded without stringing new overhead wire. The dual-powered DLRV branch line service can overlap with the electric-powered LRV service. A diesel-electric DMU can use its own power source on the LRT tracks, but a conventional electric LRV is not fully self-propelled and, therefore, cannot operate on the wireless segments of track shared with a railroad.

There are several useful implications of this type of coordinated rail transit service plan:

- Passengers need not transfer between cars where the DMUs and LRVs meet just because the wire stops or because the mechanical transmission DMUs cannot travel on streetcar radius track.
- As DMU patronage grows, LRT wire can be extended incrementally and affordably further into the DMU territory with electric LRVs gradually supplanting the DMUs.
- DMUs, thus replaced, can be cascaded by the transit authority to new railroad branches further out on the existing branch line or deployed in ventures that may not connect with light rail. Alternatively, they can be sold to other transit authorities anticipating use of DMUs on railroad branch lines. A DMU's utility can exceed its expected lifespan.
- Ultimately, research and technology can produce a dual-power or true DLRV. This vehicle is technically achievable now. It would use off-the-shelf, proven technology.

Further buttressing the rationale for the dual-power DMU are historical precedents. These precedents exist in the railroad and bus industries, dating back to the 1920s and 1930s. Public Service Coordinated Transport (of New Jersey) ordered more than 600 new and converted buses called all-service vehicles. These vehicles had gasoline or diesel engines, as well as electric transmissions (basically, generators and electric traction motors). The vehicles were capable of operating as internal combustion buses powered from their gas engine or as trolley coaches drawing current from dual wire through poles on the roof of the vehicle. The Seattle Metro Breda-built, dual-mode trolley coaches are designed with the same concept, except they use diesel engines and modern solid-state electronics.

Domestically, the New York Central; the Delaware, Lackawanna, and Western; and the New Haven railroads had locomotives featuring gasoline- or diesel-fueled internal combustion engines. These engines power generators and feed batteries that energized conventional traction motors. The former two railroads operated these locomotives as "tri-power" units running as gas-electric vehicles, as straight electric vehicles (i.e., collecting DC current), or as battery locomotives (i.e., operating independently of catenary or third rail wayside power or on-board prime mover). Although these successful bus and railroad technical precedents exist, no dual-mode light rail counterpart of the dual-mode, all-service vehicle or tri- or dual-power locomotives exists today. At least one of the DMUs listed in Appendix B (ADtranz "GTW 2/6"), though, is available as a diesel-electric DMU or as an all-electric LRV.

Often confused, the term "dual-power" refers more to source of power, rather than the type of power. A "dual-power" vehicle can draw from independent on-board diesel or generator or wayside third-rail or catenary electric-power sources. An electric car or locomotive, such as the Karlsruhe S-Bahn car, capable of drawing current from 750 vDC or 15kV, 16-2/3Hz AC (or any two different traction currents) is considered a "dual-voltage" vehicle. There are many examples of the dual-voltage rolling stock overseas and a few examples along the Northeast Corridor. Tri-voltage locomotives are becoming more common as the European Union advances plans for railroad service integration over the former nationalized European railroads that employed a variety of electric-power systems. "Dual-mode" is a term often regarded as synonymous with "dual-power" vehicles. "Dual-mode" could apply to vehicles that draw the same current from third rail or overhead catenary (or from an on-board generator).

Car system manufacturers indicate that a contemporary dual-power vehicle built on a DMU or LRV modular platform is technically feasible. They also acknowledge that such a vehicle does not now exist, but that a dual-power prototype DLRV could be assembled. The challenges suggested in designing a complex dual-power hybrid car are

- Designing the systems integration and standard interfaces for a dual-power, diesel-electric-electric drive system;
- Assembling enough market in North America to justify the development costs of such a vehicle;
- Establishing standard specifications for dual-mode and dual-power traction power components so that various car vendors can bid on the cars without having to custom redesign the system for each individual car order;
- Keeping the cost of the dual-power vehicle within reasonable limits in view of its redundant power-handling systems;
- Achieving FRA sanction for use of dual-power DLRVs on track shared with railroads while preserving the car's ability to mix with vehicular and pedestrian traffic while the car is in LRT mode; and
- Achieving dual power with a separate power source (usually a diesel generator) coupled behind or in front of a standard LRV on portions of track without catenary (the presence of this "power pack" [see Figure 6] may also serve a crash attentuation purpose when leading the consist).

The future DLRV and its predecessor DMU technologies directly relate to shared-track practices and regulation. The following list of advantages to rail operators and transit users shows that relationship. The rail authority contemplating application of DMUs (whether dual power or not) on shared track can amplify cost savings by

- Acquiring, leasing, or getting trackage rights to existing railroad right-of-way and infrastructure (i.e., saving on real estate and track, as in the Karlsruhe or Saarbrücken models);
- Using rail cars that do not need wayside power systems and that can be recycled to other new starts (i.e., saving on power distribution systems, as in the Düren model);
- Operating more speculative services without large fixed investment (i.e., saving on planning and design, as in the Saarbrücken model);
- Providing affordable rail services, on a seasonal or special-event basis, that would otherwise be infeasible (i.e., saving on special services, as in the Saarbrücken model);
- Expanding light rail quickly and cheaply by integrating or overlaying DMU and LRV services (i.e., saving on capital programming and debt service, as in the Zwickau model); and
- Accepting a modular car platform and standard traction and control system specifications (i.e., saving on manufacturing, as in the modular platform concept used by all major Western European rail car manufacturers).

*Availability and Diversity of DMU Rail Car Products*

The new generation of DMU rail cars represents a variety of body types and propulsion power trains. However, they also share some commonalties because they are designed to compete for similar markets. Some of the earlier generation DMU cars do not share all of these commonalties, reflecting an evolution in car design within a single generation. Among commonly shared characteristics are the following:

- Use of diesel engines designed for other (usually bus and truck) purposes.
- Light rail–derivative, low-floor rail car designs that are either integral to the base model design or optional.
- Compliance with EBO, but not FRA, requirements.
- Use of transit type, self-centering, multiple-unit couplers. (Most of these designs, by nature and regulation, cannot be used in conventional train consists in revenue passenger service, and so operators avoid mixed consists of railroad and DMU stock except in emergencies with compromise couplers.)
- Modern, streamlined, appealing appearance that may conceal impact-attenuating crush zones.
- Use of design for less intensive railroad service and for avoiding transition to streetcar or light rail environments. (In their present form, most of these DMU offerings cannot negotiate streetcar geometry. The modular platform concept permits some adaptation to car designs capable of mixing with both vehicular and railroad traffic.)
- Promotion as part of a family, of modular platforms or products, that can be sized or adapted to the needs of the individual transit operator.
- Double-end configuration for reversing ends at stub terminals and at ends of branch lines.

DMUs that look similar and share the previous characteristics usually still differ substantially. To fully understand the design differences and provide a current reference of the new generation of DMU products, a summary listing has been assembled as Appendix B. Thirteen distinct DMU car designs with more than 50 variants are listed or illustrated, first by profile drawing with major dimensions shown, and then by photo illustration in service. Figures 1, 2, 3, and 7 show examples of these contemporary DMUs and their variants. None of the cars are classified as one of the dual-power DLRVs described previously. Only two are available in diesel or electric (but not together) versions. For further guidance, Appendix B lists the specifications, design details, and number of units delivered for the 13 DMU types. To document the widespread use of these new generation DMU cars in Europe, Appendix C provides a list of rail carriers (including two in North America) that operate or have ordered more than 1,150 of these lightweight DMUs. No DMU can be operated commingled with railroad trains in North America.

*Petitions to the FRA for Track-Sharing Waivers*

While the public comment period was underway for the FRA and FTA shared-track policy statements, two petitions

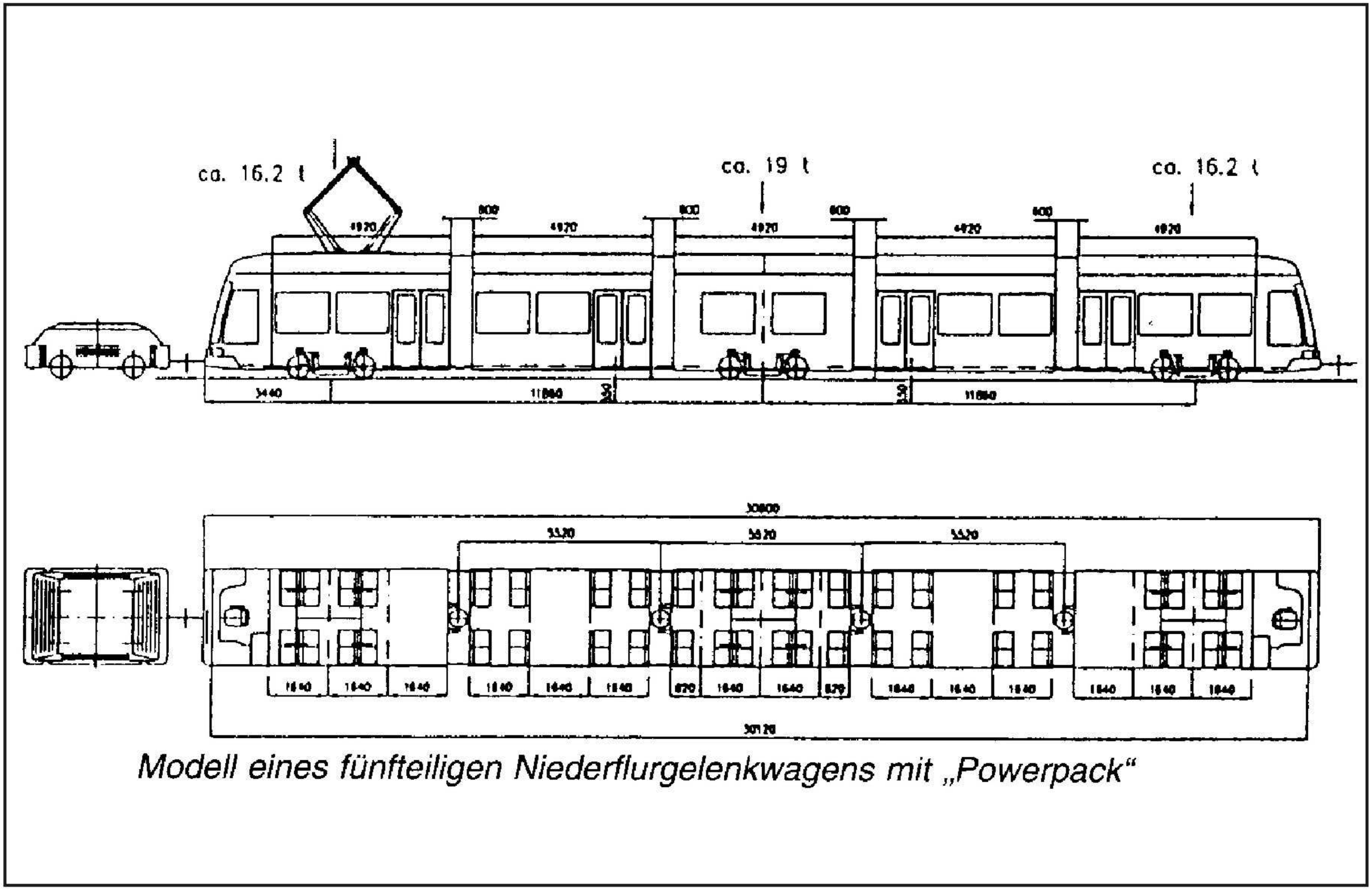


*Figure 6. Five-section, low-floor light rail vehicle with power pack trailer in towed position (formerly proposed for Chemnitz Germany shared track).*

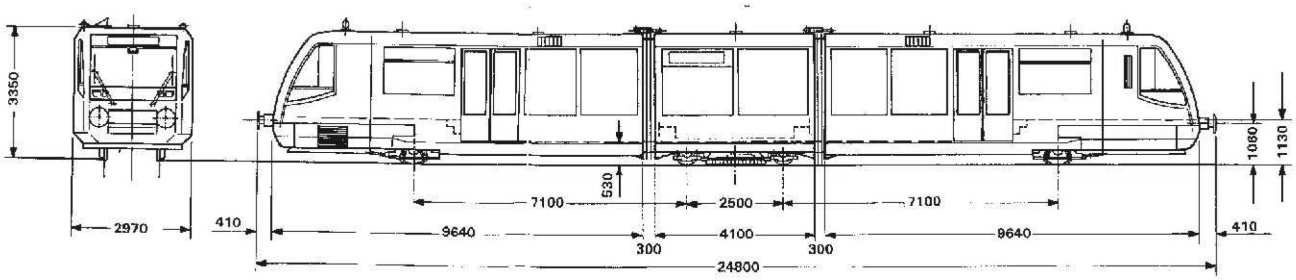


*Figure 7. Siemens's Regio-Sprinter outer two axles powered each by MAN five-cylinder diesel bus engine.*

for shared-track waivers were filed. The FRA's treatment of these petitions was consistent with the final version of the policy statements. As these waiver petitions were the first resolved since the issuance of federal policy (in draft form), they are worth noting for the precedents and FRA-imposed conditions.

To demonstrate the FRA waiver process as applied to shared track, the first of these waiver petitions is subsequently summarized. The New Jersey Transit waiver petition is explained, along with a detailed description of the waiver process and public comments received in the FRA's final policy statement (65 FR 42,537–42,540).

*FRA Docket No. 1999-6135* (64 FR 45996, Aug. 23, 1999) submitted July 13, 1999, petition granted subject to conditions on December 3, 1999, regarding New Jersey Transit Southern New Jersey LRT project. This waiver is one of two granted on consecutive days in December 1999. Granting the petition by the FRA takes the form of specifying what is permitted, listing conditions accompanying the permission, and granting relief from specified FRA regulations. The FRA granted relief from prohibitions of track sharing, contingent on temporally separated operations with an active freight railroad (i.e., Conrail Shared Asset). The petition was granted subject to the following summarized basic conditions: evidence that the State Oversight Agency has approved the SSPP, New Jersey Transit certification that the contractor operations will be consistent with the SSPP, submittal of procedures for ensuring temporal separation, safety conditions during construction and vehicle testing, and a duration of 5 years (subject to periodic review and renewal). The petitioner is granted conditional relief from the following FRA regulations: glazing, emergency exits, and headlight and auxiliary highway-crossing safety lights (but the triangular pattern of lights must be maintained).

Other shared-track waiver petitions were submitted, and conditional granting of the waivers was denied (e.g., an hours-of-service portion of at least one waiver was denied). One waiver was granted simultaneously with New Jersey Transit: Utah Transit Authority "TRAX"/Salt Lake City Southern Railroad (FRA Docket 1999-6253/Dec. 2, 1999). Subsequent pending or granted waivers include

- San Diego Trolley/San Diego and Imperial Valley Railroad (FRA Docket 2000-7137, 7274/ Jan. 19, 2001);
- Maryland Mass Transit Administration (Baltimore, Maryland) light rail/CSX Transportation, Inc.;
- Electric City Museum (Scranton, Pennsylvania)/Delaware Lackawanna Railroad/Steamtown (Laurel Line);
- New Jersey Transit "Newark City Subway" light rail extension/Norfolk Southern Corp (FRA Docket 2000-7335, Bloomfield, New Jersey); and
- Santa Clara Valley Transportation Authority (Tasman West extension).

## Other Information on Institutions, Operations, and Infrastructure

As the shared-track research process evolved, the publishing of *TCRP Report 52* represented the comprehensive scan of track-sharing issues. The issuance of the federal policy statements on shared track represented the emergence of federal policy following and parallel to the research. Both the research and the policy triggered a series of other activities. These activities included foreign study tours; domestic working groups; and an expanded research agenda of the TRB, APTA, and other organizations that address shared-track issues. The committee structure and conference itineraries of the TRB, APTA, and other groups embraced shared-track issues to expand the dialogue and awareness. Additionally, several transit operators petitioned the FRA for waivers, citing a variety of operating circumstances and rationales for granting waivers. The activities are listed in this digest not to duplicate other research documentation, but to provide citations and sources for researchers investigating various aspects of shared track in detail.

The FTA organized a fact-finding mission to Germany and Belgium between March 25 and April 1, 2000. The objective of that FTA mission was "to encourage government and industrywide consensus on technical and institutional approaches to safety challenges posed by shared-use rail lines." The mission participants represented government (i.e., the FRA and FTA), rail transit operators, railroads, rail car builders, and systems vendors. The 1-week tour included several bilateral exchange functions, but the primary purpose was to observe and study shared track in Karlsruhe. This tour was accomplished in the last week of March 2000. The principal investigator for *TCRP Report 52* participated in the study mission and supplemented that tour with additional visits to Köln, Karlsruhe, Düren, and Saarbrücken in April 2000. The information gathered during the study mission was published in an FTA and FRA "Karlsruhe" study mission report cited in the bibliography.

The TCRP International Transit Studies Program organized a 2-week study tour visiting Karlsruhe, Kassel, Saarbrücken, Strasbourg, Düren, Köln, and Luxembourg. The last destination was handled as a briefing rather than a site visit. Transit professionals and executives from rail transit operations participated.

Shared track has been presented at a series of professional and research conferences over the past 5 years. These conferences have included railway age joint-use specialty conferences in 1996, 1997, 1998, and 1999. Both APTA and the TRB have sponsored sessions devoted to shared track and corridors. These sessions occurred over a 5-year period up to and including the 2001 APTA Rail Transit Conference in Boston. The TRB conferences and most of the APTA conferences have published proceedings available in hard copy and on CD-ROM.

Special committees and working groups were formed on shared track or on issues relating to shared track. APTA formed a joint-use working group that responded to the FTA and FRA policy initiative. APTA also sponsored the Shared Track International Symposium in July 2000.

## CHAPTER 4: TRACK-SHARING ISSUES UPDATED

This research is structured in recognition of the debate surrounding joint use of facilities and shared track. This chapter identifies major issues in sharing track. Particular attention is directed at the new FRA and FTA policy on shared track, as cited in Chapter 2. Both the final policy and selected public comments on the draft policy reveal the key issues that continue as federal policy is implemented and track-sharing experience grows. These key issues provide a corridor to future research initiatives as shared-track practices evolve. Finally, issue definition helps rail operators understand and deal with the FRA's waiver process and other features of state and federal regulation.

The original purpose of a chapter on "issues" has been altered in recognition of rapidly evolving issues and newly defined federal policy on shared track. The issues developed from the original first four chapters of *TCRP Report 52* are affirmed and still stand. However, these issues have been refined and focused by a debate of the amount and nature of federal regulations and state safety oversight. This policy debate continues to provide direction and focus for new research into joint corridors and shared-track issues. The most significant emergence of issues is derived from the joint FRA and FTA final policy statement on shared track and the FRA clarification of its regulatory jurisdiction and shared-track waiver process, both published in *The Federal Register,* July 2000.

The FTA and FRA decided that a comment period would be helpful in developing the final policy statement. The public comment period extended nearly a year. Approximately 50 written responses to the draft federal policy statement were received.

### Interest Groups

Primary interest groups and their basic objectives are as follows:

- **Rail transit owners and operators** (generally public sector) want improved, cost-effective transit service for the public, including system users.
- **Freight railroad owners and operators and their shippers** (generally private sector) want return on private investment through competitive freight service.
- **Transit riders** (individuals and collective citizenry) want affordable, convenient, and safe transportation to fulfill their individual travel needs.
- **Transportation regulators** at federal and state levels (public sector) want safe, competitive transportation to protect the public users and private providers.
- **Rail equipment builders and vendors** (generally private sector) want return on investment through supplying transportation providers with competitive passenger rail and freight equipment.

### Major Issue Categories

This update categorizes shared-use issues into the following categories:

- Regulation,
- Operation,
- Physical plant and infrastructure, and
- Vehicle.

These four categories are comprehensive to the extent that they cover the entire spectrum of shared-track issues.

Table 3 shows the five institutional interests and their policies regarding the four issue categories. This table identifies which issues are important to specific interest groups. It also begins to define joint use as a policy issue.

Not all of the issues identified in this update can be quantified. Some will be of strong policy content, leading to analysis by alternative scenarios. Others can be fit into a risk analysis for a rigorous and precise quantification. If an issue is measurable, it is accompanied by a suggestion for how to treat the issue in a risk or policy analysis. All of the issues will have related ancillary or subordinate issues.

**TABLE 3 Policy matrix**

| | Regulation | Operation | Physical Plant and Infrastructure | Vehicle |
|---|---|---|---|---|
| Rail Transit Owners and Operators | S | P | P | P |
| Freight Railroad Owners and Operators | P | P | P | P |
| Transit Riders | M | P | S | S |
| Transportation Regulators | P | S | S | S |
| Rail Equipment Builders and Vendors | S | M | M | P |

Note:
P = Primary interest
S = Secondary interest
M = Minor or no interest

## Specific Issues Drawn from the Policy Matrix

Regulation issues are as follows:

- Issue: Is shared track a cost-effective and socially sound national policy worth advancing? *Policy suggestion: Compare capital and social cost savings from joint use with joint-use risk and related costs.*
- Issue: What are the options or mitigation that can be applied to satisfy regulations that prevent or impede joint use? *Policy suggestion*: *Compile risk quantification or list the most effective mitigations.*

  — Related issues: Is overseas experience in reconciling or overcoming regulatory barriers to joint use transferable to the North American experience? If so, what are the best models? Can one or a combination of proven overseas risk mitigations be applied on a case-by-case basis to enhance shared-track options without overhauling the regulatory structure or outrunning technical analysis now underway? *Policy suggestion: Compare overseas joint-use accident experience with U.S. transit joint-use risk experience.*

- Issue: Does shared-track operation inherently jeopardize personal and public safety for rail passengers, train crews, and the public near the rail line?
- Issue: Do the advantages of expanded transit service outweigh any loss of personal safety to the transit rider? *Policy suggestion: Analyze risk experience before and after joint-use implementation on a specific route (U.S. experience is meager, but overseas experience may be instructive).*
- Issue: What are the quantifiable risks and liabilities from various degrees of joint use (ranging from integrated temporal operation to complete physical separation)? *Policy suggestion: Make a priority-ordered list, based on local conditions, of preferred risk mitigations and their specific values in a guide for assignment to a specific rail route.*
- Issue: Can regulation of rail transit by state and regional entities realize a level of safety comparable to that of the federally regulated railroad system? *Policy suggestion: Compare transit risk experience (i.e., risk experience when regulated at local or state level) with railroad risk experience (i.e., risk experience when regulated at federal level).*

Operation issues are as follows:

- Issue: What elements of Japanese reciprocal-running and European joint-use operating practices can be transferred to the North American railroad and rail transit environment? *Policy suggestion: List overseas-specific operating practices as risk mitigation techniques (for potential application).*
- Issue: Should survivability and social amenity be blended into the shared-track analysis? Considerations include fire protection, evacuation, and the Americans with Disabilities Act (ADA).

Physical plant and infrastructure issues are as follows:

- Issue: Which fail-safe signaling and train-control systems currently under development or employed in collision avoidance can cost-effectively be applied to railroad and transit shared track in North America?

  — Related issue: To what extent can fail-safe train control, such as positive train separation and positive train control (described in *TCRP Report 52*), mitigate risk and liability in joint-use service? *Policy suggestion: Although it is a popular notion that positive train separation and positive train control can reduce risk, there is an insufficient body of evidence at this time to support the claim. This issue is potentially measurable.*

- Issue: How would separation of infrastructure from operations (and perhaps rolling stock), as in Europe, affect the feasibility of joint use? *Policy suggestion: Overseas, where these railroad entities have been separated as cost and management centers, more time is required to test and measure separation as a risk mitigation factor. These operations have been in effect for a short duration or are still in transition as of this writing.*

Vehicle issues are as follows:

- Issue: What vehicle design innovations being developed in Asia and Europe can be applied in North America?

  — Related issue: Which of the crashworthiness measures (i.e., heavier structure, crumple zones, operator refuges, interior surfaces, and fixation) can be applied to DMUs and LRVs as mitigation to increase safety and permit joint use? *Policy suggestion: List rail car crashworthiness measures in order of level of effectiveness.*

Comprehensive issues are as follows:

- Issue: Crashworthiness versus crash avoidance was identified early in this research as a comprehensive issue. Research is advancing on three continents in each of the two precautionary measures.

  — Related issues: Can balance be achieved between car performance and car structural design and weight, similar to the balance achieved in automotive design, that attempts to combine objectives of weight reduction, impact attenuation, and agility? What are the cultural, institutional, and social conditions that encourage shared track in some locations and not in others?

**Areas for Future Research**

Many research topics were identified as a result of the public-comment-and-federal-response process for the FRA and FTA policy statement on shared track.

Any transit operator anticipating shared track or shared right-of-way should consider a full reading of the summary comments and FRA responses, as entered in the Federal Register, Vol. 65, No. 132, Monday, July 10, 2000.

The shared-track dialogue printed in the Federal Register suggests closure on the first comprehensive research phase into track sharing epitomized by *TCRP Report 52* and other activities since 1996. The dialogue also suggests a renewed research agenda for shared track in North America. Although the matter of regulating shared-track operations among light rail, light DMU, and railroads now has a uniform regulatory treatment as a result of the federal policy, innovation can improve safety and operating practice. Chapter 3 of this update outlines the emergence of new operating practices, advancements in technology, and productive research inquiry in related fields. This technical content and the policy issue content combine to form the following research agenda items:

- Finding operating and technology alternatives for achieving equivalent safety to temporal separation in the following general areas:

  — Rail car crash attenuation (in contrast to crash resistance);
  — Continued research and testing of positive train separation, positive train control, and other applicable and affordable train control technologies; and
  — Calculated probabilities for applying various generic risk mitigation measures.

- Evaluating and quantifying elements of achieving equivalent safety in safety operating plans.
- Sharing experience and research on the relative effectiveness of state safety oversight planning following the first 5 years of regulatory experience. This research agenda item does not suggest a uniform safety oversight process, but rather an organized method of sharing what works well and what does not.

- Improving the safety data to provide more consistent and reliable input to risk analysis.
- Conducting more detailed research on overseas risk and operating experience. This research agenda item envisions a penetrating dissection of operating practices and a fuller understanding of applied technologies that goes well beyond the anecdotal experience of study tour participants.
- Refining shared-track risk assessment to include degrees and methods of physical separation of different rail modes operating on common tracks. Such research would begin with an array of degrees of separation, with diurnal separation being at the top, and work from the top downward toward lesser degrees (e.g., interlocked derails) that can be applied individually or in combination.
- Analyzing the economics of shared-track investment (e.g., comparing and reconciling the duration of waivers and waiver renewal probabilities with the life cycle cost of investment in shared-track capital).
- Studying experience from the past 5 years on any migration of railroad labor practices and requirements to rail transit operators and vice versa resulting from shared track or regulation of shared track. These practices and requirements could include, but not be limited to, hours of service and employee benefits.
- Investigating and possibly demonstrating measures and techniques for broadening the operating windows for rail transit and railroad carriers.
- Establishing a demonstration regime for testing effectiveness of various shared-track practices.
- Reviewing past shared-track waiver experience dealing with light rail DMU and railroad joint-operating practices.
- Drafting and distributing user-friendly advisory and guidance documents for transit and railroad operators anticipating shared track in North America. Discussion would include New Jersey Transit's Southern New Jersey Light Rail (DMU Trenton-Camden), Utah Transit Authority (Salt Lake City–Sandy), Baltimore, San Diego, Santa Clara, Ottawa-Carlton DMU, and other petitions subsequent to the issuance of the federal policy statements.

Chapter 5 synthesizes the scope of joint-use research, summarizes findings, and provides conclusions on the future of joint use in North America and the means for achieving it.

## CHAPTER 5: UPDATED AND REFINED CONCLUSIONS

This chapter updates and refines the findings of *TCRP Report 52*, incorporating the shared-track issues raised by the federal policy statements on shared track and by public comments. The final conclusions of this chapter discuss shared-track issues in more detailed operating and regulatory terms. Any operating entities anticipating sharing track should examine the policy statements, including the public comment and federal response dialogue, to further their institutional understanding of shared-track requirements. The SSPP overseeing rail transit operations in their respective states should also be required reading prior to initiating any rail transit planning that depends on a shared-track strategy.

### Reconsidering Key Issues Since *TCRP Report 52*

Although the key issues were refined with the issuance of final federal policy statements on shared track, issues identified in *TCRP Report 52* still stand. Key issues are still structured around the four foundations of joint-use debate, as agreed to by the peer panel governing *TCRP Report 52*:

- Regulation,
- Operation,
- Physical plant and infrastructure, and
- Vehicle.

Each of the issues that were first revealed and expressed as questions in Chapter 4 of this digest are treated in the following sections with corresponding conclusions to those questions.

### Key Regulation Issues

*Is Joint Use a Sound Policy Worth Advancing?*

The research discloses that rail passenger travel is inherently safer than vehicular modes. Rail transit suffers a fatality rate of 0.73 for rapid transit, 0.38 for commuter rail, and 0.25 for LRT per hundred million passenger miles. In contrast, the vehicular rate is 1.44 fatalities per hundred million passenger miles (Tennyson, 1998). This fact alone is not sufficient reason to justify shared track on a national basis.

In Europe and Japan, shared-track decisions are traditionally made at local, metropolitan, or state levels and on a project-by-project basis. The federal role is to develop a regulatory framework that establishes baseline standards to be applied locally and to oversee the enforcement of those standards.

The importance of risk assessment may increase and be used in providing a "steep burden of proof" to satisfy new FRA policy and to potentially allow commingled operation on shared track.

The FRA's increasing use of safety risk assessment and joint-track use proposals (e.g., high-speed passenger with freight, exemplified by Florida Overland Express [FOX] and Northeast Corridor electrification extension projects) follows a similar process used 5 years ago by the German Ministry of Railways. The difference is that the German assessment was for mixing noncompliant (at the time)

Regio-Sprinter DMUs with railroad trains at Düren and Zwickau, while the FRA application was for mixing slow- and high-speed passenger railroad trains on shared facilities. All of this evidence suggests that shared track and joint use are already being addressed with similar methodologies (as a matter of FRA policy), but not in the same applications.

*What Risk Mitigation Measures Can Be Applied to Shared Track to Reduce Risk to Tolerable Levels?*

All shared-track risk mitigation measures fall into one of two major categories: crashworthiness (i.e., passive) or crash avoidance (i.e., active). The cooperative positive train control and positive train separation demonstrations, rail car crash testing, and other research activities are currently addressing these measures in part, but definitive results are not yet available. Speed, braking distance, isolation of switching operations, and operating discipline, combined with passive (vehicle design) measures are the principal risk mitigation measures. See also Table 2, which comes from the FRA final policy statement (Federal Register, Vol. 65, No. 132, July 10, 2000, p. 42,552) and is essential reading for any potential petitioner anticipating an FRA waiver on track sharing.

*Does Joint Use Constitute a Hazard to Public Safety?*

Whether or not joint use constitutes a hazard to public safety cannot be answered absolutely with "yes" or "no." Related questions have been answered by this research. Is joint use by mixed train types more hazardous than running homogeneous train consists simultaneously on the same track? Yes, it is more hazardous, but the degree of hazard may not be significant or may be tolerable to the shared-track partners. That hazard that exists may be reduced by mitigation measures to the point at which it is equivalent to, or exceeds, the safety of homogeneous train consists on the same track. The following points support these assertions:

- No major accidents have occurred in overseas shared-track applications over the past decade of their existence. Meanwhile, during the same period, some significant losses of life have been experienced abroad and in North America by collisions between train consists of the same type.
- Data collected from risk analysis performed for German railroads, using the same risk analysis technique as those used for the FRA (in evaluating high-speed versus freight train shared-track mixes), indicate tolerable levels of risk. The German risk analysis was performed for light DMUs, such as the ones used in Chemnitz, Zwickau, Köln, and Düren, and for LRVs, such as the ones used in Karlsruhe and Saarbrücken.
- Rail transit and railroad passenger travel are inherently safer than other surface travel modes are.
- Collisions between trains and trespassers or with vehicles at grade crossings constitute 96 percent of U.S. railroad fatalities—not collisions between trains (FRA data). The most important issue in shared track expressed in the FRA and FTA final joint policy statement is the potential of a "catastrophic collision" between conventional railroad and rail transit equipment. The policy statement continues explaining that trespasser accidents have recently outpaced grade crossing vehicular and train accidents as the leading cause of death on the general railroad system in the United States.

*What Are the Quantifiable Risks and Liabilities Arising from Various Degrees of Joint Use?*

The FRA and FTA policy indicates a clear preference for temporal separation of train movements. This control measure reduces shared-track risk of collision between disparate rolling stock to near zero by totally separating railroad and rail transit movements. In time separation, typically, freight trains have a 3- to 5-h window after late-night closure of light rail operations and prior to resumption of LRT operations for the morning peak. This type of time separation is considered "diurnal," or a recurring cycle of change on a daily basis. This concept differentiates between FRA-defined time separation and short duration time windows, as in between peak commuting periods. Diurnal separation restricts freight service options to shippers and reduces opportunities to perform track and infrastructure maintenance because of the reduced ability to shut down track totally during night hours.

The German Railway Ministry, following its risk analysis findings, determined that several mitigation risk controls would diminish shared-track risk to acceptable levels for all participants in German joint-use operations:

- **Limit speed of train operations on shared track to 90 km per hour (i.e., 55 mph).** This speed limit was based on the enhanced braking capabilities of LRVs (i.e., their ability to avoid collisions through reduced stopping distances). As pointed out earlier in *TCRP Report 52*, 80 percent of German rail collisions are caused by an inability to stop in time. The limit in speed, combined with the high-performance redundant braking system inherent in DMUs and LRVs (to enable them to travel in mixed vehicular and pedestrian traffic), diminishes risk. The 90-km-per-hour (i.e., 55-mph) maximum speed can be increased to 100 km per hour (i.e., 62 mph) if certain ISO 9000 standards are followed. Because most LRVs do not exceed 50–55 mph balanced speed, this type of mitigation can be applied in the United States.
- **Prohibit or temporally separate railroad switching operations on track used concurrently with LRT.** German risk analysis disclosed higher vulnerability to

collisions with switching operations because of possible "flanking" sideswipe incidents and because of intermittent but long durations of track occupancy by static cars. This condition occurs when freight operators leave their train on running tracks while switching cars onto sidings and spurs. Prohibiting local freight during the day but permitting through (i.e., nonstop) freight trains traveling in the same direction recognizes the varying risks imposed by different types of train operation. This control measure can also be applied at increased capital costs by adding siding tracks to permit switching without interference to LRVs on running tracks.

- **Induce separation by capacity deficiency.** Temporal separation that is practiced overseas is largely because of lack of track capacity and excessive volumes of rail traffic, not safety considerations. Though not motivated primarily by safety, separation induced by capacity deficiency can impose an upper limit on shared-track volumes and, thereby, provide an incidental safety benefit.
- **Apply speed and other restrictions more rigorously with single track with passing sidings.** Risk-control standards, in the German experience, change as risk increases. Specific mitigation measures are applied on a sliding scale to intensify control measures consistently with increases in risk from higher speed or greater train density. Risk assessment should dictate the calibration of the scale.
- **Apply train-control technologies.** INDUSI-based, train-protection systems are required for routes with shared track in Germany. The type and degree of protection depend on maximum permissive speed, types of train consists, train performance (principally stopping distance), and the volume of trains. Specific mitigation using train control, signal spacing, and braking distances is applied to each case.
- **Establish wheel tread profile conformity.** This risk control is somewhat less of a mitigation and more of an operational requirement. In Germany, a compromise profile was developed, enabling Karlsruhe LRVs in Stadtbahn service to transition between in-street rail and railroad track.
- **Prevent rail transit and railroad vehicles from routinely being coupled into the same consists if the LRV has a buffing strength of less than 1500 kN (i.e., 337,000 lb).** This requirement creates a threshold principally for DMUs and applies somewhat less to LRVs. The requirement is intended to clearly distinguish among railroad trains, LRVs, and DMUs, the last of which would be most likely to be coupled with railroad rolling stock or dual-service branch line railways. The most recent light (i.e., Category 2 or 3) DMUs produced for the Western European markets are designed to European railroad–compatible (i.e., EBO) buffing requirements (i.e., 1500 kN).

*Can the United States Learn from the Shared-Track Implementation Experience in Germany?*

The German joint-use experience in regulatory matters is instructive. Denationalizing the system, by splitting operations from track and establishing open access to tracks, laid the foundation for expanding track sharing. Among these policies, open access was not significant because it enables rail transit to bid and compete on an equal basis with other rail carriers for track space on railroads. The concept of shared track in Germany was accepted more by changes in the application of regulations than by changes in the specific standards or requirements. Decisions by the German Railway Ministry (a rough equivalent of the FRA) favoring joint use, with conditions, were based on a process initiated by the Karlsruhe proposal and, later, by the Düren DMU shared-track proposals. Both processes generated specific risk analyses. The ministry's decisions were contingent on imposing compensating risk requirements, such as the substitution of active for passive risk mitigation. For example, to compensate for the lighter LRV where its passive safety (i.e., crashworthiness) is inferior to that of railroad trains, higher active safety (i.e., high avoidance of collisions) had to be substituted.

The primary mitigation rationale was to apply the reduced stopping distances of LRVs, combined, with a reduced permissive speed of 100 km per hour and improved signal spacing, upgrading, and communication. Strong local resolve and reliance on a firm operating discipline helped to implement shared-track operations. This update suggests that the German example represents an approach to reconciling various contrasting interests on the subject of shared track, trading off equivalent forms of safety measures for others. In summary, this process involved

- Scoping the specific joint-use proposal,
- Collecting data on operations and accidents,
- Performing a risk analysis and making a preliminary "go or no-go" decision,
- Determining probabilities and the appropriate risk mitigation measures to apply,
- Performing a series of controlled tests (as in the pre-service Pforzheim tests in Karlsruhe),
- Applying for permanent waiver or exception,
- Beginning service, and
- Monitoring performance.

This listed technique is not applied to joint use in Japan, where decisions are more a product of joint venture business decisions and applications for operating licenses.

This research and experience does not suggest that U.S. standards should be relaxed or that German regulations are more lenient or less complex than those in North America. In addition to federal railroad regulations comparable to those of the FRA, German streetcar and rail transit are governed by stringent standards and regulations (i.e., BOStrab) for which there are no direct equivalents now in the United States.

## Key Operation Issues

*What Elements of Overseas Joint-Use Experience and Operation Practices Could Be Transferred to the North American Rail Transit and Railroad Environment?*

Rather than transferring overseas operating practices wholesale to North America, selected lessons can be learned and selectively applied from the growing wealth of shared-track experience. The United States can learn from the ideal models, like Karlsruhe, and perhaps transfer direct elements from a limited number of models, such as Zwickau, Düren, or Saarbrücken.

In its shared-track policy statement, the FRA states that it "admires" the Karlsruhe practice, but cites different circumstances abroad that make it difficult to replicate conditions favorable to shared track in North America. These circumstances are summarized in the policy statement as traffic mix, corporate structures, labor agreements, and basic safety features. The FRA policy statement cautions against using Karlsruhe as a model. Accordingly, Karlsruhe may provide more of an ideal worth understanding than a readily transferable model of shared track. This provision is because of the differences cited by the FRA and because of other technical contrasts. A quest for more applicable models suggests that research may be better directed at the modest joint-use operations overseas that more closely approximate North American conditions and circumstances.

Unlike shared track in Europe, shared track in Japan most commonly appears in the form of reciprocal or through running. There, two or more carriers share portions of their track networks as zoned but integrated service. Although heavy rail rapid transit, interurban, and railroad shared track is relatively uncommon in continental Europe, it appears as one of the most familiar forms of reciprocal running in Japan and Korea. Light rail operating on railroad tracks, however, is relatively uncommon in Japan. Because rail freight is very subordinated to passenger service in Japan, shared track (where practiced) most often occurs between passenger railroads and rail transit operators. The common business of moving passengers in Japan enhances the popularity of shared track between operators because both the operations and the services can be integrated into a common timetable. Services can be zoned, and other cost savings can accrue to the passenger and operator. Fewer operating benefits derive from shared track between freight and passenger carriers, regardless of the rail technologies mixed.

Some overseas experience may be instructive, but is otherwise not transferable. In the United States, the metropolitan areas (even those in the Northeast) are distantly separated, and the interurban electric railroad links that once existed have disappeared. The types of connecting rail linkages found in Japan are unlikely to be restored in the United States, even if joint-use practices are accepted. The standards and distances vary too much to permit the common subway-to-railroad-to-subway model, such as that found in Kobe-Osaka city pairs in Japan. The North American situation is one of widely separated and disparate local rail transit systems, having little in common with neighboring metropolitan areas and, in some cases, little in common with other lines within their own system. Lack of common standards discourages through running and sharing of rapid transit tracks by intercity rail at both ends of its city pair service. The possibility for some through-running operations can exist even among disparate rail systems, as exemplified by the potential use of a hybrid rail car at the John F. Kennedy (JFK) International Airport.

The close proximity of metro areas in Japan, but contrasting physical standards, has resulted in an important feature in the evolution of shared-track arrangements: a hybrid rail car. The hybrid purpose-built car is designed to travel between and integrate with otherwise incompatible rail transit systems. This car is similar to the "AirTrain" in the JFK Airport Light Rail Transit Project. Now under construction in New York City, AirTrain is designed to a light rail dimensional standard, but is automated and uses linear induction motors fed from wayside third rails. The JFK system is designed as a large dual-rail–type, people-mover operation with on-airport distribution functions. The system goes off the airport to link to Long Island Rail Road and New York City Transit rapid transit systems at separate locations. Interchange of rolling stock and joint use will initially be impossible because of varying dimensions; operations (automated versus non-automated); propulsions (linear-induction motor versus rotary traction motors); and institutional problems of crossing operational, regulatory, and labor domains. Passengers will initially have to transfer at multimodal connections off the airport. Confident that some day the institutional problems of interchange can be resolved, the operator of the airport designed its rail system so as not to preclude through running using a hybrid car. The operator did not, however, design for full reciprocity among railroad, rapid transit, and people mover systems. A key feature would be a future hybrid car that can operate on the airport system and then switch to either the rapid transit or Metropolitan Transportation Authority Long Island Rail Road tracks to access midtown Manhattan. Many obstacles must be overcome before the JFK project achieves the ultimate "one seat" intermodal rail ride.

## Key Physical Plant and Infrastructure Issues

*What Fail-Safe Signaling and Train-Control Technologies Are Applied in Collision Avoidance?*

New train-control technologies are being developed and tested for several important reasons:

- To improve the already good safety record of rail transit and railroad operations in the United States and abroad,

- To leverage additional capacity from rail infrastructure by closer, safer, and more reliable spacing of train movements, and
- To apply the new train-control technologies to selected proposals for sharing tracks by high-speed passenger and freight railroad trains (e.g., the Northeast Corridor Boston Electrification Project and Florida Overland Express).

All of these technology applications by technology vendors and federal, state, and railroad sponsors are useful in enhancing the viability of joint-use practices, regardless of the train types participating in the track sharing. The third item listed previously reveals the issue that, if 60-mph freight trains can safely operate with 150-mph passenger trains using advanced train-control technology on shared track to reduce risk, why cannot the same technologies be applied to railroad and LRT train consists, with both kinds of consist going a maximum of only 60 mph on shared track? Both kinds of consist would operate within the same fail-safe, train-control and operating regimen. The issue is a matter of risk exposure and agreement between the railroad and transit entities regarding cost and liability, which are significant issues themselves. The approach of evaluating the risk of two very different types of trains sharing tracks is currently considered potentially valid in one case, but not in the other, similar case.

In contrast, the highway analogy of disparate size and weight vehicles navigating a common space with only the rudiments of line of sight, rules of conduct, signals, and signing is a commonly accepted risk. There are more than 24 examples of railroad passenger and freight trains commingling in mixed vehicular traffic on public thoroughfares in the United States. These examples are accepted from a regulatory standpoint, though not as a desirable shared use.

This research suggests that positive train separation, positive train control, and other train-control and separation technologies can be applied to validate selected mixed use by railroad and rail transit vehicles. Advanced signaling and train control is an area in which further research and testing are appropriate to determine whether positive train separation train detection and positioning can be applied to the very high-density train operations found in rail transit surrounded by dense development.

Time-tested, train-protection systems used or specified in shared track may not be "advanced." The German INDUSI train-protection system required in shared-track operations is a technology developed and applied in the 1930s and still in wide use today.

### Key Vehicle Issues

*Which Crashworthiness Measures Can Be Applied to DMU or LRV Designs as Risk Mitigations?*

A debate among practitioners continues on mixing disparate size and weight vehicles and on the relative effectiveness of active and passive approaches to passenger and crew safety. Only a risk assessment applied in each operating case will ultimately determine which of these measures or which combination of measures is most effective. In the FRA's policy statement, the FRA indicates a need to review shared-track proposals and petitions on a case-by-case basis. Risk assessment is, therefore, an important tool to this research and central to conclusions relating to the feasibility of joint-use proposals.

Some attempts are being made to include both crashworthiness and crash avoidance type measures in new light rail car designs. These designs by European-based car builders are in response to the new market for regional railways and possible other applications of shared track. Contemporary trams and LRVs in Europe typically fall into the range of 20–40 ton (44,000–88,000 lb) buffing strength. The North American buff design practice is nearer to 150–200 percent of the tare weight of the single vehicle. This weight is often referred to as the "2g spec," or a longitudinal compression equal to twice the weight of the LRV. The Portland low-floor LRV buff load specification is a little less than 80 tons (160,000 lb). The North American LRV range exceeds that of its European counterparts by a factor of two or more. The North American LRV buffing load range is 40–100 tons (88,000–200,000 lb). Further up on the scale, modern European light rail DMUs are now designed to withstand nearly 350,000 lb (1500kN). Crush zones, impact attenuation, and debris deflection devices are incorporated in the designs of these cars, which are operating on railroads throughout Western Europe. These characteristics are of a passive nature; that is, they pertain more to the design of the vehicle than to the operating performance. These cars still retain their active safety performance characteristics through use of redundant disk, tread, or track brakes and regenerative or retarder brake systems. The U.S. railroad standard is currently an 800,000-lb buff load, except for light cars in reduced fixed consists. The FRA grants exceptions. In a proposed Port Authority Trans-Hudson (PATH) new car purchase, the FRA authorized PATH to procure railcars below the 800,000-lb buffing strength. This exception was granted because PATH, though currently regulated as a railroad, does not interchange its rolling stock with the general railroad system, and its equipment is homogeneous.

### Comprehensive Issues

*Crashworthiness Versus Crash Avoidance: Can Some Measure of Both Be Applied to Mitigate Risk?*

As the FRA states in its policy, the ultimate crash avoidance is time-separated use. Passive measures are designed to prevent injury, fatality, or damage in a collision. Active measures are designed to avoid collision in the first instance. These two methods of dealing with risk are sometimes at odds. In plain terms, the heavier the vehicle is to withstand impact, the longer the braking distance required to avoid a collision. European regulators now tend to embrace active safety measures or a combination of active and passive, whereas North American regulators currently require passive measures. This different approach is partly due to German regulators' dual scope of covering rail transit and railway equipment and operations. By employing both active and passive measures flexibly, German regulators and car builders are able to interchange or adjust measures to achieve equivalent safety. For example, controlled deformation of car bodies may compensate for lesser structural stiffness requirements designed to reduce injuries and fatalities. Equivalent safety of proven measures can be effective leverage in favorable waiver petition treatment.

In North America, regulation now is concentrated on railroad equipment and operations safety. Rail transit vehicles (LRVs primarily) are designed to interact with roadway vehicular traffic or each other. In contrast, railroad cars are designed to interact with other railroad objects equal in weight and bulk.

An additional crashworthy feature is impact attenuation or crush zones that are commonly used in the automobile industry. In such designs, the impact of the crash is absorbed by the car structure, which deforms in a predetermined manner according to design. Sacrificial structures and voids within the car body are designed to reduce the G-Force of a collision, which, in combination with soft interior features, reduces injury from passengers flying about the car interior during impact. Reduced chance of injury is achieved by designs that incrementally collapse the car structure in an anticipated sequence and in an increasing resistance.

What are not apparent in exterior car designs are the passive measures that are included in the interior design of the cars. These measures include impact attenuators on interior surfaces and appurtenances, which have a minor effect on car weight and performance but which diminish risk of injury and fatality to car occupants. Subtler in appearance is the use of structural members for appearance and strength of the car. At least two contemporary DMU car designs use diagonal members in a truss-like arrangement along the side of the car body to increase the longitudinal strength of the car and to control the rate of collapse. Also not apparent are voids within the car structure, such as equipment cabinets, lockers, latrines, baggage and bike racks, and the operator's cab (which can be speedily evacuated), all of which serve as incremental crush zones. Although these zones will not prevent a "catastrophic collision," they can mitigate the consequences.

Also, in these and other designs of lightweight DMUs are pilots, functional fasciae, or cowcatchers, all of which prevent derailments from overrides of foreign objects and perform the traditional pedestrian safety functions of vintage trolley fenders. When Japanese subway cars are adapted to use at-grade tracks with grade crossings on interurban and commuter railroad lines, metal pilots are added below the sills at car ends. To the extent that these interior and subtle exterior physical measures can be integrated into the car design without weight penalty, the crash avoidance and crashworthiness characteristics of the cars can be reconciled within a single car design.

*Parallel Research Activities*

By adapting and recommending use of the risk analysis technique, this research is supportive of and in parallel with the other efforts in quest of safer and more productive rail passenger systems. These other efforts include

- APTA's Passenger Rail Equipment Safety Standards Committee;
- FRA jointly sponsored (with railroads and vendors) research, demonstration, and testing of positive train separation and positive train control at the Pueblo Test Track and in various other locations (e.g., Illinois, Washington, and Pennsylvania);
- APTA-sponsored Commuter Rail Safety Management Program, Rail Transit System Safety Program Plans, and Rail Safety Audit Program;
- The FRA's Safety Assurance and Compliance Program;
- The development of state oversight of state system safety program standards, which provide a quasi-requlatory framework for FRA-noncompliant systems;
- Monitoring of overseas innovations in safety, operating practices, car design, train-control technology, and regulatory reform;
- University research programs; and
- Overseas study missions, such as those conducted by TCRP and U.S.DOT administrations.

The European approach to survivability considers the totality of active and passive safety mitigations. Europeans combine measures for optimal safety in operation and rolling stock design. For example, impact attenuation is considered over a more robust car structure under the assumption that passengers impacting the interior of the car in a collision can be as fatal as intrusion or "telescoping" of two car structures. Such measures as speed restrictions and upgraded train control further reduce risk. Quantifying these mitigation measures' effectiveness singly or in combination can provide a direction for a national research agenda.

*What Cultural, Institutional, and Social Conditions Will Influence Joint-Use Decisions and Create Environments Hostile or Advantageous to Joint Use?*

The Pacific Rim and European examples of joint use cited in this digest demonstrate that shared track can exist in varied cultural, institutional, and social climates.

Shared-track practices are being expanded and refined overseas through an evolutionary succession of institutional reform, research, planning and risk studies, system design, and joint venture. Research in preparation of this update discloses that joint use is not achieved through any single document, person, or action. Changes in institutions, business, and technology create a regulatory environment more conducive to sharing of facilities. These changes are epitomized by

- Privatization;
- Breakup of national transportation monopolies (and formation of new enterprises);
- Changing federal, state, and local roles;
- Creation of the European Union in Western Europe;
- Restructuring of transportation institutions;
- Advanced state-of-the-art communications and train-control technologies;
- Deregulation in some sectors;
- Inducements for nontraditional business partnerships;
- Adopting business practices in public transport; and
- Establishing a climate conducive to public-private partnerships among the operators of freight and passenger transport services.

Absent these types of changes and environment in North America, shared track will likely continue to be confined to temporally separated examples.

Under existing FRA policy and regulations, the "heavy burden" for establishing simultaneous shared track would rest with the waiver petitioner to prove that risk has been diminished to acceptable levels or that it never existed in sufficient magnitude to endanger public safety. This petition process would not depart from the current waiver application requirements (FRA Safety Standards 49, CFR Part 238) or from the new clarified policy statement on waiver process (Appendix to FRA Safety Standards 49, CFR Part 211).

**Lessons Learned from the Track-Sharing Dialogue**

During the course of performing this research and during the dialogue resulting from federal shared-track policy statements, a variety of informal views were expressed on the issues raised by joint use. These views generally fell into two categories: for joint use or against joint use.

Arguments for joint use include the following:

- Joint use is feasible if fail-safe train control and separation systems are applied to moderate-to-low train movement densities.
- Regulatory constraints on joint use in North America should be periodically reviewed in view of technical innovation in the same manner that waivers must be renewed.
- In spite of the cultural differences, shared track as in Germany and reciprocal running as in Japan can be applied in the United States with proper controls and safety.
- "If they can do it over there, we can do it here." (This argument is popular, but sometimes logically flawed.)
- Risk assessment can be used to measure, control, and justify joint use.
- A range of mitigation choices can reduce any risk to tolerable levels.

Arguments against joint use include the following:

- Except where a waiver petitioner meets a "steep burden of proof," only shared track by temporal separation will be permitted in North America.
- None of the overseas experience can be applied in North America because North American railroads, operations, and urban development are too disparate.
- North American regulators and North American transit and railroad operators are reluctant to assume joint-use obligations because of the fear of a catastrophic accident. Therefore, prevailing attitudes, laws, and institutional climates contribute to a mistrust of shared-track practices.
- Shared tracks by such disparate rolling stock as railroads and rail transit constitute an inherently unsafe condition that is unlikely be resolved in North America.
- Insurance and legal liabilities unique to North America discourage any meaningful joint use in North America.
- Political and regulatory methodology in the United States often precludes any approach not based on evolutionary changes to existing railroad safety regulations.

The expectation is that joint use and its application will continue to be treated as a potentially viable transportation option, though joint use will not prove feasible in all applications. This conclusion is expressed because the research disclosed no reason for suggesting absolute joint-use prohibitions or dismissals without further research. The FRA policy statement is clear on this point as the FRA states that the FRA is "open to any reasonable proposal [for shared track]." A process is evolving that, at maturity, will provide tools to evaluate risk and apply other factors to make case-by-case decisions on applications of joint use.

The fundamental questions associated with the potential for shared track in the United States include (a) do the potential cost savings associated with the implementation of shared track outweigh the additional risks and (b) can the additional risks be mitigated sufficiently to satisfy appropriate regulatory agencies? Commingled joint-use track arrangements could exhibit advantages, such as shorter implementation schedule, lower capital costs for infrastructure, reduced operating costs, and cheaper and quicker new starts. Cooperative joint use cannot easily happen when one of the partners is reluctant to participate.

Is joint use or shared track a potential transportation alternative in the context of major-investment study (MIS)–type alternative studies and other new-start ventures? Shared-track alternatives often are dismissed early in the alternative evaluation process by planners using a fatal-flaw approach. Federal regulations or the new policy on simultaneous shared track are cited as the screening flaws without the benefit of knowing risk or cost assessments in individual local applications. Although some shared-track proposals may have no merit other than for their joint-use characteristics, alternatives with otherwise competitive advantages may be retained longer in the analysis of options.

As described previously, risk assessments are performed with federal oversight in proposed joint freight and/or high-speed passenger railroad facilities, such as the Northeast Corridor and the Florida Overland Express. Risk analysis is also being employed by Utah Transit Authority for Salt Lake City and by New Jersey Transit. Risk assessment used in this way is acknowledged by the FRA and rail operators to be a tool in demonstrating that public safety will not be violated by certain types of railroad joint operations in the United States now. Risk assessment for joint railroad operations is only applied currently

- Between different types of FRA-compliant railroads (e.g., freight and intercity passenger rail),
- Temporally between rail transit and railroads, and
- For temporary waivers.

To provide the preliminary tools for evaluating potential joint-use risks, the research team drafted a risk assessment guide (Chapter 6 of *TCRP Report 52*) that could be applied at local option at the metropolitan level and in individual corridor studies. The purpose of this risk analysis approach is not to undermine U.S. safety regulations. On the contrary, the risk analysis approach is intended to assist users in quantifying where potentially high-risk and unsafe conditions would be present under a joint-use operation.

## Other Lessons Learned

None of the overseas experience described previously offers a single optimal model for application in North America. *Elements* of each of the overseas joint-use examples profiled in this update and detailed in *TCRP Report 52*, Chapters 7 and 8, demonstrate experience that can be applied very selectively and lessons learned, even though fewer rail transit environments exist (19 states) in North America than overseas.

### *Institutional Lessons*

One characteristic common to both Germany and Japan is the proliferation of private-sector– and third-sector–type railways. In North America, a comparable condition is the creation of DBOM consortia and short line and regional freight railroads and their recreational and dinner train affiliates. In Germany, these types of new rail enterprises fall into the regional, or Stadtbahn, category. In Japan, they are more commonly considered "interurbans," or third-sector short lines.

Since the disappearance of the interurban electric railway in North America, there has been no common term for contemporary examples of these long-distance transit systems. TRB paper sessions have been organized around the theme of "regional railways." Equivalent operating systems in the United States are exemplified by St. Louis' LRT, Chicago's "South Shore," and San Francisco's Bay Area Rapid Transit District. In the United States, "regional rail" has been applied to light rail, rail rapid transit, and commuter railroad systems that perform similar operating functions, but in varying degrees with a variety of equipment.

Because shared track can be accomplished far more rapidly than can the building of an all-new parallel track, the evolution of rail systems under such an arrangement compresses time and budgets. In Karlsruhe, the regional LRT-based system had a 25-year gestation, but when the precedents and common interests were established and when the practices were proven feasible on the interurbans, the full railroad and LRT shared-track innovations came in rapid succession. The hardest parts to achieve are increased CBD trackage capacity, new major physical connections, and institutional arrangements. Subsequent improvements come easier and in rapid succession, as Saarbahn demonstrates. In the past 5 years, six Karlsruhe railroad corridors have been converted to regional Stadtbahn and LRT service, totaling more than 120 route kilometers (75 route miles). Ridership growth over the previous railroad service ranges from 100 to 470 percent, the latter growth on the Karlsruhe-Bretten/Gölhausen S4 service.

In Karlsruhe, shared track is deployed in several ways, not all of which can be readily applied in North America. One of the principal advantages of German light rail is derived from converting obsolete regional DBAG railroad-based services to LRT-based Stadtbahn services. There are a few direct equivalents for these types of passenger railroad service in the United States; most of the equivalents that existed were discontinued or replaced by bus. The advantages in Germany of converting railroad to rail transit using the same tracks are

- One-person operation,
- Lower operating cost per kilometer (DM 5 per LRV kilometer versus DM 12–17 per train kilometer),
- Lower energy cost (savings of DM 18,000 per train annually), and
- Time savings, with LRVs at 90 km per hour top speed, save 6 min on 32-km line compared with railroad train, at 120 km per hour (the superior start-and-stop performance of the LRVs provided the time advantage).

Other potential savings in crews, equipment, and energy may not apply in North America, except where LRT or DMU services might favorably compare with regional bus services.

In addition to having operational advantages, the Karlsruhe system has jointly managed physical and real estate assets. Initially, ownership is important in establishing shared-track rules and practices, but over time, as tenant and host become more acclimated to joint operation, the ownership distinctions become less defined and shared risk, shared benefits, standardization, and common interest prevail. The most dramatic example of full maturation of shared track is when one of the partners adopts the rolling stock standard of the other organization.

As described in *TCRP Report 52*, Chapter 8, the six successor railroads to Japan National Railway have purchased and operate rail buses in joint service with their other railroad-size freight and passenger rolling stock. In Germany and Switzerland, railroads purchase rail buses, DMUs, and LRVs, operating them in their indigenous railroad tracks in mixed traffic for reasons of economy and business performance. A specific example is at Karlsruhe, where DBAG purchased light rail rolling stock identical to the LRT operator to substitute for more costly railroad DMUs and locomotive-hauled passenger trains operating on their own railroad lines.

This practice of purchasing equipment specified by the other parties in track sharing constitutes acknowledgement by a railroad that shared track and integrated operations can work with cost savings incentives. Because post-1981 railroad passenger and freight businesses are separated in the United States, these types of applications are limited. Selling the railroad physical assets to a transit operator in exchange for exclusive trackage rights for railroad freight service is another practice.

In Japan, the broad range of joint-use arrangements has unintentionally promoted standardization of equipment. As rail rolling stock is retired, the replacement equipment is specified to a more uniform standard, in some cases to go beyond joint or reciprocal running to actual pooling of equipment.

*Lessons on Costs and Cost Savings*

Related to the safety issue are costs and cost savings. Can a balance be achieved between joint-use benefits (e.g., better service, more new starts, and lower costs) and the potential risk and liability associated with shared track? Although it is always difficult to weigh injury and fatalities with convenience and cost savings, the cost of litigation and claims, rather than the benefits to users, tends to drive potential North American transportation liability decisions. Practitioners worry, "If we do this, will we get sued?" Recognizing the issue of costly litigation in North America, and acknowledging that locally performed risk analysis can begin to estimate cost risk specifically on a case-by-case basis, the following dramatic examples begin to quantify cost benefits of joint use without sacrificing safety.

In 12 selected Japanese metropolitan areas, the total rapid transit route miles number 406 mi (654 km). Rapid transit service with joint use totals 789 mi (1,269 km). The difference in these two numbers (383 route miles, or 615 km) represents the increase in rapid transit service route-mile coverage as a result of joint use or reciprocal running. Because of reciprocal running, rail transit route miles were increased by 94 percent. An additional benefit is reducing mandatory transfers between carriers with end-to-end coordinated rail services. Another benefit is the capital cost savings resulting from avoiding or minimizing costly subway construction. With the high density of Japanese metropolitan areas, such rapid transit expansion would not occur on the surface and, in any case, would be extremely disruptive to the social, economic, and natural environment.

If one conservatively estimates the cost of double-track rapid transit route miles in subway at $100 million per mile, the national gross cost savings in Japan is $32.8 billion. Although these savings are diminished by the need for new rolling stock and critical track connections and other costs associated with the integration of two or more rail systems, the costs are relatively modest and can be phased over time. The cost estimate is, of course, hypothetical because that amount of money would not likely have been spent and the expansion of route miles would not have happened using tunnel construction.

A similar capital cost savings estimate for one European metropolitan area produces more modest, but significant savings. It is estimated that Karlsruhe gained 127 route miles as a result of joint running with electric interurban, DBAG, and Sudwestbeutsche Eisenbahn AG (i.e., "SWEG") railroads. A conservative capital cost estimate for LRT route miles of double track on reserved right-of-way is $20 million per mile. Applying that estimate to Karlsruhe VBK and electric interurban network results in a gross savings, based on 127 route miles, of $2.5 billion in Germany. The relatively modest capital costs of integrating the two systems through track connections, compliant rolling stock, and infrastructure should be subtracted from the estimated benefit savings. As in the Japanese experience, the rail lines would never be justified as separate facilities at these costs. Most of these new starts overlay existing or formerly obsolete services.

The lesson suggested from both preceding paragraphs is that joint use not only is a more cost-effective way of preserving and expanding existing rail transit systems and initiating rail transit new starts, but also (and more importantly) enables more new starts to begin using finite funding resources and lowers the cost feasibility threshold for cities that could not otherwise afford rail new starts.

Other potential capital cost savings arising from shared track are standardization of equipment, pooling of rolling stock (because of higher-performance LRVs, Karlsruhe saves a train consist [3 LRVs versus 4 railroad consists]), joint purchasing, and selective pooling and sharing of maintenance and operating facilities. Cooperation breeds other cooperation and savings. Uniform or universal fare collection systems are among the cost-effective cooperative ventures accompanying shared track.

Operating-cost savings from resource conservation include the reduction of energy consumption. Officials in Karlsruhe claim that Karlsruhe saves DM 18,000 ($10,000) annually per train and saves labor costs by substituting smaller transit crews for railroad crews. The latter labor savings translates into a minimum of halving train mile costs, or DM 5.5 per kilometer for LRVs and DM 12–17 per kilometer for railroad consists. The initial joint-use lines in Karlsruhe perform at an 85-percent cost recovery ratio. Prior to the latest downturn in the local economy-dependent steel prices, Japan's modest Sanriku Railway third-sector, shared-track railbus operation showed a 99-percent operating cost recovery.

*Lessons on Applying Joint Use to North America*

During the course of conducting this research, discussions with several advocates of rail transit disclosed the view that the use of shared track overseas proves that joint track use can be accomplished in North America. This research does not support that premise. It also does not try to "make a case" based exclusively on European or Pacific Rim experience. Operating and social conditions are different in North America, and this fact casts doubt on the direct application of overseas practices. This research does, however, consider what is to be learned and transferred to improve and expand North American transit practices.

Recalling the key issues identified in Chapter 4 of this digest, which issues and accompanying policy suggestions apply to transferring overseas joint-use experience to North America?

- **Regulation:** Overseas joint-use safety experience versus U.S. non–joint-use experience, as well as before-and-after service benefits or costs versus before-and-after risk. Insufficient data on both sides thwart direct comparisons. Risk analysis techniques are compatible.
- **Operation:** Specific overseas operating practices can be applied to risk mitigation.
- **Physical plant and infrastructure:** Track, signaling, and train control systems are being applied now.
- **Vehicle:** Crashworthiness measures apply to North America. Most passenger rail transit car design is nondomestic.

Karlsruhe is held up as "the model" of joint use, yet some prevailing *myths* surround Karlsruhe's extensive joint-use system. Misunderstandings include the following:

- Karlsruhe overcame obstacles to joint use in a short time (it took more than 25 years).
- Karlsruhe was the first to implement contemporary joint use (Cologne was earlier).
- The regulatory and institutional obstacles facing the Karlsruhe region in implementing joint-use practices were less difficult than and otherwise different from those in North America.
- After shared track had been achieved at Karlsruhe, expanding the system meant merely replicating the experience with the initial line.
- Because Germany accomplished joint use, North America can accomplish it in the same way.
- Some features of the Karlsruhe circumstances or key operating discipline, if applied in the United States, would instantly ensure acceptance and success for shared-track arrangements in North America.
- Karlsruhe is a model for direct application of practice to North America because it is considered a European model.

Karlsruhe may not be the first operator to practice joint use, but is currently the most widely known internationally by rail transit practitioners. It is distinctive because it pioneered applying extensive and varied joint-use practices, expanded its system incrementally, and achieved success within 25 years. Karlsruhe provides multiple case studies in applying shared-track use in a variety of social, economic, and geographic environments.

The following profile of Karlsruhe's shared-track experience should be considered when introducing or expanding shared track in North America:

- Dynamic and persistent leadership by a strong-willed and skilled personality was important to implementing joint use.
- The system began very modestly, with practitioners first absorbing and then converting a failing meter-gauge interurban Albtalbahn, which provided joint passenger and limited rail freight services.
- Each successive shared-track addition to the system was an incremental achievement in joint-use practice because it was more innovative and more operationally advanced than previous additions were. Each increment increased system complexity, bringing rail transit and railroads into greater cooperation and operational intimacy. The current level of integration and coordination was achieved incrementally, "raising the bar" at each step.
- Participating joint-use institutions reached agreement on shared-track specifics when doing so became in their best interest.
- Shared-track credibility came with more and intensified joint-use experience. After the advantages of joint use were confirmed and the benefits distributed among all partners, subsequent joint-use proposals were more readily accepted.
- Joint use was accompanied by supportive changes in social, economic, and institutional structure. Alternatively, joint use requires or is triggered by a desire to reform and improve public transportation of all modes. Most notable among these improvements was the shifting of local and regional transit financing and decision making down to the land, or provincial level.
- Although differences exist between German and North American railway equipment and practices, institutional concerns between railroad operators and their respective regulators are similar.

*Overseas National Policy Lessons*

Switzerland and Germany have pioneered joint-use applications of various types and circumstances. France and Benelux countries are planning similar joint-use applications.

National policies in Switzerland and Germany do the following:

- Encourage regionalism of railways through establishment of local organizations for planning, financing, and managing such projects, usually cast-offs of the national railway system;
- Favor public transport in general and rail transit in particular vastly more than they favor highways;
- Privatize elements of the national railroad system, setting into motion open access to tracks and separating various elements of the railroad business;
- Frequently divide national railway organizations into separate businesses, including infrastructure ownership and maintenance, rolling stock ownership and maintenance, rolling stock ownership, freight and passenger operations ownership, and real estate management (although this diversity creates a complex environment for track sharing, it opens opportunities for tracks to be shared by a wider variety of operators);
- Establish a body of law under which private companies can compete for operating contracts for a variety of rail services (this condition differs from opening tracks to access by competitive services);
- Open access to rail infrastructure for a variety of private or regional rail carriers (including LRT operators);
- Govern tram, rail transit, and railroad operations and physical standards separately;
- Comply with European Union mandates and directives that overlie, and in some cases compel, federal regulations and institutional reform (the resulting greater uniformity encourages some forms of track sharing, even across international boundaries within the European Union);
- Can evaluate new regulatory concepts politically and can apply risk analysis to a high degree in developing new regulations; and
- Allow for collaborative integration (or retention) of freight and passenger operations under common management at the local level while separating these operations at the national level.

The Netherlands varies from the previous Swiss and German policies because it groups three adjacent but separate metropolitan areas that may grow into a single, common LRT-based system to function among and within three cities. The national planning group (Railned) is charged with the responsibility for establishing basic standards and resolving technical compatibility issues between the national railroad and among the city LRT systems.

Railned's policy on risk pertains to North American circumstances and is worth quoting:

> Railned has stipulated that dual mode operation should pose a greater risk than for pure heavy rail operation. Any extra risks resulting from dual mode operations (additional service [train density], different operating speeds, crashworthiness, braking potential, train detection, change of derailment) must be compensated by extra safety elsewhere. Risks are assessed in accident/train km and the number of injuries to passengers and staff. Railned will be making careful assessment of crashworthiness both with other rail vehicles and broadside with road vehicles (*International Railway Journal*, March 1998).

A major difference between the U.S. circumstance and the Netherlands circumstance is that, unlike cities in the Netherlands, U.S. cities with light rail systems are far enough apart as to preclude any concerns about compatibility between LRT systems. The issue of equipment compatibility between rail transit and railroads remains for all systems.

*Contrasting Pacific Rim and European Joint Use: Lessons and Applications to North America*

Major differences exist between the Pacific Rim and European arrangements. These differences have implications for North American application:

- Japan has no common examples of joint use between light rail and main line railways. Like the United States, but unlike Germany, Japan motorized (using buses) substantial portions of its former street railway network. There are no Pacific Rim Karlsruhes. There are, however, many Japanese interurban electric- and diesel-propelled (i.e., railbus or DMU) operations that integrate with railroads and rapid transit. In a sense, the interurban railway is the agent for joint use in Japan, whereas light rail is the agent for joint use in Europe.
- Three major types of joint use have evolved in Germany and are spreading elsewhere in Western Europe:
  - **Regional railways** based on light rail and railroad (i.e., Category 1 and 2) DMU technologies on railroad branch line service and venturing onto main line railroads (e.g., DKB and DBAG).
  - **Stadtbahn railways** based on light rail technology integrating service between streetcar or tram and railroad branch and main lines (Karlsruhe Albtalbahn).
  - **Metros and pre-metros** where light rail and heavy rail rapid transit are integrated with the objectives of extending the reach of metro service cheaply, of converting light rail to heavy rail in phases, or both (Köln KVB).
- Two types of generic shared track exist in Japan. These two types do not lend themselves to classifying relative to rail modes or institutions, as shown in the previous German example. The resulting arrangement between

two or more rail carriers does not form separate railways, though third-sector railways are formed to accomplish portions of shared-track arrangements. The two types of generic shared track in Japan are as follows:

— **Joint use among railroad passenger, interurbans, and rapid transit railways in urban areas.** One railway runs over another's track beyond its customary terminal or ownership, with the host or tenant relationship not being reversible.
— **Reciprocal running.** There are two kinds of reciprocal running: (a) internal combustion reciprocal running, which is among diesel interurbans, railbuses, and DMUs and the national railroad network represented by the Japan Rail group of railroads (two or more railways of compatible standards, joined end to end, run over each other's tracks in an integrated service; these railways tend to be suburban or rural) and (b) electric reciprocal running, which is among rapid transit, light rail, railroad, and interurban (this kind of reciprocal running tends to exist and flourish in urban areas).

- Another major difference between European and Pacific Rim experience is that Japan's ambitious rail construction programs and plans include significant new construction built in anticipation of future joint use. In Western Europe, joint uses are largely reclamations of existing, abandoned, disused, or underutilized capacity on the railroad system in response to current demand. Purpose-built joint use does exist in some European light rail, pre-metro, and metro systems as a temporary means of phased expanding of heavy rail. New construction consists of key connections between metro, LRT, and railroad networks, rather than all new lines purpose built with eventual shared track in mind.
- Both of these joint-use philosophies are currently rare among North American transit-governing boards. Rail transit infrastructure and people mover infrastructure are built with little regard for potential interchange and, in some cases, may exclude any future integration with other modes or carriers.

### General Shared-Track Conclusions

Risk analysis and foreign experience indicate the following:

- Risks can be quantified according to circumstance and situation.
- Joint-use risk could be brought within and managed at acceptable limits, although railroads and transit operators would have to negotiate how to share risk between them.
- Risk can be reduced by applying mitigation measures.
- With guidance by a basic national regulatory framework, decisions on joint use can be entrusted to parties that assume legal and financial risk.
- Selective application of joint-use practice can be made on a case-by-case basis with the cooperation of the freight and passenger rail partners using a preliminary, pre-risk assessment screening matrix (see Table 4).
- Additional research is required to fully translate and understand the German literature, to interpret the German literature's findings, and to routinely collect new overseas joint-use and risk analysis studies as they are released. Continued on-site inspection of overseas examples to understand joint-use practice and opportunities is a logical extension of this research.
- There is limited accident data and history from overseas on which to base risk assessments. Although these meager data reveal increasingly safer rail transit and railroads, they also retard the ability to quantify risk.
- Continued testing and application of advanced technologies are needed to diminish risk and improve safety.

Although there is insufficient joint-use accident experience at this time to quantify risk conclusively, probabilities of collisions, let alone catastrophic incidents, on low-density freight lines appear to be modest. These low probabilities enable local decisionmakers to determine risk, consider applying shared-track practices, and petition for waivers accordingly.

Application of additional physical and operating measures, such as speed reductions and an increase in the sophistication of train controls, would further mitigate risk. The FRA waiver process introduces these measures selectively on a case-by-case basis. In Germany, these measures are applied using a more stringent BOStrab (i.e., streetcar) regulation to offset risk exposure caused by exceeding an EBO railway standard. In other words, the active performance (i.e., deceleration capabilities) of an LRV offsets the lack of passive (i.e., crash resistance) capabilities of that same LRV. In Europe, enhanced stopping performance is achieved by augmenting friction brakes with redundant braking systems, including regenerative braking on LRVs and multiple retarders on Category 2 and 3 DMUs.

In North America, this issue of active versus passive performance has been debated as crash avoidance versus crashworthiness. Regrettably, these two objectives are seldom complementary because one may be achieved only at the expense of the other. A Volpe Center study (Tyrell et al., 1997) claims that increasing the crush zone at car ends does not exact a significant weight penalty or, thereby, exact a reduction in car braking performance related to weight.

The motivations for instituting joint use, where it is practiced, are institutional and economic. In Europe and the Pacific Rim, shared track itself is not considered a reform. It is considered a device for implementing reforms that are motivated outside the transport sector. It is considered inseparable from fundamental economic and development

**TABLE 4 Preliminary screening matrix for joint-use feasibility and application of risk assessment**

| **Freight and RR Service and Passenger RR for Columns 1-3** | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| > 12 thru trains | RA | RA | RA | OK - RA | OK - RA | OK - RA |
| 6 - 12 local / thru daily | RA | RA | RA | OK - RA | OK - DIS | OK - RA |
| 2 - 6 local / thru daily | RA | RA | RA | RA | OK | OK - DIS |
| 1 - 2 daily local | Time window only RA | Time windows RA | Time windows RA | OK | OK | OK - DIS |
| < 1 train daily or as needed | Time window potential | OK | OK | OK | OK | OK |
| None or night operations only (with full temporal separation) | OK | OK | OK | OK | OK | OK |
| Rail Transit Model Car Type | **Light Rail LRV**<br>< 30 min base headway | **Category #3 DMU**<br>[DLRV]<br>(in diesel mode)<br>(in electric mode) | **Category #2 DMU**<br>[DLRV] | **Category #1 DMU**<br>[rail diesel car] | **Commuter Railroad EMU**<br>Or Loco. Hauled (LH) | **High Speed Intercity EMU/LH** |
| | (NON FRA COMPLIANT) | | | (FRA COMPLIANT) | | |

Notes:
DIS = discretionary use of risk assessment
DMU = diesel multiple unit
EMU = electric multiple unit
LH = locomotive hauled
LRV = light rail vehicle
OK = okay, satisfactory
RA = risk assessment should be considered
RR = railroad
Risk assessment subject to local conditions, values and determinants.
Consider which mitigation of risk will permit upgrading joint-use potential within each cell as automatic train control, positive train control, and positive train separation enable higher concentrations of train density.

policies and initiatives. Safety is not considered in isolation, but is weighed with other economic, social, and institutional factors. When national railroad systems and related activities are reorganized and privatized, the reorganization and privatization trickle down to the branch lines, exemplifying a massive overhaul of the overseas national railroad systems (and of the North American railroad megamergers). In this context, the advantages and shortcomings of joint use are weighed in light of achieving national policies and state or local objectives. The advantages include

- Consistency with national transport policy (or, in the United States, Class 1 railroad policy) to shed local branch lines whose continuance cannot be economically justified by a large railroad;
- Transfer to local authority (or, in the United States, to a regional or short line carrier), resulting in less expensive train operation, as exemplified by third-sector railway efficiencies in the Pacific Rim and bidding of public transport by independent contractors or by DBOM consortia elsewhere; and
- Relationships and precedents, among current "hold harmless" and other legal and liability provisions in joint-use agreements among U.S. freight and commuter railroads, that are adverse to shared track, even among railroads operating FRA-compliant, FRA-compatible equipment.

Research disclosed no extraordinary joint-use accident experience abroad that merited coverage in the professional rail trade press, nor did any surface from the direct overseas contracts. The research team found no case in which joint use was revoked for safety. The law of averages dictates that such an incident will occur; however, after a decade of experience (some of which was in very heavy rail corridors), there is no evidence that shared use of track, as applied, inherently causes incidents any more than do other types of shared tracks by multiple train movements.

There are circumstances under which mixed operations by certain types of high-speed, high-volume rail modes or vehicles constitute an unacceptable risk to the public. There are other low-volume, low-speed commingled conditions in which the risk is minimized or negligible. All of this range of circumstances is currently treated by a common standard in North America. One of the objectives of this project was to determine if there is a way to differentiate between the risk extremes by applying overseas experience and quantified risk analysis.

There are, however, several fundamental differences between the approach being considered in this digest and what is currently practiced. MPOs, state regulators, and independent DBOM consortia can be the vehicles of change. These three groups can apply conventional planning to track sharing in the same manner that planning is applied to other transport projects. The groups may do the following:

- **Develop a more user-friendly planning process in which costs, risks, impacts, and benefits can be considered together in potential joint-use applications.** The stakeholders (i.e., parties that assume risk and invest capital) will make decisions on whether joint-use benefits to the participants offset the calculated magnitude of safety. This approach is consistent with traditional federal planning policy for decades through the local and regional 3-C, Alternatives Analysis, and MIS processes. Transportation planning and design are performed locally, and local choice is exercised under federal (i.e., FHWA and FTA) guidelines and scrutiny, but without precluding local prerogatives. Similarly, local decision making on joint use, as well as shared track integrated into the planning process, could be conducted under regulatory scrutiny to avoid any potentially flawed, unnecessary, or inappropriate analysis.
- **Apply the screening matrix (see Table 4) and risk analysis in a multistep process.** Include these processes within the MIS or similar options screening method in selecting optimal rail transit alternatives, but only if joint-use alternatives apply and do not create an undue burden on local authorities.
- **Encourage joint ventures among various business interests (e.g., transportation and development) and government interests.** These ventures offer a climate in which joint use can flourish. Joint use of tracks is, however, only one aspect of joint venture. The Pacific Rim "third-sector" experience demonstrates that the right combination of complementary nontransport and transport business interests encourages joint use, joint venture, and joint opportunities. Currently, DBOM popularity brings diverse transportation and nontransportation interests together in a common venture. States such as New Jersey have passed legislation encouraging these partnerships to expedite transport projects that were formerly the sole domain of the public sector. Reintroducing the private sector to public transportation and sustaining its existing interest in railroad transportation creates a business atmosphere with common goals that can cross modal boundaries and institutional interests.
- **Build a stronger relationship among other rail safety research, technology ventures, and shared-track research.** Demonstrations of shared-track operation have helped overseas and may be considered for application here. Rather than treating these demonstrations as separate research efforts, practitioners can treat these demonstrations as complements of one another that can be integrated. An example of such complementary efforts is that of federal and industry cooperative research and demonstration ventures with railroads on advanced train control.
- **Conduct case-by-case evaluations, within the context of the current federal policy and state regula-**

**tory environment, but allowing for more input in the decision-making process at the metropolitan level.** The conventional planning process and institutions for this cooperative process with federal insight is already in place through the federally mandated MPOs. The MPO or similar institution could advance a study agenda and provide a forum for the public, the transit operators, the railroads, and the federal and state interests to analyze and debate shared-track issues.
- **Improve risk assessment tools to support local decisionmakers.** The risk assessment technique can improve as the safety database grows and as joint-use experience broadens. The risk analysis guidance and screening matrix are two such tools. Collecting and compiling data in support of these tools is a priority.
- **Continue to monitor overseas experience.** Although there are no direct U.S. equivalents of German shared-track cities or U.S. locations where Japanese-type reciprocal running can now be directly applied, these and other overseas precedents are instructive in forming any unique U.S. type of shared-track arrangements. Overseas pioneering in rail new starts and enhanced existing services will benefit domestic practitioners by avoiding overseas mistakes. Directly equivalent conditions or circumstances need not exist to learn from the experience of others.

### Potential Follow-Up Research

Considering these challenges and the North American obstacles to shared track, what kind of measures can be considered to advance the state of the art and to bring North America to a state of rail transit technology comparable to that found overseas?

- Consider demonstrations of North American DMUs that most meet the needs of North American transit operators. Like the previous tour of the Regio-Sprinter in Calgary and Tampa, the demonstrations should be of sufficient detail and duration to fully test concepts and practices. Earlier demonstration efforts with the Regio-Sprinter to heighten public awareness and promote the technology were impressive, but did not prove or disprove conclusively that the DMU concept would work in practice locally. The new demonstrations should test these vehicles in a variety of North American railroad and rail transit operating environments. Among these DMU application tests could be

  — Shared track with various types of railroad services,
  — Shared in-street track with vehicular and pedestrian traffic on existing LRT systems,
  — Shared track with LRT (running in electric LRV slots commingled with LRV assignments on routine schedules under wire), and
  — Running on an independent former railroad branch line reclaimed for transit as a test of the economics of new rail starts using DMUs (no shared track).

- Open discussions with rail car operators and manufacturers to establish DLRV design parameters for a North American, standard, dual-power drive train specification adaptable to various manufacturers' existing modular DMU or LRV car platforms.
- Initiate a market analysis of the estimated potential number of DMU and DLRV unit orders in North America over a defined future period.
- Begin a further research initiative to determine suitable design criteria, standards, and capital cost estimates for a North American version of DLRVs. Assuming the cost differential between DMU and electric LRV and knowing the cost differential between single- and dual-voltage electric LRVs, the costs of dual-power LRV are expected to be the highest of these rolling stock options. Are these costs higher than electrification? Can these DLRVs operate on streetcar track geometry? Directed research should produce an answer.
- Continue dialogue and research on shared-track policy that can accommodate the new generation of DMUs and LRVs with risk assessment–proven equivalent safety.

These suggestions are not intended or considered to be inconsistent with current domestic regulatory authority as expressed by federal policy. Nothing in this digest suggests a policy contrary to current FRA and FTA joint policy statements. It is concluded, however, that the process of treating shared track through the waiver process will continue to evolve. A principal conclusion is therefore offered.

### Principal Conclusion

Regarding the viability of joint use in North American railroads and rail transit systems, this research does not result in a specific recommendation except that joint use merits consideration. Deciding where and how to consider joint use is more properly done elsewhere, where the risks are assessed and assumed. This research, however, suggests a technique for making cooperative judgments on whether to share track. The decision process may be presided over by the various interests coming together for cooperative deliberation. These interests include, at a minimum,

- Rail transit operator(s);
- Railroad operator(s);
- Railroad owner (when different from the rail transit operator or railroad operator);
- Federal regulatory agencies, if applicable;
- State(s) safety oversight agency or agencies, responsible for rail transit and operator rail transit safety pro-

gram plans and for consistency with federal policy framework and regulatory standards; and
- Private-sector, joint-venture turnkey or DBOM partners and their prime consultant, if applicable.

Risk analysis is currently not required in joint use or other rail facility planning. However, risk analysis is selectively used to evaluate very specific parts of a proposed system that are suspected to be risky. San Diego did not employ risk analysis in San Diego's initial joint use between LRT and railroad. Salt Lake City used risk analysis to assess LRV and freight train temporal separation only. Seattle is using risk analysis for a portion of Seattle's proposed commuter rail joint use with a freight railroad. South New Jersey used risk analysis in South New Jersey's Trenton-Camden DBOM using noncompliant DMUs. The FRA will, however, require risk analysis as a condition to meeting the steep burden of proof before granting waivers or exceptions for commingled operation on shared track.

No new planning or major public investment process is suggested as part of this research. Existing MIS or alternative analysis framework can apply through the MPOs for certifying and making projects eligible for public funding. Competitive turnkey or DBOM procurement processes, to the extent that they are required for federal funding or environmental concurrence, also provide a safeguard for evaluating joint-use options.

For rail transit new starts, the following steps in determining joint-use feasibility are suggested:

1. Use the preliminary screening matrix for joint-use feasibility and application of risk assessment (see Table 4). This matrix is intended as a preliminary guide to determine when to apply risk analysis. It is not intended to prescribe the circumstances in which joint use between rail transit and railroads are viable.
2. If the inquiry passes Step 1 and if there are joint-use options under serious consideration, consider a risk assessment. Early advice and guidance from the state oversight agency and the FRA, as recommended in the federal policy statements, will assist in screening options in a prewaiver, prerisk assessment sequence. Such advice can help determine whether the cost of the risk assessment process is justified and whether temporal separation or commingled operation is advisable. The risk assessment guide in *TCRP Report 52*, Chapter 6, is designed for novices in risk assessment to determine whether a joint-use alternative is appropriate for consideration in an alternative analysis, MIS, or other screening technique. Other risk assessment guidance, such as the system described in Military Standard 882D, is also available.
3. Apply the MIS or other alternative selection process. The shared-track alternative or alternatives may still be rejected on technical or other feasibility measures when subjected to the conventional screening criteria. The opportunity thereby exists to assess joint use with other techniques for expedited and cost-effective new start implementation within the currently accepted planning process.

A value-engineering exercise may be applied at this point as an option to confirm the validity of the selected alternative (whether joint use or not). If joint use is selected, prepare a waiver petition using the guidance in the FRA policy statement, the FRA waiver guidance chart, and the CFR.

As risk analysis techniques improve and the reservoir of safety data accumulates, the processes suggested by this research might gain more credence.

## ACKNOWLEDGMENTS

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## GLOSSARY OF JOINT-USE TERMS AND ABBREVIATIONS

The following definitions are revised from or added to definitions in *TCRP Report 52*. (J) Japan or (G) German denotes origin of foreign terms.

APTA - The American Public Transportation Association.

BMV(G) - "Bundes Ministerium fur Verkehr," Eisenbahn Bundesamt, Federal Ministry of Transport, Railway Division.

BOStrab (G) - "Bau und Betriebesordung fur Strassenbahnen," German federal uniform regulations governing operation and physical standards of tramways and street railways.

Buffers or Buffer Plates - Devices, two to an end, used with steel links in the coupling of European railroad cars.

CBD - "Central business district." In Germany, sometimes called "zentrum."

CFR - "Code of Federal Regulations," a codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the U.S. federal government.

"Consult" (G) - A suffix applied to various transport consulting firms, several associated with public transport enterprise. For example, Rail Consult (which subcontracted to EK on *TCRP Report 52*) is affiliated with and owned in part by KVB Köln transit. Deutsche Eisenbahn Consult is owned by DBAG; Verkehrs Consult Karlsruhe is owned by KVV.

DB (G) - "Deutsche Bundesbahn," the former West German railway that merged with Deutsche Reichsbahn, the former East German railway, to form DBAG.

DBAG (G) - (Deutsche Bahn, AG) German (Federal) Railways, Inc., formed by merging the East German (Deutsche Reichsbahn [DR]) and West German (Deutsche Bundesbahn [DB]) on January 1, 1994. DBAG is wholly federally owned, but with the intention of being divided and privatized into separate infrastructure (Fahrweg), passenger (Personenverkehr), and freight (Gutertransport) enterprises. The first step was to form these separate companies still held by DBAG as a holding company, then make offerings on the three affiliates.

DBOM - "Design, build, operate, and maintain," a turnkey procurement technique.

DBV (G) - Dresdner Verkehrsbetriebe.

DKB - "Dürener Kreisbahn," Düren County Railway.

DLRV - "Diesel-electric-electric light rail vehicle," a Category 3 DMU derived from light rail vehicle origin or type, characteristically dual-power diesel and electric, capable of operating on light rail track geometry and independently of wire.

DMU - Category 1 or 2 diesel (mechanical or electric transmission) multiple-unit, self-propelled rail car. Used generically to describe any internal combustion (including alternative fuel) propelled rail cars.

dual mode - Capable of drawing the same voltage traction current from third rail or Overhead catenary (used to describe a locomotive or rail car).

dual power - Capable of drawing dissimilar (i.e., electric and diesel electric) power from wayside and/or on board power sources as in diesel-electric-electric (used to describe a locomotive or rail car).

dual voltage - Capable of operating from two or more traction currents (used to describe an electric locomotive or EMU).

DWA (G) - Deutsche Waggonbau AG.

EBO (G) - "Eisenbahn Bau-und Betriebsordung," uniform federal railway operating and physical standards applying to railroads, interurbans, and certain regional stadtbahns.

Eisenbahn (G) - Railway or railroad, also "bahn" or railroad.

EK - Edwards and Kelcey, Inc.

EU - European Union.

FOX - Florida Overland Express.

FRA - The Federal Railroad Administration of the U.S. Department of Transportation.

FTA - The Federal Transit Administration of the U.S. Department of Transportation (formerly UMTA).

HGK (G) - Häfen and Güteverkehr Köln AG.

ICC - The Interstate Commerce Commission.

ICE - Intercity Express.

INDUSI (G) - "Iduktive Signalsicherung," roughly translated: "inductive signal protection." An intermittent wayside and rail vehicle passive (magnet) inductive track occupancy system introduced in the 1930s in Germany, providing train protection by activating automatic train stop. It is mandatory for German shared-track operations.

JFK - John F. Kennedy.

JR - Japan Rail.

KBE (G) - "Köln-Bonner Eisenbahn AG," interurban railway affiliate of KVB.

KVB (G) - "Kölner Verkehrs–Betriebe AG," the city of Cologne transport operator.

KVV (G) - "Karlsruhe Verkehrsverbund," transport oversight agency that coordinates the single-fare system and other service issues between public and private operators of all modes of transport (in Karlsruhe region).

Light Railway - A term stemming from English law and related to local railways, other than those under control of the crown. "Light" usually, but not exclusively, refers to the type of construction and duty, which dictates a light duty and usually lightweight vehicle. Freight, passengers, steam, and diesel "light" railways exist. In contemporary use, "light rail" describes the difference between tram or streetcar of modest performance, operating most typically in street trackage, and newer, heavier LRVs operating predominantly on private right-of-way.

LRT - Light rail transit.

LRV - Light rail vehicle.

LZB (G) - A linear train-control technology based on transponder-activated train location and automatic train separation used in Germany for 100+ mph operations on DBAG.

MAN - "Maschinenfabrik Augsburg-Nuernberg."

MIS - Major-investment study.

NORAC - The Northeast Operating Rules Advisory Committee.

Open Access - An operating concept rooted in the earliest railroad experience when a railroad owner permitted any qualified carrier to enter and run upon its tracks in exchange for an agreed-upon fee or toll. Implicit in this "open access" arrangement is joint use by several carriers of common trackage. Open access is an issue where railroad infrastructure and railroad sources are corporately separated.

PATH - Port Authority Trans-Hudson.

PTS, PTC - Positive train separation and positive train control (two systems). Communications-based train location and control systems using global positioning and other technologies to reduce risk of train collisions. Tests and demonstrations underway.

Rail Bus - A passenger rail vehicle (typically non-articulated or rigid frame) that was derived from bus propulsion and construction technology, but which may evolve into larger dimensions, performance and characteristics similar in appearance to a small Category 1 DMU. (See Chapter 8 of *TCRP Report 52* for a full description of this type of rail vehicle in its several forms.) Rail buses are characteristically FRA noncompliant.

Rail Car Transmissions (Electrical) - Electrical traction motors transmitting energy as the final drive in rail car propulsion. In a typical electric-drive DMU application, motor leads and wires convey electrical energy between the car body–mounted diesel and alternator set and the swiveling truck where traction motors are mounted. Some motors are car body–counted.

Rail Car Transmissions (Mechanical) - The hydraulic fluid coupling or geared mechanical transmission that provides the final drive, usually through angle drive (cardan or drive shaft and universal joints) couplings. In a typical mechanical drive DMU, shaft and universals convey mechanical energy between the car body–mounted diesel prime mover and the truck-mounted gear case. This relatively inflexible arrangement reduces the minimum radius track curvature capability of the car.

Risk - Vulnerability to hazards or damage. This vulnerability may be expressed as a mathematical likelihood.

Risk Analysis - Systematic use of available information to identify hazards and to estimate the risk to individuals, populations, property, or the environment.

Schienenbus (G) - A generic rail bus design evolved from the 1930s and operated by various rail carriers, including DBAG. These rail cars are bus-derivative car bodies and prime movers now replaced by modern DMU designs.

Shunting - In Europe, the term describes (of rail cars) railroad function. In North America, the term applies to closing a track circuit occupied by a rail car conducting the low-voltage circuit between the rails.

SNCF Socièté Nationale des Chemins de Fer Francais.

SSPP - Safety system program plan.

Stadtwerk (G) - "City works," City enterprise or civic utility consortium. This institution is common in German cities and typically consists of two or more of the following public utilities: electric, gas, water, steam, parking, parks, rail, and bus transit.

STB - Surface Transportation Board, which assumed some regulatory responsibilities of the ICC.

SWEG (G) - Sudwestbeutsche Eisenbahn AG.

TCRP - The Transit Cooperative Research Program.

Temporal Separation - A separation into lengthy blocks of time when the tracks are dedicated to one of the joint users exclusively. In effect, the railroad is shut down during the transition between periods of exclusive use while it is verified that the previous user is off the tracks.

Tram - A streetcar or strassenbahn street railway. There is a subtle difference from light rail in the tram's lower performance and high-density operating environment.

TRB - The Transportation Research Board.

VBK - "Verkehrsbetriebe Karlsruhe," Karlsruhe Transit System, part of city administration.

VDV (G) - Association of German Transport Undertakings ("Verband Deutscher Verkehrsunternehmen"), roughly a German equivalent to APTA in North America.

VEK (G) - "Verkehrsbetriebe Karlsruhe," Karlsruhe Transit System part of the city administration.

Verkehrs (G) - "Traffic," "transport," "transportation," found frequently in German compound words or titles to describe transport enterprise.

Verkehrsbetriebe (G) - Transport institution or enterprise.

Verkehrsverbund (G) - Transport unification governmental.

VRS (G) - Verkehrsverbund Rhein-Sieg GmbH.

VVS (G) - Verkehrsverbund Saarland.

## APPENDIX A: SUMMATION OF NEW-GENERATION DMU RAIL CARS

**13 Individual Rail Car Designs**

**6 Variants based on Modularity or Power Systems**

**50+ Design Options and Combinations**

**14 Major Manufacturers (4 principal groups)**

**8 Wheel/Drive Train Arrangements**

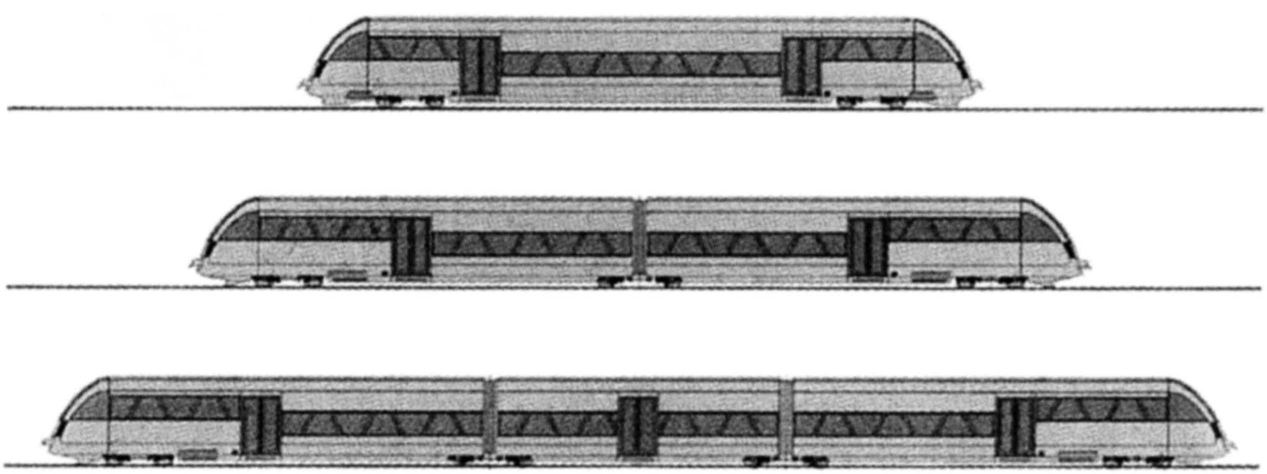
**1-5 Unit Configurations**

**16m-53m (53'-175') Length Options**

**50+ Separate Rail Operators**

**+1,157 Total Units - plus 167 on order**

Summation: Light Rail and Bus Derivative Diesel Multiple Unit Cars in Western Europe that are replacing the first-generation Schienenbus and second-generation rail diesel cars. Variety of design options is enhanced by modularity in DMU and LRV configurations as illustrated below:




Modular concept applied to ADtranz rail car platform. Note optional configurations and end caps or "head designs."

## APPENDIX B: LIGHT RAIL AND BUS-DERIVATIVE DIESEL MULTIPLE UNIT CARS

| Name | Units | Wheel Arrangement[2] | Configuration | Length | Seats | Drop Seats | Standees | Drive Train | Engine | Manufacturer |
|---|---|---|---|---|---|---|---|---|---|---|
| Regio-Sprinter | 46 | A2A | 3 units | 25m | 64-74 | 6-10 | 84-100 | Mech. | 2/5 cyl. | Siemens/Duewag[4] |
| Desiro (DB 642) | 210 | B(2)B | 2 units | 41.7m | 110 | 13 | 90-110 | Mech. | 2/6 cyl. | Siemens/Duewag[1] |
| Regio-Shuttle (DB 650) | 184 | BB | 1 unit | 25.5m | 68 | 4-8 | 83-94 | Mech. | 2/6 cyl. | ADtranz |
| ITINO | -- | BB | 1 unit | 25m | -- | -- | -- | Mech. | 2/6 cyl. | ADtranz |
| ITINO | -- | B'(2)B' | 2 units | 38.4m | 128 | -- | -- | Mech. | 2/6 cyl. | ADtranz |
| ITINO | -- | B'(2)(2)B' | 3 units | 51.3-54.7 | 176 | -- | -- | Mech. | 2/6 cyl. | ADtranz |
| IC-3 Flex Liner | -- | BB | 3 car trains | 193' | -- | -- | -- | Mech. | 4/6 cyl. | ADtranz |
| GTW 2/6 (DB 646) | 114 | 2' $B_o$ 2' | 3 units | 38.6m | 78-124 | 10-17 | 103-106 | Elec. | 1/12 cyl. | Bombardier – DWA ADtranz-Stadler[1] |
| Talent (DB 643) | 180 | B'(2)(2)B' | 3 units | 48.3m | 120 | 17 | 150 | Mech. | 2/6 cyl. | Bombardier-Talbot[4] |
| Talent (DB 644) | -- | $B_o$'(2)(2)'$B_o$ | 3 units | 52.1m | 120 | 41 | 150 | Elec. | 2/12 cyl. | Bombardier-Talbot[4] |
| Talent Regionbahn | -- | B'(2)'B | 2 units | 34.6m | 84 | 14 | 100 | Mech. | 2/6 cyl. | Bombardier-Talbot[4] |
| Integral ID5 (bi-level options also) | 17 | AA111A | 5 units | 52.9m | 141 | 20 | 200 | Mech. | 3/6 cyl. | DEGV/BZB/BEG Consortium[1] |
| Coradia LINT27 (DB 640) | 30 | B'2 | 1 unit | 27.2m | 60 | 13 | 69 | Mech. | 1/6 cyl. | Alstom-LHB[3] |
| Coradia LINT41 (DB 648) | 54 | B'(2)B' | 2 units | 41.8m | 116 | 15 | 103 | Mech. | 2/6 cyl. | Alstom-LHB[3] |
| TER 73500 (DB 641) | 240 | (1A) (A1)' | 1 unit | 28.9m | 63 | 17 | 82 | Mech. | 2/6 cyl. | DeDietrich/Alstom/LHB |
| Dosto-Schienenbus (DB 670) | 7 | 1A | 1 bi-level unit | 16.3m | 68 | 10 | 32 | Mech. | 1/6 cyl. | Bombardier-DWA |
| LVT/S | 24 | A1 | 1 unit | 16.5m | 45-53 | 14 | 40-41 | Mech. | 1/6 cyl. | Bombardier-DWA |

Notes:
1. Also available in an all-electric light rail vehicle version.
2. Wheel and drive train variants: Rail cars vary in wheel arrangements and power train configuration as follows:
   - A = single powered axle
   - B = 2 powered axles on single truck assembly
   - C = 3 powered axles on single truck asssembly
   - 1 = single unpowered axle
   - 2 = two unpowered axles
   - 3 = three unpowered axles
   - ( ) = denotes separate articulated truck/bogie
   - o = denotes separate axles under a common unit
   - -- = information not available
3. Available in EBO and BOStrab versions
4. UIC 505-1 compliant

## APPENDIX C: REPRESENTATIVE CARRIERS USING NEW-GENERATION, LIGHT RAIL–DERIVATIVE DIESEL MULTIPLE UNIT

| | Operator/Railroad | Type Rail Car(s) Operated | Manufacturer |
|---|---|---|---|
| 1. | Deutsche Bahn (DB) | Regio-Sprinter, LVT/S, Desiro, Talent, Regio-Shuttle, GTW 2/6, LINT 27 & 41, TER 7350 | All |
| 2. | Vogtlandbahn (Regental Bahn Betriebe GmbH – Zwickau | Regio-Sprinter | Siemens/Duewag |
| 3. | Bayerischen Oberlandbahn GmbH – München (BOB) | Integral ID5 | Consortium |
| 4. | Mittelthurgaubahn – Radolfzell/Stockach, Shafthausen (MthB) | GTW 2/6 | Adtranz/Stadler/SLM |
| 5. | Karlsdorfer Eisenbahn (KEG) Burgenlandbahn, City Bahn – Chemnitz, Naumburg | | |
| 6. | Ruhrtalbahn (Dürener Kreisbahn) – D_ren (DKB) | Regio-Sprinter | Siemens/Duewag |
| 7. | NaerumBanen – Naerum | Regio-Sprinter | Siemens/Duewag |
| 8. | Slovenischen Bahnen – Slovakia (ZSR) | GTW 2/6, Desiro | Adtranz, Siemens/Duewag |
| 9. | Griechische Staatsbahn – Greece (OSE) | GTW 2/6, Desiro | ADtranz, Siemens/Duewag |
| 10. | Kahlgrund Verkehrs (KVG) | Desiro, Regio-Shuttle | Siemens/Duewag, ADtranz |
| 11. | Schönbuchbahn/WEG – Schönbuch | Regio-Shuttle | Adtranz |
| 12. | Württenbergische Eisenbahn – Württenburg | Regio-Shuttle | ADtranz |
| 13. | Hohenzollerische Landesbahn (HZL) [Rail Charter) | Regio-Shuttle | ADtranz |
| 14. | Regental Bahnbetriebes GmbH/Waldbahn [Rail Charter) | Regio-Shuttle | ADtranz |
| 15. | Südwestdeutsch Verkehrs-AG (SWEG) 5 separate operations [Charter] | Regio-Shuttle | ADtranz |
| 16. | Breisgau S-Bahn – Breisgau [Rail Charter] | Regio-Shuttle | ADtranz |
| 17. | Tochter Ontenau S-Bahn – Tochter/Offenburg [Rail Charter] | Regio-Shuttle | ADtranz |
| 18. | Bodensee – Obschwaben – Bahn GmbH (BOB) | Regio-Shuttle | ADtranz |
| 19. | Erfurter Industriebahn GmbH (EiB) – Erfurt | Regio-Shuttle | ADtranz |
| 20. | DB Zugbus Regionalverkehr Alb-Bodensee (RAB) | Regio-Shuttle | ADtranz |
| 21. | Rhein Mosel Bahn GmbH | Regio-Shuttle | ADtranz |
| 22. | Südthüringenbahn | Regio-Shuttle | ADtranz |
| 23. | Eurobahn – Alzey, Kircheimbolanden (BGW) [Charter] | LVT/S, Regio-Shuttle | DWA/ADtranz |
| 24. | Zwerkverband/WEG | Regio-Shuttle | ADtranz |
| 25. | Kahrgrund – Verkers (KVG) | Regio-Shuttle | ADtranz |
| 26. | Danish State Rys. | IC3 Flexliner | ADtranz |
| 27. | Israelie State Rys. | IC3 Flexliner | ADtranz |
| 28. | Ostmecklenburgische Eisenbahn (OME) – Schwerin | Talent | Bombardier Talbot |
| 29. | Dörtmund – Markische Eisenbahn (DME) – Dörtmund | Talent | Bombardier Talbot |
| 30. | Regiobahn – Mettman | Talent | Bombardier Talbot |
| 31. | Eurobahn – Bielefeld | Talent | Bombardier Talbot |
| 32. | Norwegisch Staatsbahn (Norway) | Talent | Bombardier Talbot |
| 33. | Mass Transit North America (MTNA) – Ottawa | Talent | Bombardier Talbot |
| 34. | NJ Transit (NJT) | GTW 2/6 | ADtranz et.al. |

| Operator/Railroad | Type Rail Car(s) Operated | Manufacturer |
| --- | --- | --- |
| 35. 8 Misc. Operators Electric Version – 57 Units | GTW 2/6 | ADtranz et.al. |
| 36. Hessische Landsbahn (HLB) | GTW 2/6 | ADtranz et.al. |
| 37. Landesnohverhrsgeshaft Niedersachsen (LNVG) – Osnabrücke | LINT 41 | Alstom – LHB |
| 38. Deutsche Eisenbahn G. (DEG Nord) Nordwestbahn – Kiel | LINT 41 | Alstom – LHB |
| 39. Stadtwerke Schwerin | LINT 41 | Alstom – LHB |
| 40. Syntus/Niederlande | LINT 41 | Alstom – LHB |
| 41. Franzosische Staadtsbahn (SNCF) | TERX 73500 | DeDietrich/Alstom - LHB |
| 42. Butzbach – Licher Eisenbahn | GTW 2/6, LVT/S | ADtranz, DWA |
| 43. Deutsche Regionalbahn (Dessau – Wörlitzer Eisenbahn) | Schienenbus | MAN |
| 44. Verkehrs betriebe Elbe – Weser GmbH (EVB) | Schienenbus | MAN |
| 45. Genthiner Eisenbahn (Klb) | Schienenbus | -- |
| 46. Hellertalbahn (HTB) | GTW 2/6 | ADtranz |
| 47. Kassel-Naumburger Eisenbahn (KNE) | GTW 2/6, Regio-Shuttle | ADtranz |
| 48. Prignitzer Eisenbahn GmbH (PEG) | Schienenbus | MAN |

Note: “Charter” denotes contract operation

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