Transit Cooperative Research Program

Sponsored by the Federal Transit Administration

RESEARCH RESULTS DIGEST

March 2002—Number 47

Subject Areas: 1A Planning and Administration Public Transit, VII Rail

Responsible Senior Program Officer: Gwen Chisholm

International Transit Studies Program

Report of the Spring 2000 Mission

Germany's Track-Sharing Experience: Mixed Use of Rail Corridors

This TCRP Digest summarizes the 12th study mission performed under TCRP Project J-3, "International Studies Program." The report includes information on the cities visited, lessons learned, and discussions of policies and practices that might be applied in the United States. This Digest was prepared by S. David Phraner of Edwards and Kelcey, Inc. for the Eno Transportation Foundation, Inc., the contractor for the project, on the basis of reports filed by the individual mission participants.

INTERNATIONAL TRANSIT STUDIES PROGRAM

About the Program

The International Transit Studies Program (ITSP) is part of the Transit Cooperative Research Program (TCRP). The ITSP is managed by the Eno Transportation Foundation under contract to the National Academies. TCRP was authorized by the Intermodal Surface Transportation Efficiency Act of 1991 and reauthorized in 1998 by the Transportation Equity Act for the 21st Century. It is governed by a memorandum of agreement signed by the National Academies, acting through its Transportation Research Board (TRB); by the Transit Development Corporation, which is the education and research arm of the American Public Transportation Association (APTA); and by the Federal Transit Administration (FTA). The TCRP is managed by TRB and funded annually by a grant from FTA.

The ITSP is designed to assist in the professional development of transit managers, public officials, planners, and others charged with public transportation responsibilities in the United States. The program accomplishes this objective by providing opportunities for participants to learn from foreign experience while expanding their network of domestic and international contacts for addressing public transport problems and issues.

The program arranges study missions for teams of public transportation professionals to visit exemplary transit operations in other countries. Each study mission focuses on a central theme that encompasses issues of concern in public transportation. Cities and transit systems to be visited are selected on the basis of their ability to demonstrate new ideas or unique approaches to handling public transportation challenges reflected in the study mission's theme. Each study team begins with a briefing before departing on an intensive 2-week mission. After this stimulating professional interaction, study team members return home with ideas for possible application in their own communities. Team members are encouraged to share their international experience and findings with peers in the public transportation community throughout the United Stated. Study mission experience also helps to better evaluate current proposed transit improvements and can serve to identify potential public transportation research topics.

Study missions normally are conducted in the spring and fall of each year. Study teams consist of up to 15 individuals, including a senior official designated as the group's spokesperson. Transit properties are contacted directly and requested to nominate candidates for participation. Nominees are screened by a committee of transit officials, and the TCRP Project J-3 Oversight Panel endorses the selection.

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Study mission participants are transit management personnel with substantial knowledge and experience in transit activities. Participants must demonstrate potential for advancement to higher levels of public transportation responsibilities. Other selection criteria include current responsibilities, career objectives, and the probable professional development value of the mission for the participant and the sponsoring employer. Travel expenses for participants are paid through TCRP Project J-3 funds.

For further information about the study missions or individual travel awards, contact TCRP (202-334-3246) or the Eno Transportation Foundation (202-879-4700).

About the Digest

The following digest is an overview of the German track-sharing study mission. It reflects the views of the contributing participants, who are responsible for the facts and accuracy of the data represented. The digest does not necessarily reflect the views of TCRP, TRB, the National Academies, TDC APTA, FTA, or the Eno Transportation Foundation.

GERMANY'S TRACK-SHARING EXPERIENCE: MIXED USE OF RAIL CORRIDORS: MISSION 12, JUNE 15-JULY 2, 2000

Introduction

The spring 2000 mission of the TCRP's International Transit Studies Program was devoted entirely to study of track sharing. Fifteen U.S. public transit professionals visited their counterpart planners and practitioners in Germany, Luxembourg, and France. The mission participants explored issues relating to concurrent sharing of track by rail vehicles of differing sizes and weights. The mission team visited seven cities in Germany (Cologne, Dueren, Kassel, Karlsruhe, Saarbruecken, Rhine/Ruhr-Dortmund, and Gelsenkirchen), as well as Strasbourg, France, and Luxembourg City, Luxembourg. This itinerary was intended to examine first-hand different aspects of track sharing at varied stages of development in cities of different size and circumstance. Some of these overseas metropolitan areas visited by the study mission shared characteristics similar to North American urban places.

The mission participants represented transit operators from large and small metropolitan areas. Some of these domestic operators have well-functioning, mature rail transit infrastructure, and others represent smaller cities that are planning or aspire to rail transit, bus rapid transit (BRT), or other fixed guideway transit. The purpose of this study mission was to investigate Germany's successful experience with railroad track sharing by disparate types of rail rolling stock. The study mission participants were eager to consider potential applications of this experience in North American cities of varying size and transit needs. At the onset, "the stated theme of the mission was Germany's track-sharing experience: (in) mixed use of suburban rail corridors." As study mission investigations unfolded, however, the mission's scope expanded well beyond suburban corridors. Because of the variety of rail operations and locations visited, "all types of rail corridors" became a more appropriate description of the reach of the mission's investigation. The mission examined the so-called "German model" of railroad passenger and freight, regional diesel multiple unit (DMU), and urban light rail and tram-type vehicles sharing intercity and branch line railroad tracks. This is the first of the TCRP study missions with a narrowly defined focus (track sharing exclusively) that responds to specific current rail transit and railroad industry concerns in the United States.

Over a span of 2 weeks, the study mission participants focused on a variety of specialized research topics including regulation, urban development, rail operations, signaling and train control, infrastructure, institutional changes within the European Union (EU), and rail car design. Each mission participant selected topics of particular interest or specific application to their native city or professional specialty. The resulting papers form the foundation and structure of this digest.

Several kinds of track sharing have evolved in nearly a decade of renewed interest in the subject in North America. It became important to distinguish between specific track-sharing applications here and abroad and direct research on the most transferable track-sharing practices. For example, no time-separated (as practiced in the United States) operations were sought out or detected. Very close dispatching of different train types on a common track, employing schedule slots measured in minutes, were commonly observed. The intent of this mission, therefore, was to research *concurrent or commingled* operation of conventional railroad freight and passenger trains with light rail vehicles (LRVs), rapid transit, or light DMU vehicles. Competition for track space between freight railroad and passenger railroad trains, common in the United States, is treated only in the context of German federally mandated *open access for all types of carriers operating compliant rail cars on the national system of railroad tracks in Germany*. Temporal separation, as practiced in the United States, is uncommon in Germany and therefore little could be learned on this practice overseas. Sharing rights-of-way, but not necessarily tracks, is also common and taken for granted in Germany that it provides little transferable experience in negotiating difficult agreements between track owners and tenants in the United States.

For reasons cited above, this digest is organized around key issues for potential direct application to U.S. cities or lessons learned for indirect applications to North American environment and institutions. It is not in a travelogue format, nor is it arranged by cities visited. Mission participants were urged to explore their specialties primarily. Accordingly they focused their individual papers on their specialty topic, which treated one aspect of the common shared track topic, but as practiced in seven different European metropolitan areas.

Finally, the papers forming this digest were edited and the digest assembled by an independent professional that had not accompanied the spring 2000 TCRP mission overseas. He had, however, previously visited the same key track-sharing areas in Germany, and he briefed the mission participants prior to their departure.

This digest is organized around the major topics addressed by the study mission participants. The sequence of topics and major headings tend to follow from the most comprehensive issues, to the more specialized interests selected for treatment by the participants. For example, German national and local policies touched every specialty topic. Understanding German transport and urban development policy is fundamental to understanding shared track motivation and popularity. Policy therefore appears first.

BACKGROUND

Policy Overview

At the onset of the mission, concerns over the growth in U.S. shared track proposals and the potential risks they posed were the subject of an evolving policy discussion among federal agencies (FTA/Federal Railroad Administration [FRA]) and the rail transit and railroad sectors. This discussion is motivated primarily by concern for passenger and crew safety.

U.S. Federal Policy on Track Sharing

Federal joint policy had been drafted in 1999 and exposed for broad review and comment into year 2000. Final federal policy statements on track sharing were published and codified after the study mission tour was completed. The resulting U.S. domestic policy depends heavily on absolute time separation of railroad and rail transit train movements, and issuance of waivers to permit this limited type of track sharing. This policy is in contrast to what the mission observed in Germany, where simultaneous operation of various types of equipment is permitted by a *single ministry, regulating both the railroads and rail transit operators at the federal level*. There, track sharing is generally permitted by code, and exceptions to that rule are considered by regulators. All U.S. proposals for sharing track are reviewed and permission granted only by exception or waiver.

Though a federal policy now exists for managing and regulating proposals for sharing track in the United States, the dramatic success of overseas shared track experience opens avenues for new research to which the mission addressed itself.

Key policy issues arise. Can these successful German shared track innovations and technology be imported to North America to produce the same dramatic results? What are the obstacles to assimilating shared track operations into the railroad environment in the United States? The mission, therefore, sought to determine institutionally, operationally, and technologically the root origins of Germany's successful track sharing. Most importantly, its major inquiry was, could these roots be transplanted in North America?

Same Problems, Contrasting Transportation Approaches

In the 19th century, people moved into cities in response to the industrial revolution. In the 20th century, the technology revolution allowed people to move residences and jobs outward from urban centers. Research has long proven a strong relationship between transportation modes and infrastructure and the urban form. The increased need for longer distance for travel to, from, and within lower-density suburban areas creates an environment hostile to public transportation and inefficient use of transportation resources. Because the automobile is often the only practical means of accessing areas beyond the reach of public transit, this spread city of people and jobs also reduces mobility options for those who prefer to use, or must depend on, public transportation. Western Europe and North America share this affliction, but the study mission detected somewhat different approaches and remedies between Western Europe and North America.

U.S. and German Remedies

By way of review, track sharing by railroads and rail transit now exists in a few U.S. cities, including Salt Lake City, Baltimore, Newark, Scranton, and San Diego. All are time separated—that is; railroad trains and light rail vehicles do not occupy the same track simultaneously. Each mode is assigned a significant period to occupy tracks exclusively. Tracks are shared, but not at the same time. The mixing of differing types of passenger and freight equipment on shared tracks was once very common across the entire North American railroad system between the late 1800s and mid-1900s. The reorganization of railroads in the United States into separate and exclusive passenger and freight businesses created separate rather than shared systems. Freight railroads by agreement and with regulatory surveillance shared tracks with other railroads, but not with rail transit carriers such as light rail or rail rapid transit.

In the late 1970s, Germany took track sharing to a new level when it began extending city-oriented, light rail-type passenger vehicles into outlying areas on routes typically used exclusively by regional and intercity express and freight trains. Usually, these were not new services, but cheaper light rail substitutes for locomotive-hauled railroad-crewed trains. This integration of the railroad system with selected streetcar lines has brought more direct access to city centers from towns in surrounding exurbs. With key track connections and dual voltage LRVs, convenient light rail services were expanded beyond the streetcar network at a fraction of the cost, dislocation, and time otherwise needed with new construction to expand rail transit. Over 30 European cities and conurbations have or are considering shared track as a means of initiating a rail transit new start, restoring formerly abandoned tram service, substituting inefficient railroad commuter service or expanding their light rail systems.

As a result of ongoing mergers and efficiency improvements by U.S. railroads, rights-of-way are becoming available for other uses, including "rails-to-trails" bikeways and BRT "busways." Some of these surplus or underused railroad lines offer potential to be adapted for cost-effective extensions of existing urban electrified light rail lines as demonstrated in St. Louis and elsewhere domestically. The supply of disused rights-of-way has, however, a short self-life and is diminishing. As the supply reduces, track sharing becomes a more viable option. These rights-of-way and tracks can create the basis for new starts, using a new generation of light rail DMU services, which may be even more cost-effective. Why not use electric light rail vehicles here? Because the United States has less than 1 percent of its railroad route miles electrified. In Germany, it's over 45 percent. The Camden to Trenton, New Jersey, service, scheduled to begin operations in late 2003, will be the first such wireless LRV track-sharing application in the United States. It is notable for its use of railroad trackage and in-street tram-type track geometry. This innovation is a rarity, even in Germany.

Thus, the promise of track sharing worldwide is to maximize the efficient use of existing rail corridors to improve mobility between urban and suburban areas. Track sharing also promises to reduce automobile dependency and to provide more people with a fast, convenient, and enjoyable way to travel across regions.

TRACK-SHARING RELATIONSHIPS TO ECONOMIC AND URBAN DEVELOPMENT

Balancing Safety and Other Social Benefits of Track Sharing

One of the more subtle relationships of track sharing revealed during the mission's tour is its use by German officials in support of planned urban and economic development. Track sharing is applied as a mobility tool to achieve social benefits through rapidly enhancing transportation services. Transportation, and specifically track sharing, is not planned and delivered in isolation. It is facilitated by urban institutions that by their nature coordinate all municipal transport with other services as a matter of urban policy. In all the German conurbations visited by the study mission, urban development, public utilities, regional rail transportation, and track sharing are regarded as indivisible practices. This is explained in greater detail in the section of the report on institutional experiences, but it is mentioned here because it helps explain why German cities provide worthy models of urban planning and why track sharing is becoming more widely accepted overseas. Official support for track sharing in German metropolitan areas appears in several subtle forms:

1. Transportation projects are developed and planned in coordination with, or by the same entities responsible for regional planning and development. Transportation, fiscal, economic, and physical urban development planning are integrated at the regional and metropolitan level.
2. Quantifiable benefits of track sharing (capital costs and other savings) are compared and balanced against the quantifiable safety risks of joint rail operation to determine feasibility of new rail services. While safety is of primary importance, it is not the only consideration. For example, on the Karlsruhe-Bretten Karlsruhe Transit (VBK) S-bahn route S4 using shared track, ridership increased by 400 percent over previous regional railroad service. More and faster LRT service was provided at lower operating cost. Initial service over shared track was initiated within months, not years. Introduction of VBK light rail service using shared track to Bretten increased housing values threefold. Overall, 40 percent VBK light rail ridership came from previous automobile users (the comparable bus ridership draw is 3 percent). Within 15 years, the VBK system in Karlsruhe grew from a tram system and one interurban railway totaling approximately 90-route-km of service to a combined tram and S-bahn network of over 360 km. Nearly all of that expansion of service is attributed to shared track operation. On the other side of the Karlsruhe balance sheet, neither major accidents nor fatalities are attributed to track sharing since it was implemented by VBK.
3. Transportation is used as one instrument in guiding and controlling development, combined with more stringent land use policies and controls common in Europe. Often, new or expanded rail transit is provided rapidly (facilitated by sharing track) in anticipation of, rather than in reaction to, new development.
4. German rail operations are regulated by the same government entity responsible for both federal rail transit and railroad policy. The centralized German federal rules for *railroads,* EBO (*Eisenbahn*-Bau- und Betriebsordnung), and for *streetcars*/rail transit, BOStrab (Bau und Betriebsordung fur *Strassenbahnen*), are coordinated and regulated under a common ministry. That same ministry is also responsible for federal urban development policy. Land use and transportation policies are therefore coordinated at the highest level, as well as at land (provincial) and municipal levels. The

final level of regulatory enforcement is, however, by the state or land. This coordination of development and transportation means that *public safety and other social benefits are weighed together in track sharing and other policy and regulatory formulation.*

5. All German and French cities hosting the study mission had created a public works consortium combining utilities (gas, water, transit, etc.). Financial planning and transport planning are therefore integrated across the full spectrum of public services. While these consortia called "stadtwerke" alone do not implement track-sharing proposals, they help create an environment in which track sharing can advance and thrive.
6. Most German metropolitan regions (and all of the ones visited by the study mission) have organized their public and private transport carriers under a super regional transport organization. This agency does not manage the individual systems, but it does coordinate fares, services, and schedules into a seamless, user-friendly transportation network. The first U.S. track-sharing domestic operator, San Diego's MTS (Metropolitan Transit System), is a close domestic approximation of this type institution.

In North America, shared track discussion and research are directed almost exclusively to issues of safety, exemplified by the following issues: What are the probabilities of injury, accidents, fatalities, and resulting costs in sharing track? What is the most intrusion-impervious car body design to protect passengers? Who is liable for accidents? How are these cost burdens and liabilities shared among the track users? What extra measures are required to protect trespassers on shared track?

These important issues are the most frequently acknowledged risks in track sharing. Largely overlooked in these risk assessments, however, are the potential track-sharing benefits and social and capital costs lost in discarding track-sharing alternatives from study consideration. Expressed in terms of new alignments compared with shared track, these benefits include capital costs saved by using an existing railroad right-of-way and fixed infrastructure, avoidance of social disruption due to carving out a new track space through urban and suburban communities, and takings and dislocation of homes and businesses. Environmental damage associated with new transport projects is often cited by the very citizens and property owners that these projects are supposed to benefit. Projects are delayed—or in some cases defeated—because of the social or capital costs of securing a new track space and eliminating track sharing as a valid alternative.

A Context for Track Sharing as a Public Benefit

Passenger rail transportation in Europe is very often held up as a model of success by U.S. transit professionals. From a North American perspective, it seems as if the nations of western Europe are blessed with an extensive rail network buttressed by federal policies favoring transit, strong government financial support for transit, and a culture in which people value the convenience of railroad and rail transit travel. Our admiration grows only greater whenever our local transit operators are forced to strenuously defend the mass transit subsidies in the face of competing interests.

As the study mission discovered, much of our image of public transportation in Europe is true. It is hard to visit Germany and not be impressed with the vast landscape of track and electrified rail infrastructure and the freedom of choice to travel extensively by bus, light rail, tram, or train. The importance of transit can be seen in the number of trips as a measure of total population. Some 9.35 billion transit trips were taken in Germany in 1988 when the population totaled 82 million. Compare that with the United States, which saw 8.7 billion trips in 1988 when the population was 270 million.

Yet a closer look at the German experience shows many of the same challenges that have confronted U.S. transit managers for the past 30 years. In visits to six German cities and one French city just across the border from Germany, the study participants learned that passenger service on many urban and regional lines had been either discontinued or scaled back over the past 3 decades in reaction to automobile popularity. In fact, some 900 km of tramway lines were closed throughout Germany between 1967 and 1984. Saarbruecken and Dueren are but two examples of local obsolete streetcar systems totally abandoned in the 1960s but restored in the 1990s, starting from scratch with modern LRT on new (largely railroad) alignments. "In the mid-1960s, the meter gauge tramways disappeared from the streets of Saarbruecken," according to Dr. Walter Keudel, managing director, Stadtbahn Saar GmbH (SBS). "At that time, however, Saarbruecken was far from being the only German city in which tramway networks fell from favor. In some cases, extensive rail systems were being abandoned and replaced by "cheaper to operate" buses." In the nearby small city of Neuenkirchen, the entire tramway system including an LRT suburban operation arrived on railroad branch lines as part of a regional commuter system surrounding Saarbruecken.

As German transit ridership fell, public subsidies were reduced, a downward spiral familiar to many transit providers in the United States. The result in Germany was inadequate resources to maintain many passenger train stations properly or to replace aged rolling stock. This disinvestment can be traced back to decisions by DB, the German national railway organization, to "rationalize" spending (e.g., discontinue or substitute buses for the worst financially performing regional railroad services). Similar draconian measures were occurring among many rail transit operators.

Another North American similarity is the suburbanization and dependence on the automobile in Germany that began after World War II and has grown extensively in recent decades. Competition with the automobile dispersed development in many German metropolitan regions seem very similar to the dynamic that has caused so many U.S. transit systems to redefine their roles in providing regional mobility. For example, the decision of the German postal service to relocate a mail-handling facility outside Kassel where it could not be well served by the rail network is a familiar anecdote to North American planners. Although the transit agency (Kasseler Verkehrs Gesellschaft or "KVG") was not aware of the decision until it happened, providing service to employees at the new location became "our problem," according to the head of planning and marketing for KVG.

There are now over 40 million automobiles in Germany, for a ratio of one automobile for every two people. Traffic congestion is considered a major problem. It not only impedes travel into and out of cities, but it degrades the quality of life within cities where pedestrian access and economic vitality go hand in hand. So why haven't more people embraced transit? Surveys taken in 1992, 1994, and 1996 in both the western and eastern parts of Germany indicated that the availability of the private automobile, relatively inferior transit service, and the frequent need to make transfers are the most important reasons why public transportation is not used more often and widely.

This finding regarding lack of convenience due to transfers is not at all surprising given the fact that the main train stations in several cities are located too far away from the central business district to be convenient for people commuting from the suburbs. Dortmund, a city of 600,000 and the major industrial center of the Ruhr region, is a good example. Its Hauptbahnhof (main train station) is located outside the major activity center of the city, where a new 10.3-km metro line with 13 underground stations was opened in the early 1980s. "Two separate worlds" is the way Otto Schliesler, head of the Dortmund metro, described the resulting isolation of suburbs and city. "You have to think of regions, not just the city," he said. People want to be mobile in the whole region." This is a striking, but particularly appropriate statement for those familiar with the Rhine/Ruhr region. Transport policy in Dortmund and its 12 neighboring cities, 90 Westphalia municipal jurisdictions, and seven rail systems in Rhine/Ruhr conurbation is to integrate public transportation with common or reciprocal fares, services, schedules, and rolling stock. Track sharing is common among rail transit operators and to a lesser extent present between rail transit and freight railroads in this region. Given the similarities in German and North American post-war economic growth, how did German track-sharing proclivities evolve in contrast to those in the United States?

German Policies Encouraging Track Sharing

The reform, privatization, and reorganization of the national railroad system in Germany (described below) and the enforcement of EU mandates formed a backdrop for two major policy changes that are transforming public transportation in much of Germany.

First, responsibility for providing urban regional railroad transit services has been gradually transferred from DB to regional authorities with both the resources and the controls necessary to restore and develop new passenger service.

Second, over 30 cities in Germany, Switzerland, France, and the Benelux are planning or have begun planning and design to connect their light rail systems with the tracks of their regional and national railroad system. This means light rail trains sharing tracks with commuter, intercity, high-speed passenger, and freight trains. Between 1984 and 1999, the route miles of railroad track used by local rail services (S-bahn, Metro, light rail, and tramway) increased nearly 70 percent. Much of this dramatic increase is due to track sharing of various kinds. The goal in linking urban and regional track networks has been to expand both the reach and convenience of train service to compete with the automobile mode.

This physical track linkage has been accompanied by the introduction of other policies that make travel between urban centers and surrounding suburbs more seamless. "It must be a central endeavor to offer the customer a uniform public transport system: one network, one schedule, one tariff, one ticket independent of the transport undertaking," states a paper prepared by VDV (Verband Deutscher Verkehrsunternehmen), Germany's equivalent of the American Public Transportation Association. The study mission observed substantial evidence of this comprehensive and centralized approach in Germany through the emergence of strong regional transport oversight organizations (verkehrsverbund) in each city visited by the study mission. These oversight organizations, at a minimum, set uniform fare policies and administer a common or coordinated ticketing system for local service providers. More detail on these unique and now threatened institutions is provided below.

A short digression would help better understand the various types of rail services commonly operated in Germany. Commuter rail, often referred to as "regionalbahn," is differentiated from the similar, but higher density light rail or rapid transit-based stadtbahn or "S-bahn" services. Comparable services in the United States are not as well defined to enable distinguishing between types. One cannot generalize, however, about the mode and character of regionalbahn or stadtbahn services, even in Germany. They take different forms in different cities. In Berlin, S-bahn takes the form of surface or elevated operated heavy rail rapid transit. In Karlsruhe, S-bahn is light rail. In Stuttgart, S-bahn is commonly high-platform electrified multiple units transitioning from meter gauge tram and standard gauge LRT. In the Karlsruhe region, these services are defined by "R" for regiobahn and "S" for stadtbahn prefixes to their route numbers. In Karlsruhe, regional or "R" services are typically operated by DMUs or short-consist locomotive-hauled commuter trains, operated under contract by DB (Deutsche Bundesbahn), with the regional oversight agency, KVV (Karlsruher Verkehrsverbund). S-bahn is operated by AVG Albtal Verkehrs Gesellschaft), the regional transit operator, also with oversight by KVV. For foreign visitors, these interlocking organizations are bewildering. However, understanding their functions and how they relate is important to grasping why shared track works well in Germany.

In contrast to the DB-operated regiobahn trains, the S-bahn trains are more frequent, light rail-based, and operated by the regional transit operator AVG. KVB (Karlsruhe Verkehrsbetriebe) is the local tram (streetcar) and bus operator. All are subject to oversight by KVV, the super agency. The regional and Stadtbahn services share track with the intercity railroad system. The third category of rail transit service in Karlsruhe is the tram or streetcar ("strassenbahn") routes. These have no designated prefix. Trams are prohibited by regulation from venturing onto railroad tracks because of their design and equipment. Only S-bahn, LRVs can transition between railroad and streetcar/tram tracks. Only LRVs are compatible with railroad and streetcar modes. Light rail cars and articulated trams may seem to be very similar in appearance, but the LRV is a more robust design. In summary, railroad trains can't physically negotiate tram track geometry, and trams cannot institutionally operate on railroad tracks. LRVs can and do transition between both, thus making them ideally suited to perform S-bahn shared track services in Germany.

While currently not practiced today in the United States, commingled joint use of tracks, unrestricted by time of day, has enabled cities such as Karlsruhe, Kassel, and Saarbruecken to increase service reach, grow ridership, reduce traffic congestion, spur economic development, and reinvigorate center city pedestrian activity. All of these objectives are being fulfilled at far less cost than if new right-of-way or new tracks for rail transit service had to be built.

Can not these same objectives be accomplished simply by implanting conventional railroad commuter trains or compliant DMUs on the freight railroad tracks, as exemplified by these commuter rail new starts in the United States? To an extent, yes, but combining the line haul functions of commuter rail and the downtown distribution functions of streetcar can only be accomplished by a mode that is compatible with mixed vehicular, pedestrian, and railroad train traffic. Though subject to continued debate, LRVs (diesel or electric propelled) are the only fixed guideway mode able to perform those combination of functions.

Being able to document the benefits of track sharing is extremely important because of the sizable technical and regulatory barriers, as well as safety challenges inherent in commingling passenger and freight trains of differing weights, propulsion systems, and sizes. Clearly, considerable investments have been made in Germany to make the safe sharing of tracks possible, including common signal and train control systems and vehicle engineering to reduce the likelihood of an accident as well as to limit injuries in the event of a collision. The question arises, has track sharing been worth the cost and effort in Germany? Would it be worth it to apply in the United States? As described at the FTA/APTA shared track workshop on July 13, 2000, there are 14 projects in North America (including five light rail projects) currently in preliminary engineering or final design, which propose to share track with conventional railroad trains.

European Institutional Experience in Track Sharing (Emphasis on Germany)

Institutional Events and Ownership Changes Facilitating Track Sharing

Track sharing in Germany did not occur in a vacuum. A host of institutional events and changes at the national, state, regional, and international levels all created an environment where the concept could flourish, and are now continuing to shape it. EU and national policies drove these institutional changes, but they did not alone produce or promote track sharing. The institutional changes did, however, create an institutional and operating environment more conducive to track sharing. A chronology of these changes and events us summarized in Table 1 and described in more detail subsequently.

Early Federal Recognition of Rail Transit Need

While Germany has had exceptional public transit systems for many decades, a significant event in the mid-1960s helped spur the growth of light rail transit, which in turn led to the track-sharing concept. Realizing that the rapid growth of private automobile traffic was severely affecting cities, the federal government commissioned a study of the problem. The report, released in 1964, identified the transport problems faced by municipalities and called for a major upgrading of the public transport system. The study particularly recommended the expansion of rail transportation, starting with light rail. The study also identified the huge financial commitment and long time frame (DM 37.5 billion and 30 years) it would take to meet the projected transport needs (VDV Stadtbahnen in Deutschland, p. 23).

This same sentiment on the role of light rail was expressed by several of the host properties visited by the study mission. Dr. Dieter Ludwig of Karlsruhe, for example, stated that long ago his organization realized that rail transit could divert people from their cars far more effectively than bus transit could. Furthermore, Ludwig commented, about 40 percent of commuters have destinations outside the city area. Thus, officials saw a need for an integrated transit network with the DB regional rail system, working with local trams and buses (Karlsruhe Meeting, June 23). Dr. Rainer Meyfahrt, of Kassel's (KVG) Planning and Marketing Department, also spoke of the efforts to expand

TABLE 1 Significant institutional events and changes that facilitated track sharing in Germany

DATE	EVENT	RESULT
1964	Federal government study released on measures required to solve municipal transport problems	Recognized problems of growing private transport, called for major upgrading of public transport, identified the large funding commitment required.
1966	Tax Amendment Act	Created a tax on oil with funds going to local roads and public transport.
1971	Municipal Transport Financing Act (GVFG)	Gave legal basis to 1966 oil tax, earmarked significant share for public transport, established projects eligible for funding. Initially was infrastructure only, later expanded to include buses (1987) and rail vehicles (1992).
1992	Tax Amendment Act - modifications to the GVFG	Transferred much of the responsibility for the public transport program from the federal government to the states. Of total funds available, 80% were now reserved for the states' programs, with feds only responsible for major projects in high-density areas.
1993	Railway Reorganization Act	German Railways, previously a public authority, was converted to a public limited company. Act effectively privatized the DB into separate infrastructure, passenger, and freight enterprises. Of key importance, it opened up DB rail network to third-party operators who bid to provide services on the infrastructure company's tracks.
1993	"The Basic Study" by German Ministry of Railways on study of LRV's and railway vehicles in mixed service. Supplemented by Risk Analysis Study.	Major government study which evaluated the early experience of shared use in Karlsruhe, laid foundation for future shared use projects in other cities. Supplemental Risk Analysis Study used "expert" risk analysis to deal with the risk-related issues of join use, and to ultimately develop a national policy for regulating joint use.
1995	Transport Ministry statement on Special Conditions for mixed use of LRVs and standard vehicles on railways.	Established National Policy for regulating joint use on railroads.
1996	Federal Act on Regionalization of Public Transport (Regionalization Act)	The states now have sole responsibility for the functions and financing of all areas of public transport, including regional rail service. Receive funding from federal government, from the oil tax. Most states created regional transit associations to handle these duties.
2000	Europewide Deregulation/Privatization Talks	Current talks in the European Union could lead to the deregulation and privatization of public utilities, including power and water, as well as public transport. This has potential funding reduction impacts for current public transit operators, through elimination of the cross subsidies, which help cover public transit operating deficits.

the local tram system beyond the central city area to meet the commuting needs of a growing number of residents in exurbia (KVG Meeting, June 22). Kassel's original tram system stopped at the city border, but growth continued beyond that border. Bus routes were extended further into the suburbs, but bus service was not as popular as the tram. Outward migration of population combined with the unpopularity of buses combined to cause a loss of almost one-third of (KVG) transit ridership, a scenario not unlike U.S. post-war experience. Initially, KVG's response was to use railway rights-of-way abandoned between 1971 and 1985. Other innovations were applied to attract patronage. Kassel was the first operation in Germany to use low floor trams. In 1955, KVG introduced joint use between pedestrians and trams in pedestrian shopping precincts. Finally, KVG and the regional railroad (Kassel-Naumburger Eisenbahn) cooperated on shared track in the compact and wealthy suburb of Baunatal.

Transit-Funding Programs

Transit-funding milestones to back up the federal government's findings were initiated in 1966, with further changes in the 1970s through 1990s. The Tax Amendment Act of 1966 created a 3-penny (pfennig) per liter tax on oil, with the proceeds going to improve municipal transport conditions (VDV, p. 485). The funds were initially split 60:40 between local roads and transit. In 1971, the Municipal Transport Financing Act (GVFG) was passed, giving a legal basis to the oil tax, and in 1972, the tax was doubled to 6 pennies per liter. The funds ratio was also revised to 50:50. While the transit monies initially could only be used for infrastructure, the law was later revised to include eligibility for bus purchases (1987) and rail vehicles (1992) (VDV, p. 485). Though the exact funding amount and formula varied in future years, a consistent and reliable federal-funding program for transit was thus established. A federal-funding commitment became one of a combination with other institutional and policy changes that encouraged development of track sharing. This describes the origin of the supply side of German federal-funding commitment. The distribution and cost sharing is described below, in the Kassel example.

Institutional Funding Shares in Support of Transit

In Kassel (and other German cities), the KVV agency's internal subsidy combined with a modest municipal government subsidy (DM 10 million) is used to match federal state (state of Hessen) subsidies. This federal subsidy is administered through the regional transport oversight agency or verkehrsverbund described above. In Kassel, this agency is called Verkehrsverbund Nordhessen (NVV), which covers Kassel and five counties in the Land of Hessen. The federal match distributed by the NVV must be matched 50/50 by city, county, or village recipients. Typical distribution of capital and operating costs and revenue sources for Kassel are summarized as follows:

TABLE 2 Typical distribution of cost and revenues in German urban transit

Capital/Infrastructure Costs:	80% from state of Hessen through oversight agency (NVV)
	20% from the stadtwerke or public utility agency (KVV)
Operating Costs:	50% from farebox
	25% pass through from NVV
	25% from city, county, village jurisdictions

Railway Reorganization Act

An institutional change of major significance occurred with the reunification of East and West Germany. When Germany was divided into zones following World War II, the railroad system was split into two separate networks. The reunification of Germany resulted in the combining of its formerly separate eastern (Reichsbahn) and western (Deutschesbahn) railroad systems into a new national railroad called Deutsche Bundesbahn AG or "DBAG" (or simply "DB"). Following this consolidation came an attempt to privatize the railroads with the enactment of the 1993 Federal Railway Reorganization Act. The German National Railways had previously been operated as public authorities. Under this Act, the new DB Rail was converted to a public limited company and was divided into three components (Cologne KVB Meeting, June 20):

DB Nets – Responsible for maintaining and leasing the railroad infrastructure,

DB Cargo – Responsible for the freight portion of the business, and

DB Bahn – Responsible for the long-distance passenger rail service.

Overlaying these reforms and reorganization of Germany's national railroad system was the creation and subsequent rule making of the EU. These EU rules are complex, but for purposes of this research, their transport provisions have among their objectives the integration of the former nationalized railroads into a cohesive European network to fortify economic reforms. Consistent with EU directions, other western European nations were also following this method of denationalizing their railroads, but the degree and detail of institutional separation of the railroad ownership and management varied. It should also be noted that while nationalized railroads formerly dominated European railroad operations, privately owned and operated railroads do exist in Germany, Switzerland, and elsewhere. These private railroads, like their North American counterparts have, on their own initiative, developed agreements on sharing tracks, but these are largely outside of the scope of federal mandates.

Other Institutions and Ownerships that Influence Track Sharing

Another important institution having a bearing on track sharing, and which is undergoing change in Germany, is the "Stadtwerke." All of the German cities visited have similar institutions created for the purpose of managing public utilities within a metropolitan area. In Kassel, for example, the transit operator is Kasseler Verkehrs Gesellschaft (KVG), a subsidiary of a large municipal public utility holding corporation called Kassel Verkehrs und Versorgungs Gesellschaft (KVV). KVV as a holding company controlling subsidiaries that provide water, gas, electricity, waste removal, and phone service, as well as public transport to the city of Kassel. These public utility services combined yield a profit, part of which (about DM 30m. annually) is transferred to the KVG. The fees collected by the profitable public utility sector, therefore, cross subsidize the unprofitable, but essential, public transport sector, all within a single agency. Another advantage of the Stadtwerke is that new urban development initiatives are integrated with utility and transport planning at the municipal level. Municipal government officials, urban planners, transport authorities, and utility management are structured to integrate and coordinate their plans and programs.

Opportunity for a similar cross subsidy arrangement once existed in the United States when gas and electric public utilities and streetcar/motor coach enterprises were commonly combined under a single holding company management. These holding companies in some cases grew to large, multicity syndicates attracting the attention of antitrust reformers. They differed from the Stadtwerke, because they were mostly privately owned. The U.S. Federal Public Utilities Holding Act of 1935 and antitrust government pressures split up the holding companies into separate transit and utility corporations. Today, our public utilities remain profitable in private hands, while the public transport sector is unprofitable in public hands. There were obvious synergies between the transport and utility sectors, including the generation and distribution of electric energy for streetcars. Of specific interest to this research is in the common sharing of rights-of-way for utility and rail transit.

Relationship of Railroad Reunification and Reform on Track Sharing

Of key importance, under the German reorganization act, DB Rail was now required to provide open access to third-party operators (including DB Cargo and DB Bahn), who bid to provide services and occupy tracks on the Nets' infrastructure. DB Nets would receive fees from these "tenant" operators to pay for maintenance in return for the use of the infrastructure. Explicit in this arrangement was open access to all qualified rail operators, including rail transit entities. What this means for track sharing is that transit agencies, such as KVV in Karlsruhe, who wished to extend their systems out to suburban areas where growth was occurring could now obtain the use of these tracks for a fee. This was far more feasible and economical than the expense of purchasing and developing a completely new right-of-way. A major institutional barrier to track sharing had been overcome, but other requirements still imposed burdens on rail transit operators wanting access to the national railroad system tracks.

Federal Studies on Mixed Use

In the same time frame that the national railway was being privatized and opened up to other operators, the German Ministry of Railways sponsored a major study ("The Basic Study") of the use of LRVs in mixed service with regular railway vehicles. This study examined the demonstration projects and experience in Karlsruhe, which dated back to the mid-1980s, and laid the foundation for subsequent joint use projects in Karlsruhe, Cologne, and Dueren. As a supplement to that study, the Ministry contracted for a Risk Analysis Study, which used "expert" analysis to deal with the risk-related issues of mixed use. This analysis was issued in February 1995 and was key to the development of a national policy for regulating joint use (Phraner et al., Ch. 7, p. 3).

Transport Ministry Policy on Special Conditions for Mixed Use

The previously described study was closely followed by a Transport Ministry Policy statement on "Special Conditions for the Operation of Light Rail Vehicles (LRV) in mixed service with Standard Vehicles of the Railways of Public Transportation." This milestone policy, issued in April 1995, detailed the vehicle requirements, right-of-way requirements, operational considerations, and possible exceptions involved in mixed use operations (Phraner et al., p. M-1).

In Germany, two sets of federal regulations govern rail transportation. The "German Federal Regulations Governing the Construction and Operation of Railways (EBO)" covers the railroad system, while the "German Federal Regulations on the Construction and Operation of Light Rail Transit Systems (BOStrab)" governs local rail transit systems. Effectively, what the new ministry policy implemented was a requirement that LRVs on shared use tracks meet the requirements of both the EBO and the BOStrab regulations (VDV Meeting, June 19). Of key importance was the requirement that the light rail vehicle must have a "train-influencing system" that can automatically bring the vehicle to a stop if operating speed exceeds safe conditions. That system, called INDUSI, is described in detail below.

For those situations where the LRV cannot be made compliant with the requirements of EBO, the regulations will allow a new system to be implemented if "comparable safety" can be shown to exist. Measures that the regulators have accepted as having characteristics of "comparable safety" include (a) improved braking capability, (b) improved acceleration, (c) speed restrictions on the LRV, (d) freight trains sharing the tracks, and (e) vehicle design elements that focus on occupant protection through collision force absorption rather than through high buffing strength (Martin Karr Meeting, June 24).

Federal Act on Regionalization of Public Transport (Regionalization Act)

In 1996, the federal government enacted another public law, which, again, created an inducement for shared use, and also affected public transport funding. The Federal Act on Regionalization of Public Transport transferred nearly all functions and financing for public transport, including regional rail service, to the states. The funding transferred was the tax on oil previously assessed under the GVFG. Many of the German states, in turn, established regional transport associations to administer these responsibilities (VDV, pp. 33-35; Keudel, 1998.).

The study mission met with officials of one of these transport associations, the Verkehrsverbund Rhein-Ruhr (VRR), in the state of North Rhine-Westphalia. VRR is one of nine public transport associations created in that state. Among their duties are to decide on medium- and long-term local transport plans, to coordinate planning with adjoining associations, and to enter into agreements with operators for service provision. They also integrate fare structures and marketing, set design standards for public information, and set standards for headways and hours of service among the carriers in the region (VRR Meeting of June 21).

Thus, under the Regionalization Act, a considerable amount of the responsibility to design and implement services was placed under an association with a regional service coordination perspective. This responsibility includes the authority to put regional rail services out to bid. While under the previous system, DB Rail operated all regional rail services, VRR can now put those services out to bid to potentially obtain lower costs through competition and privatization. DB Rail has become an operator, which must compete with other companies for the operation of these services. This dovetailed with the "open access" changes granted by the Railway Reorganization Act, and also created the opportunity for cost-effective LRV services using shared track concepts to supplant the former, high-cost, locomotive-hauled train consist regional rail service.

Europewide Deregulation/Privatization

One final institutional change that may influence track sharing is the new regulations being promulgated by the EU, which provide that all local public transport systems will eventually need to offer for bid any routes that have an operating deficit (VRR Brochure, p. 15; also, Kassel Meeting, June 22). In addition, all public utilities will likewise need to be offered out for bid. While this may encourage track sharing with new bidders for open access to track space, it also may separate profitable public utilities from their deficit sister transit organizations. This change will threaten the existence of the Stadtwerke and may result in its demise, along with its advantages of coordinating transport and utility planning within urban areas. This condition would replicate the similar separation of utilities and transit in 1935 in the United States as described above. While the 1935 Public Utilities Holding Act was antitrust motivated, the comparable German separation appears to be motivated by economics.

This major change was a common theme mentioned by all of the host properties visited by the study mission, and it has these agencies concerned. As described above, many of the local public transport operations are part of larger municipal holding companies, which also operate power, water, and other utilities. These utilities have typically made a profit in the past, and that profit has been used to help cover the operating deficits of the public transit operators. These "cross subsidies," as they are referred to, could evaporate if all utilities and services are put out to bid and profits are retained by the private companies who won the bids. How the transit deficit will be covered, absent the cross subsidies, is not known. More subtle and potentially damaging would be the dismantling of the now unified management, policy, and planning under the holding company leadership.

For example, at the Cologne KVB system, officials there told the mission team that their funding for operations is 65 percent from the farebox and 35 percent from public utility cross subsidies (KVB Meeting, June 20). The Kassel transit system also relies on cross subsidies for operations since its farebox recovery is only 50 percent (KVG Meeting, June 22). Kassel officials were particularly concerned about this, as they indicated that the salaries for operators are 40 percent higher than for private companies. They will face the need to rebid when their current concession from the state ends next year. Labor concessions will likely be necessary to help prevent local operations like these from being challenged by private companies. This dilemma varies in severity from city to city. In Strasbourg, it is not a problem, as the tram farebox recovery there is 128 percent. This profit is sufficient to cross subsidize their local buses that operate at an impressive 82 percent recovery rate. It's no wonder that Strasbourg officials want to increase the tram mode split in the central business district from 33 to 70 percent.

Aside from the possible effect on all public transport finances that these new regulations will have, it would appear that shared use might get a further boost. With the favorable economics of LRVs versus heavy railroad equipment on regional services, competition and bidding would appear to favor the LRT shared use operator. Accordingly, DB-Bahn (the railroad operator), in order to compete, is adopting cost-effective DMU, LRV rolling stock, and more rail transit labor practices. And, of course, the cost of extending service to new areas is far more economical using existing rights-of-way or public thoroughfares (buses) than in acquiring or building new ones. Although a matter of debate among professionals, the perception of buses on public thoroughfares being cheaper to operate than light rail on exclusive rights-of-way might cause a shift in preference by operators to the bus mode. This happened in the United States following the mid-1930s rise in operating costs. The study mission participants shared this concern over the future of rail transit and public transit in Germany, facing this major institutional change with its financial implications

Political Leadership:A Determining Factor in the Ability of Cities Building Rail Transit

Regulation, institutional reform, and policy aside, without strong local leadership, rail transit new starts have an uncertain prognosis, even in Germany. All of the transit officials addressing the study mission emphasized the role of political leadership in the successful implementation of their new rail transit systems. Dr. Walter Keudel, CEO of the *Saarbahn+Bus* system, noted that while professionals often take the blame for failure, "there are many fathers of success." He stressed that "at the beginning of a project there must be nearly unanimous support because there are many problems along the way (that may erode that support)." Officials in Dortmund commented that "technical solutions are not enough—we need to have entrepreneurial partners and leaders who are willing to take risks." The role of a local champion was reiterated as also key to success. In Karlsruhe, the mayor and KVV chief executive (Dr. Dieter Ludwig) collaborated to meet the challenges of working with the German Federal Railway and to resolve the myriad of technical and operational issues in this pioneer track-sharing operation. On user-friendly track sharing and integrated services, Dr. Ludwig commented, "You don't need to know who owns the roads to drive a car—how can we expect people to use transit if they can't do it just as easily?"

Not all the study mission visits were success stories. A recent dramatic change in political leadership in Luxembourg caused a major setback for that city's planned light rail system. As yet another city that dismantled its tram system in the 1960s, Luxembourg City (pop. 80,000) initiated planning on a new regional "tram-train" system in the mid-1990s. An unusual combination of city and national elections at the same time in the fall of 1999 brought not only a new political party to power, but also a new mayor who objected to the plan to bring light rail into the city center. The project was officially put on hold earlier this year and local transit needs in Luxembourg City continue to be served primarily by municipal and regional bus systems.

European transit officials also stressed the importance of providing community leaders, labor unions, and the general public visual examples of the kind of transit system that is being planned. Normal human resistance to change, noted Strasbourg tram project director Georges Muller, can often be mitigated by experiencing or visualizing a new proposal. "Lots of people were against the project because they couldn't imagine how it would be." Transit officials in Strasbourg used computer-generated photo simulations to communicate system characteristics to elected officials and other stakeholders. Mr. Muller contended that during the project-planning stages, he was "taking bus drivers and community leaders every week to see success demonstrated on the new tram systems in nearby cities."

Local political leadership is also essential to secure the financial commitments needed to construct new or enhanced transit projects. Similar to the United States, albeit with greater federal fuel tax revenues, the German systems of cost sharing for transportation projects require a combination of federal, state, regional, municipal, and local town funding sources, in some cases based on mandated federal or regional formulas. For example, in most regions, outlying towns must pay a set share of both the capital and operating cost of establishing a tram stop in their area. Once a tram line is operational, this approach may be an easier sell to the local council, but early commitments toward new systems can require substantial risk-taking by local officials.

Finally, while it is generally the job of transportation professionals to conceptualize and design a potentially successful transit system, the burden of cheerleading a long-range project, particularly one with shared track, inevitably falls on the shoulders of local elected officials. "More than any other public investments, transport projects are publicly discussed at all social levels. Political representatives are particularly sensitive when transport projects are controversial," notes Alain Groff, former director of the Luxembourg transit development program. He adds that planners can help elected leaders advocate worthwhile projects by ensuring adequate public education and information, by working closely with land use planners and other agency officials, and by not becoming too complacent about high public opinion ratings.

DESIGN

Designing for Electric and "Wireless" (DMU) LRV Safety on Shared Track

Prudent innovation is reflected in the German design of both infrastructure and rail cars. A uniform and proven train protection system (INDUSI) described below and stringent operating rules reduce probabilities of accidents. These values are shared in North America. The study mission participants are mindful of the obstacles associated with direct transfer of technology and design concepts from Germany to the United States. These obstacles existed in Germany when the shared track concepts were in their formative stages. Some of the specific measures in car design and the track structure are detailed in this digest to illustrate the *types* of measures that could be applied in North America. An application strategy thereby examines a wide range of remedies that German planners, operators, regulators, and designers used to overcome the common obstacles to shared track found on both sides of the Atlantic Ocean. All measures may not apply, but the techniques developed to find the most applicable measures provide sound experience for North American application.

Some of the rationale for track sharing was discussed above. These include urban growth into the suburbs, growth in demand for medium-length trips, gaining higher market shares for public transport, maximizing the rail infrastructure investment, managing environmental and political constraints, and advancing sustainable life style. These values can translate into rail car design and passenger safety.

Rail Car Design and Safety

The study mission noted some philosophical differences between U.S. and European regulators when assessing and treating safety issues. This difference in approach is translated into rail car design. In any comparison of domestic and European rail car safety, three terms require definition. *Crashworthiness* is the ability of a rail car to survive a crash intact or nearly intact and minimize injury to occupants. *Crash avoidance* is the ability of a rail system to avoid the crash in the first place, through use of advanced braking and signaling technologies. *Crash attenuation* is the ability of a rail car to deform gradually and in a designed sequence, to absorb the energy of a crash into the car shell and to protect its occupants. There are well-known automotive equivalents in crash attenuation research. How are these differences reflected in terms of contrasting national policies here and abroad?

A substantial difference between the United States and Germany (and the EU to the extent they are standardizing vehicle safety regulations) is in the philosophy toward train collisions. U.S. FRA regulations presume a crash is likely to occur and demand vehicle strength to maintain car body integrity and maximize occupant survivability. The German philosophy presumes that accidents can be avoided and sets about to devise means of supporting that presumption. Accidents do happen and therefore, in Germany, an equally compelling desire exists to ensure passenger survivability and minimize injury in a rail accident. The German approach, however, is characterized by improved signaling and braking systems to avoid crashes in the first place, and by vehicle design standards that absorb the energy of a crash, in the event one takes place.

There is in Germany a strong ethic to ensure passenger survivability and minimize injury in a rail accident. Emphasis in the German standards is placed on performance and redundancy of braking systems, translating into reduced stopping distance to avert accidents. German research at KVV examined one thousand accident reports on train collisions and determined that conventional trains could not stop fast enough to avoid harmful collision impact. Dr. Ludwig of KVV stated that 80 percent of such accidents demonstrated insufficient stopping distance for the rail equipment involved. This reduced stopping distance also places a demand for lighter designed cars on German car builders. The German car transit builder/operator sector states, “Light rail and tram vehicles are still too heavy in comparison with buses” (VDV). In contrast, the requirement for car body integrity and strength on U.S. rail cars demands that the car designer increase the weight of the car, thereby unintentionally increasing the stopping distance especially on single-track segments. Even modest crumple zones designed into passenger rail cars allow light car structures to absorb (without permanent car body deformation in the 5 to 7 km/h range according to VDV) impact while protecting passengers, but such designs can be penetrated. Heavier, impervious car structures prevent penetration and telescoping of car bodies, but degrade performance.

The data in Table 3 are derived from the VDV Cologne briefing and other VDV sources. The data summarize dimensions and other performance contrasts among typical examples of rail car design extremes. Consider that the LRV type must be designed to operate in both the tram and railroad operating environments and note how the specifications prohibit railroad and trams to operate on each other’s tracks. Consider also the disparity in performance, size, and weight between these rail car types. Weights are shown for both U.S. electric multiple unit (EMU) rail cars and diesel-electric locomotive in common use on North American commuter and freight railroads. Dimensions are shown in a range and are typical of the various car types.

Meeting with VDV officials in Cologne early in the tour, the study mission determined that German rail operators and regulators demonstrated no less zeal than their American counterparts, in achieving increased safety. German regulations on rail car design may be different than the U.S. standard, but they are equal to or exceed the stringency and sophistication of domestic regulations as summarized below.

In summary, German and U.S. regulations have the same goal of safety. They share objectives of passenger and crew survivability. Their approaches diverge resulting in contrasting rail car features and performance designed for two different operating environments. Swap these different car designs between contrasting operating environments or run cars of different types in the same environment and greater risk is likely to occur. Alter the environment and the risks can be mitigated.

Vehicle Design Guidelines

The BOStrab provides the general guidelines needed by any entity operating or proposing to operate a local streetcar system. There is nothing quite comparable in the U.S. rail transit, at least at the federal level. The regulations provide a combination of specific requirements, such as the following, regarding vehicle dimensions and operating prohibitions:

TABLE 3 Contrasts in rolling stock

	Articulated Streetcar Tram/*Strassenbahn*	LRV *S-bahn*	Railroad *Eisenbahn*
Min. turning radius	<25 m (82’)	25 m (82’)	180 m (590’)
Min. width	2.2 m (7.2’)	2.65 m (8.7’)	3.29 m (10.8’)
Approximate weight	35 tons	50 tons	60 t. (EMU) 130 t.(GP-40)
Floor height	<350 mm (<14”) “low”	350-600 mm (14-24”) “medium”	650-1,000 mm (26-40”) “high”
Buffing strength	200-600 kN (45-135k lbs.)	1500 kN (337k lbs.)	>3560 kN (800k lbs.)
Operating mode	line of sight	signals/train control	signals/train control
Stopping distance	70 m (230’)	>70 m (230’)	700m (2,300’)

Part 5 - Vehicles

§ 34 Vehicle Dimensions

(3) Vehicles required to run on track located in the public highway may not exceed the following dimensions.

a. Width: (a) up to 3400 mm above rail level 2650 mm

(b) above 3400 mm above rail level 2250 mm

Indicator and marker lights, rear view mirrors, open doors, and retractable footsteps in the extended position do not need to be included in the vehicle width.

b. Height: The maximum height above rail level to the top of the pantograph in the lowered position must not exceed 4000 mm.

Conversely, some of the regulations can be considered guidelines, leaving it to the equipment purchasers and manufacturers to properly interpret the requirement:

§ 33 Vehicle Design

(4) Windows and similar glass, must have properties as least as good as Safety glass *(using the term as generally understood)*.

(5) Windows of passenger compartments must be so designed that passengers cannot lean out.

With respect to the railroad regulations, Eisenbahn-Bau- und Betriebsordnung or EBO regulations are also issued by the German Ministry of Transport and cover similar requirements as those in BOStrab, except that they are applied to railroads.

While both EBO and BOStrab regulations have the same objective—to provide safe, uniform operation—they vary with each other in specific requirements. In establishing new regulations on shared track, federal regulators reviewed both to achieve the best combination of both rules. Discussions among Ministry of Transport officials, Deutsche Bahn AG (DBAG), and local undertakings resulted in a set of mixed use regulations that were formalized by the German Regulators of Joint Use and issued by the Ministry on April 24, 1995. It is titled "Special Conditions for the Operation of Light Rail Vehicles (LRV) in Mixed Service with Standard Vehicles of the Railways of Public Transportation" and outlines vehicle conditions, way conditions, and operational conditions. Railroad and light rail regulations in Germany were therefore reconciled.

Federal Risk Assessments Used to Formulate Rail Car Design Regulations for Shared Track

In the process of defining German policy on shared use of track or "special conditions," accident analyses and risk assessments were conducted to ascertain whether or not track sharing was likely to be safe. The same problems were encountered in Europe that would be encountered in the United States in such an accident analysis—a dearth of accident data and almost complete lack of data involving rail vehicles of vastly different sizes and weights. To compensate, in the initial European studies, surrogate information was used. This approach is not uncommon in risk assessments where data are unavailable or suspect. Researchers analyzed existing accident data and reconstructed the accidents as if LRVs had been involved. They then estimated the damages from the reconstruction. As might be expected, the lighter vehicles did not fare well. That information was then used to develop standards for vehicle strength, braking, and signaling systems that could reliably avoid the accidents in the first place. Lighter vehicles can stop much faster than heavier vehicles, so braking requirements were strengthened on heavy rail vehicles and speed limits for the heavier trains were imposed where necessary.

In Germany, heavy and LRVs have separate federal safety and infrastructure standards. If an LRV (tram/streetcar or DMU) goes on the heavy rail line, it must comply with both sets of standards. If an operating entity believes it cannot or should not be required to meet a specified safety standard, it must propose an alternative that produces at least *equivalent* safety results. It is the result of that analysis that is used to render an exception or waiver, not how it is achieved. This practical concept at work is demonstrated by the Dueren and Zwickau successful efforts to get the noncompliant Regio-Sprinter DMU certified for running on shared track.

Some physical compatibility standards are common in North America and Germany. Among these are the issues of wheel and flange profile, turning radius, traction power types and sources, level boarding, and clearance envelopes.

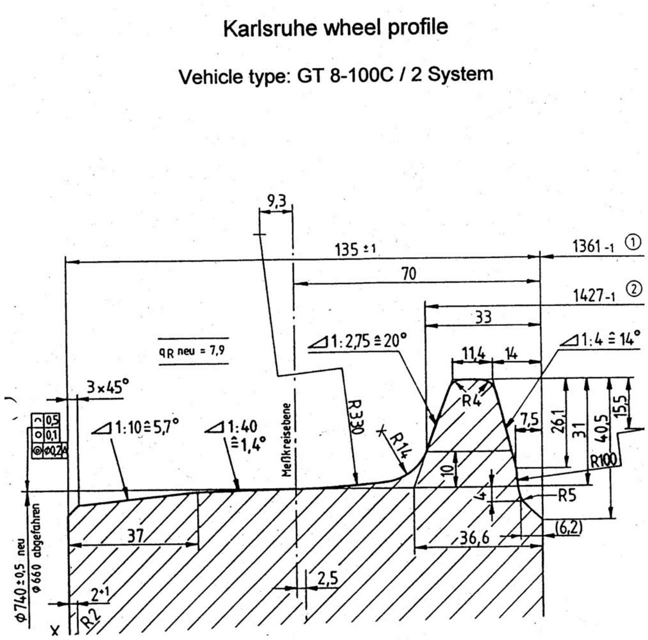
Rail Car Wheel Profile and Turning Radius

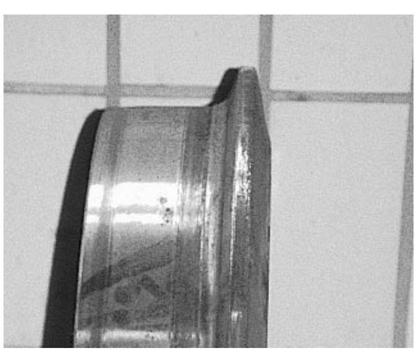
For those German S-bahn systems where the LRV would operate on an *existing* local tram system as well as regional railways, a compromise wheel profile was necessary. The larger flange and wheel tread width on the standard railroad wheel profile is not compatible with the tight curves and grooved or girder rail of a city tram track. Tram wheel treads are 18 cm wide and railroad treads are 30 cm. Karlsruhe, because it was overlaying light rail on both tram and railroad track had to develop a special wheel profile in which the flange's outside edge is tapered to be compatible with both rail systems (Karlsruhe Meeting, June 23). With this compromise, Karlsruhe was required to accept restrictions on the use of their LRVs on some DB tracks (Phraner, 2000).

Saarbruecken, by contrast, designed its all-new system using railroad track and railroad wheels and flange profiles. There was no need to compromise with a hybrid profile that would have been necessary with evolving from a tram-only system to an LRT, tram, and railway system. The advantage of this approach is that the Saarbahn can operate its LRVs on any DB Rail tracks without any restrictions or regulatory waivers. This flexibility enables it to respond to demands for seasonal or special-event rail services at remote locations on rail lines. However, the wider flangeway groove on street trackage is a greater hazard for pedestrians and bicyclists (Phraner, 2000). Figures 1, 2, and 3 illustrate some of these issues.

Turning radius is particularly critical for light DMUs. Few of the current generation of light DMUs in Germany can negotiate streetcar radius track curvature. Beside wheel diameter and profile, those DMUs with diesel mechanical or hydraulic drives do not have sufficient drive train flexibility to accommodate the pivot of a LRV truck through a tight radius streetcar curve. Those DMU models equipped with electric transmissions have more flexibility, yet only a few models can negotiate down to a 130-ft radius. This was a major consideration in NJ Transit selecting a DMU model for its Trenton Camden diesel light rail service.

Electric light rail cars do not have this problem because the transmission of power to the truck is typically through wire motor leads that can easily flex as rail cars negotiate streetcar curvatures (see Table 3). The most curvature-compliant articulated diesel-electric DMUs have a minimum radius of approximately 130 ft. Articulated electric LRVs can handle about 80 ft. Articulated electric streetcar's minimum radius is typically around 60 to 70 ft, while non-articulated streetcars such as a conventional PCC can negotiate around a 40-ft track radius.





Figures 1 and 2. Karlsruhe special wheel profile with flange modified to be compatible with street rail and railway operation. Picture of wheel at bottom is from Karlsruhe maintenance shop.

Figure 3. End view of new rail being installed at Saarbahn line extension in Saarbrucken. Note deep flangeway, which accommodates standard railroad wheel flange.

Level Boarding: Rail Car Floors and Station Platforms

A critical design consideration in shared use systems is the relationship between the rail car floor and the platform, both in terms of height and in terms of the lateral gap between the vehicle and platform edges. These concerns are further complicated by varying platform heights that may exist on one line in the city versus the regional railway platforms, and the desire to have level boarding, where possible, to facilitate access by persons in wheelchairs, strollers, and passengers with other disabilities.

Most of the cities visited by the study mission had deployed vehicles with 70 percent or more low-floor sections. In the city portions of the lines, level boarding was often achieved with low-floor cars mating with low platforms. On the regional railroad shared track portions of the routes, use of a telescoping step mounted at door thresholds on the side of the vehicle resulted in level boarding or reduced step height to enter the vehicle. Karlsruhe, however, uses a medium-floor height vehicle, with a retractable step with two height levels, in order to accommodate the varying platform heights encountered in the system (see Figure 4).

Platform car floor gap is seldom a problem where light rail cars and trams share the same track. Where larger dimension freight cars and locomotives use the same track as LRVs, lateral distance between car floor and station platform is problematic. Three remedies were observed during the study tour. In the city portions of the lines, many of the systems visited provided level boarding with no gap, and thus no further design accommodation required. However, on the railways, EBO clearance requirements mandate a minimum gap between the vehicle and the platform for passenger safety. In Kassel, this gap was reduced through use of a secondary "gauntlet track" set, which places the vehicle closer to the passenger platform. Automated track switches are designed to place LRVs, but not freight trains, on the inner pair of gauntlet tracks so that a sufficient lateral clearance is maintained for the freight trains while the gap for passengers to cross meets standards. Gap fillers or platform extenders are used also used in Kassel. Bridge plates were used in a few cases as observed at the low-floor DMU shared track operation at Dueren. Saarbruecken and Karlsruhe employed telescoping steps on the outside of the car body to close the gap as well as provide the height adjustment for access. (See Figures 5, 6, and 7.)

Of particular note is that none of the rail transit properties visited met U.S. Americans with Disabilities Act (ADA) requirements strictly. According to the German Municipal Financing Act (GVFG), capital investments can be subsidized only if they "take account of the needs of disabled people, the elderly and other persons with impaired mobility" (VDV, *Stadtbahn in Deutschland*). It is not clear, however, who determines the standards for fulfillment of this provision of the act. ADA-type specifications relating to platform/vehicle gaps, edge texturing, and other treatments were not apparent, yet there appeared to be a conscious effort as a matter of sound business and social consciousness to provide for disabled passengers on public transport. Standards for rail car and station design developed by VDV and the transport ministry are applied for general "user-friendly" purposes, which includes elderly and disabled passengers. Two observations reinforce this point. Numerous mobility-challenged people were noted using the systems with ease, and low-floor cars enabling level boarding originated in Europe and are concentrated in widespread use there**.**

Other Rail Car Design Considerations for Track Sharing

German streetcar traction voltages run between 600 v DC and 760 v DC. Railroad traction currents in Germany are standard at 15 kv AC. Other western European railroad voltages most commonly are 750 v DC, 1500v dc, 25kv AC. This presents a challenge to sharing track, but it is a dilemma that has already been addressed and resolved with dual- and

Figure 4. Karlsruhe LRV with two-height retractable steps deployed at higher level for high platforms.

Figure 5. Picture from Duren brochure shows use of deployable wheelchair ramp.

Figure 6. Kassel LRV stops at platform with highlighted extensions to bridge car-platform gap. Extensions are stationary. Paint treatment is to highlight safety awareness. Cars have deployable ramps for wheelchair access.

Figure 7. "Gauntlet track" system at a station on Baunatal shared-use railway line in Kassel. Automated equipment with entered codes aboard the LRV signals the switches to select the tracks nearest the platform.

triple-voltage railroad rolling stock crossing international borders. EU will promote continuance of multiple voltage equipment, and it is, therefore, technically realistic to apply it to equipment that shares tracks and overhead catenary traction currents. This is a nonissue in North America, where electric traction on railroads is a rarity. The DMU or dual power (electric and internal combustion) becomes the equivalent way of powering a rail car that must operate under streetcar wire and independently with on-board generated power when on railroad track.

Radio equipment and communications protocols also have to be resolved for cars that will migrate between different rail, power, and signal systems.

Wireless Light Rail DMU and Shared Track Potentials in Smaller North American Cities

Perhaps the most exciting and least anticipated finding by the study mission was the widespread use and application of DMU technology in Germany. In addition to many railroad DMUs, over 1,200 modern light rail-type DMU units operate in Germany, Switzerland, and France. In contrast, about two dozen rail diesel cars or RDCs remain in service in the United States. The mission's DMU findings provided the most dramatic motivation and easiest to implement potentials for direct application of German track-sharing ideas to North America. The itinerary of the study mission included Dueren because of its innovative use of DMUs in a "wireless" light rail S-bahn-type service over low-density railroad branch lines. DMUs are used extensively elsewhere in Europe on conventional railroad lines in substitution for locomotive-hauled consists on lighter density regional services. The study mission also observed consists of DMUs in commuter service in Cologne's main train station (hauptbahnhof).

Most contemporary DMUs offered by rail car builders in Germany are compliant with EBO or railroad standards. But they meet less than half of U.S. buffing strength requirements measured in longitudinal pounds of effort against the coupler. Two different model DMUs are being imported to North America for use by NJ Transit in Trenton and by O-Train in Ottawa, Canada. The ease of DMU assimilation into the North American railroad environment was verified in the nearly 2-year demonstration tour of the Siemens Regio-Sprinter light weight DMU in the United States and in Canada. Over a dozen metro areas and demonstration venues were visited by this car (see Figure 8). FRA granted a temporary waiver (with Amtrak-supervised safety conditions) to enable the tour.

Dueren (pop. 90,000) provides an appropriate model of DMU application on shared track because of its striking similarities to small, formerly industrialized cities and regions in the United States in quest of new economic stimulus. Dueren's parallels with some U.S. cities was most apparent. Dueren had eliminated its obsolete streetcar system earlier. Its local railroad service was failing. The major railroad demonstrated little interest in Dueren's nonelectrified branch line operations and therefore sought its discontinuance. Dueren's economy was changing.

In response to these common afflictions of smaller German (and U.S.) cities and counties, Dueren created a countywide improvement authority to preserve and operate essential public services including rail branch line operation (and therefore jobs in wayside industries). Bus service had already been absorbed and integrated at the county level by the authority. Dueren's similarity with U.S. counterparts diverged when it entered the rail passenger business. A rail passenger operating entity (Duerener Kreisebahn or DKB) was formed as part of the county bus system. Initially rail buses or "schienenbus" were used to provide modest service over the two nonelectrified railroad branch lines. Later, modern Siemens "Regio-Sprinter" cars replaced the schienenbus. One of these Regio-Sprinters, now in Dueren, was used on a demonstration tour of the United States and Canada in 1997-1998. These low-floor cars were ridden by the study mission and their features demonstrated during the mission's visit to Dueren. The introduction to DKB of these light rail-derived, low-floor, bus-engined rail cars was deferred until the German federal regulatory authorities

Figure 8. Joint bus and tram maintenance facility in Duren.

(BMVBW) completed the risk analysis of the "Special Conditions" Study" described above. The risk analysis was a key element in justifying the certification of these noncompliant (even in Germany) cars in mixed use.

The Special Conditions study specifically treated Dueren's operating circumstances on the two branch lines and where they connected, using a short segment of the busy DB main line between Cologne and Brussels. Working with the DMU builder and the education/research community, the rail transit operator proved equivalent safety. These DMU cars were certified by virtue of collision risk reduction, enabled by their enhanced stopping distances and redundant braking systems. Specific speed restrictions and other limitations were imposed as conditions to the DMUs certification. The speed limit in the certification was determined by tests and research confirming DMU stopping distances under various conditions and speeds. This was a renaissance, even for rail-wise Germany. How did it happen and what role can DMU technology play in support of other low-density rail transit applications?

Planning Aspects of Light Rail DMUs on Railroad Track

As a part of this renaissance story, this section of the digest highlights key planning characteristics of new rail transit systems in the small- and medium-sized European cities of Dueren, Saarbruecken, and Strasbourg, and how DMU and LRV technology combined with track sharing helped achieve their local mobility objectives. All of the cities visited, except Cologne, are near or below 300,000 in population. All have modern rail transit. The smallest and lowest density cities in Germany depend on wireless LRVs or DMU rail cars. Since DMUs have become the vehicle of choice on local railroad branch line services, they reach even the smallest municipalities. Accordingly, their applicability in marginal North American rail passenger markets is worth examining.

The special needs of smaller urban areas (under 300,000 in population) inspired the development of a new kind of rail vehicle in Germany in the early 1990s—a low-floor, nonelectrified light rail-type vehicle (or DMU). This type car was adaptable to diverse operating environments. It could run on standard gauge (and meter gauge) rail lines. These modern DMU vehicles were derived from earlier rail bus and light rail technology in common use throughout Europe. These cars appear to be modern light rail vehicles, except without the overhead contact wire or catenary. Designed for use on existing but underutilized and nonelectrified rail lines, new low-cost, low-maintenance "wireless" rail transit systems are now able to link suburban and rural corridors with reviving smaller city centers.

Some lesser-known advantages of the light DMU were observed by the study mission in Dueren's (DKB) maintenance facility. When the new Regio Sprinter cars were added to the transit system, a new maintenance facility just for the DMUs was thought to be too expensive. Instead, DKB retrofitted its modern bus maintenance building by adding two rail spurs to accommodate the new DMUs. The DMUs clean dual diesel engines are derived from common bus designs. The rail cars also use bus hydraulic transmissions. Common parts inventory and common labor crafts reduce operating costs, therefore, the cars are maintained by the same mechanics who work on the diesel buses.

The German approach to track sharing is explicitly designed to make more efficient use of existing rail transportation infrastructure in order to serve regional transportation needs. It is reflective of national policy that supports rail transit through gas tax financing and other measures. The rail infrastructure in Europe is extensive and much denser than in the United States. Nevertheless, this general objective—more efficient use of existing transportation resources—is key to recent European innovations in transportation. It is also directly applicable to addressing our severe traffic congestion problems in the United States. The goal of efficient use of existing transportation infrastructure to serve regional transportation needs is applicable, even in small- and medium-sized urban areas. There, suburbanization is less pronounced, sprawl is less prevalent, financial resources are fewer, and there are more potentials to expand transit choices, thereby affecting land use decisions in the shorter term. Of the cities visited by the study mission, the small- and medium-sized cities of Dueren, Saarbruecken, and Strasbourg best exemplify the conditions found in their U.S. counterparts.

Regional Rail Transit Systems Support Community Values

German track-sharing innovations are, among other purposes, designed to focus future development as a valid alternative to the automobile. Transportation officials in Karlsruhe (pop. 270,000), Saarbruecken (pop. 190,000), and Strasbourg (pop. 270,000) each expressed the view that their reinvented rail transit systems can and are inducing more sustainable residential commercial and industrial land use decisions. They also said that their new LRVs have been instrumental in reinvigorating downtowns and in serving recreational and visitor travel. (See Figure 9.)

All of the cities visited, in developing successful rail transit systems, had a clear vision of a more inviting and environmentally stable urban character. In pursuit of that vision, Dr. Walter Keudel, managing director of the new Stadtbahn Saar or "Saarbahn" LRT, and Peter Hackelmann, Saarbruecken city planner, outlined Saarbruecken's transport objectives. Note that the Saarbahn rail initial operating segment was only one in a series of complementary planning objectives. Shared track is not mentioned specifically, but it is important in accomplishing the other objectives on an aggressive schedule. These objectives are detailed below and summarized in bold print:

1. **Reduce private automobile use by 20 percent.** This goal required a two-thirds increase in transit use, which

Figure 9. Strasbourg's city center is reserved for pedestrians and trams.

planners determined could be met only by augmenting the bus system with a new LRT system (buses could only divert about 3 percent of automobile users). Similar to many U.S. towns and cities, Saarbruecken's original meter gauge tram system had been dismantled in the mid-1960s.

2. **Avoid the negative impact of automobiles in the city center.** The Town Plan provided for restricted automobile access to the downtown area by reducing traffic lanes, narrowing streets, adjusting signal timing, and establishing exclusive bus/LRV transit lanes. Parking fees and a system of real time parking information displays were begun. The high number of automobile accidents in the (pre-LRV) city center was another inducement for the automobile reduction program. Under the traffic-calming and transit incentives plan, automobile accidents have been reduced to 10 percent of earlier accident rates.
3. **Promote bicycle use**. In addition to assisting with traffic calming on local residential streets, striped continuous bicycle lanes on major city streets and sidewalks help support and direct bicycle traffic. An enhanced bicycle and pedestrian path along the Saar River also encourages bicycle use and bikes are allowed on the Saarbahn LRVs. Local university students are a particularly active bicycle market. Saarbahn trains now pass near the university and future extension of the rail system will directly serve the university.
4. **Upgrade public transportation by constructing a new LRT line,** in order to significantly increase transit ridership, support the downtown city center, serve the outlying region, and to promote European Union seamless border principles. The SaarBahn+Bus system links a new city center pedestrian precinct with outlying neighborhoods and extends south into the small city of Sarreguemines in France. The new tram line uses the old German regional railroad line south of the city, and new line was built to connect with the downtown. The line is also designed to promote transit to seasonal recreation venues like the regional fair grounds. Rail use has exceeded projections because "rail effectively draws people from their cars," according to Hackelmann.
5. **Support pedestrian-oriented urban design, which works together with the transit system**. Traffic-calming measures in Saarbruecken allow for widened sidewalks, outdoor seating, and easier pedestrian travel. The main downtown area has been transformed into a pedestrian-only zone with large plazas. Townhouse-density housing together with mixed use neighborhood commercial areas along transit corridors help to create pedestrian- and bicycle-friendly neighborhoods.

Mission participants were assured by host officials that achieving these city objectives did not happen quickly. "Quickly" however, may be a relative term. The Saarbahn LRT initial operating segment of 19 km was completed in less than 6 years (Feb.'92-Oct.'97) from planning authorization to the first turn of an LRV wheel. The comparable gestation period for contemporary North American LRT takes twice to three times that. It became apparent to the study mission that perseverance is essential to advance innovative light rail projects, even those embodying shared track. It also took a consistent leadership effort to maintain the momentum and the vision to finance and carry out the city plan for a major investment in rail transit. None of the planning objectives above and criteria listed below for LRT are startling or innovative. These objectives mirror current environmentally focused planning efforts in the United States. All shared track transit operators embraced these types of objectives. While it may seem that the objectives above and the criteria below are irrespective of track sharing, the mission found a strong urban planning element embedded within shared track initiatives.

Criteria for Determining Suitability for Rail Transit on Shared Track

Inspiration for a number of the new German LRT systems that use existing railroad track arose when the German

Railways (DB) began to reduce its regional intercity rail service in the 1970s and 80s. In an attempt to contain costly federal subsidies, DB was reorganized, regionalized, and privatized. All three measures helped to introduce track sharing, but did not cause it.

German regionalization of transport in the mid-1990s took two seemingly opposing forms. The nationalized railroad was split and decentralized, as was local funding and control over transit, but the local transit operators now had incentives to form consolidations and cooperative ventures with neighboring transit operations. Both of these regionalization forms, from the top down and the bottom up, nurtured track sharing, each in a different way. Making provincial and regional units of government financially responsible for those portions of the federal rail system in their jurisdiction induced them to seek partners to coordinate services and share costs. The federal subsidies were still present, but locals now had to furnish a matching share

Privatizing and restructuring DB divided its operating and infrastructure functions into separate government-owned businesses, hopefully to achieve profitability and sale to the private sector. The Conrail government intervention and eventual "sale" as an independent private corporation demonstrates a parallel in North America. This led to open access on DB with operators competing for track space. Each operating turf could contract with a private operating company (including DB) to provide service on the former national system. Privatization and reorganization of DB thereby provided the statutory authority for rail transit operators (along with any railroad operator) to use railroad tracks as long as safety and other requirements were fulfilled.

Transit officials in Dortmund noted that regionalization "opened our thinking" and supported a more regional view of transportation and transit development than had been present in the three decades since the demise of many older European tram systems.

More local control and funding required jurisdictions to more carefully consider the criteria under which their rail domains would be structured and operated. These general criteria are described and italicized below, based on observations and dialog with the organizations hosting the study mission during the spring of 2000.

Rail transit systems are not for everyone, even in Europe, and exclusive bus systems can work well in areas with no existing suitable rail lines and relatively low transit ridership. Specific criteria for application of light rail on shared track are summarized with italics below. Planners in Karlsruhe derived the figure of *4,000+ riders/day in an existing bus corridor as a threshold for potentially successful conversion from bus to tram or light rail.* The Dueren (pop. 90,000) Rurtalbahn, as the DKB rail operation is locally known, using light rail derived DMUs, attracted a modest average daily weekday ridership of 3,850 in 1999. This is considered successful for such a small urban area. Consider what factors make this marginal passenger volume worthy. DKB has to maintain its tracks anyway to serve local railroad freight-dependent industries. It would have to provide alternative bus service if the one-person crew DMUs did not exist with labor constituting most of the operating cost. While DKB's weekday volume is slightly lower than Karlsruhe's marginal threshold for rail, Dueren's rail operation is lower density, with less costly DMUs on less capital-intensive, nonelectrified infrastructure. DKB's volume though relatively low has demonstrated consistent growth (see Figure 10). The synergies of these factors for a town of less than 100,000 population surrounded by farms demonstrate potential applications in North American locations where rail transit was thought to be unaffordable, if not impossible.

If an existing active rail line is proposed for shared use by LRVs and other rail users, *local public ownership of the line was identified as desirable* in being able to develop suitable track-sharing arrangements rapidly. While not absolutely essential (nor prevalent) to German track-sharing practice, officials in Saarbruecken and Karlsruhe stated that ownership of the existing rail lines by local transit operators tended to ensure more timely progress on the development of new tram systems. One transit official noted that even though DB is still owned by the federal government, DB "had a problem for every solution" and asserted that the "owner of the track decides the priorities." Thus far, in each of the existing and proposed temporally separated joint track arrangements in the United States, the rail transit operator has acquired ownership of the tracks from a freight railroad.

In each city where use of the existing DB line has been or is currently under consideration, *location and alignment of the existing track* is a key factor in determining its usefulness for rail transit. Existing, and in many cases underused, former nationalized railroad lines are currently being analyzed by many German and other European cities for their potential use as part of modern urban and suburban LRT and bus systems. Planners also consider current freight and passenger train traffic volumes, parallel bus ridership, and the nature and location of existing and projected development.

In the case of cities like Saarbruecken, the existing DB lines were suitable for the outer regional portion of the new Saarbahn. A Saarbahn LRV could traverse the full length of the initial operating segment, entirely on parallel railroad tracks, but it was important to access CBD pedestrian precincts, commerce and shopping areas directly. Therefore, a new, in-street rail segment in the city center was constructed to ensure that the LRT system provided direct and intimate service to the downtown, thus eliminating potentially undesirable transfers. "People are lazy," notes Dr. Dieter Ludwig of Karlsruhe, president of the German national transit association (VDV) and a pioneer in track-sharing innovations. He adds, "The joint use concept grew out of the idea that people should be able to use one transit ticket and take one ride to get from their suburban homes to (and distribute within) the city center." In areas where an existing rail line was available and where existing or planned development was located, this approach was employed. In some suburban

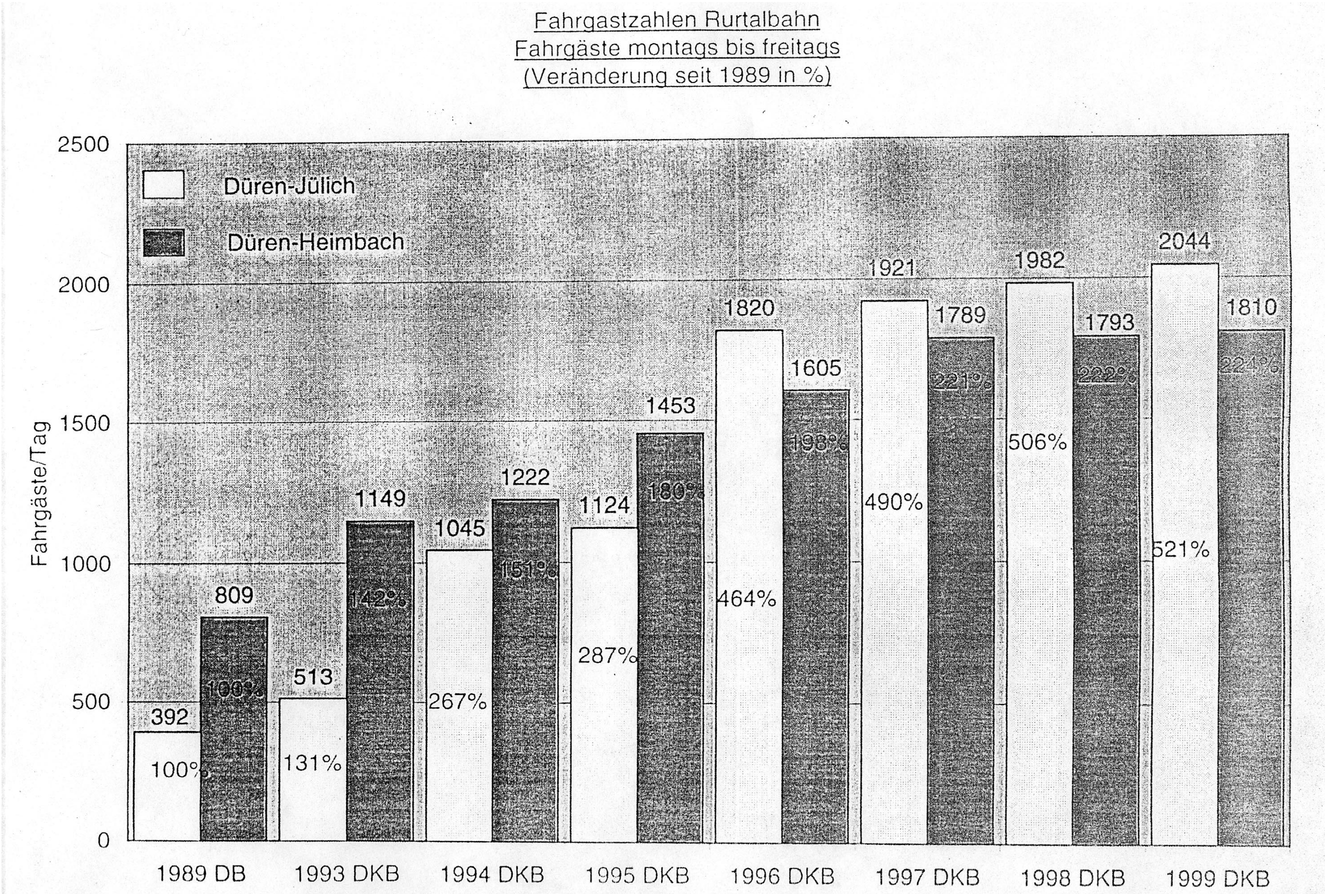


Figure 10. (Duren) Rurtalbahn Weekday Ridership (percent change since 1989)

clusters within the Karlsruhe region, S-bahn tracks were constructed from the railroad alignment into the village center and back out again so that the LRVs would not use the remote railroad alignments strictly. To do so would have bypassed the center of these villages. This approach is being applied elsewhere in city centers, including France.

Strasbourg was one among several notable LRT "new starts" in France and an important visit for the study mission. Its location made it convenient for the study tour access. Like Saarbruecken, Strasbourg is located in the crossroads border region (Alsace) between France and Germany. Unlike Saarbahn's shared track LRT however, Companie des Transportes Strasbourgeoise (CTS) initial operating segment was built as a modern, but otherwise conventional tram line. CTS is now exploring the "tram-train" concept as it seeks to expand outward to meet suburban growth. "Tram-train" is becoming a universal descriptor for "shared track" as exemplified by the Karlsruhe model. Strasbourg's quest for tram-train solutions is not isolated in France. Other quests are currently underway in Mulhouse, St. Etienne, Paris, Nantes, and elsewhere. According to a recent *TR News* article (issue No. 216), over 20 percent of population in France is located in exurbia and that number is growing. As currently planned, French National Railways (SNCF) will play a major role, working with municipal authorities like CTS, in developing the tram-train concept to link those exurban populations with city centers. SNCF has asked a rail car builder to develop up to seven variants of its modular tram-train platform to operate in as many as 15 candidate French cities (*International Ry. Journal*).

Because of more limited resources, application of the cost-effective joint use concept is particularly relevant in smaller urban areas such as Dueren in Germany. For the same financial reason, it is adaptable (with regulatory constraints) in small- and medium-sized U.S. cities as well. In addition to serving the suburban to city center travel market, the Dueren *Rurtalbahn* markets itself as serving the region's highly scenic Ruhr River valley and its attendant recreational uses. Dueren transit officials note the environmental and economic benefits of shifting visitor and sightseeing travel onto transit, and commented that people who have an automobile available to them are more inclined to use the tram for recreational trips than the bus. As one transit official in Strasbourg commented when asked about their high proportion of visitor use of their new tram, "Rail provides the security of a return trip to their starting place. Visitors are not as willing to sacrifice their cars for a less comfortable bus with a complicated route [structure]." Clearly, high-visibility fixed guideway, like LRT, provides a homing device for sightseers and others unfamiliar with the city and its attractions (see Figure 11). This works well now in Strasbourg with its single tram line. The homing instinct is somewhat lost when the tram-train concept multiplies and blends light rail services with a complex network of local railroad branch lines.

Finally, upgrading existing rail lines can be combined with *enhancements such as the adjacent pedestrian and bicycle paths*. Mission participants observed them in some proximate relationship to almost all of the rail lines visited.

While in some locations the paths were fairly informal, many of the pathways had been paved and were explicitly designed for bicycle and pedestrian use. Pedestrian and bicycle grade crossings have been installed to allow for ease of access while also ensuring safety and physical access control. Except in dense urban locations adjacent to local tram routes, the bike and pedestrian ways observed by the mission were not immediately beside the active rail lines without protective fencing. Rail and pedestrians shared an axis or linear open space, or perhaps a common right-of-way, but not a common trackway (see Figures 12 and 13).

System Design Ensures Safe, Satisfied, and Increasing Ridership

Do these new rail transit systems using shared track inspire people to leave their automobiles at home? Transit officials in Cologne estimate that 14 percent of new tram

Figure 11. Strasbourg trams and tracks provide a highly visible "homing device" for sightseers and tourists confused by complex bus routings.

Figures 12 and 13. A wide variety of bicycle and pedestrian pathways run adjacent to urban and rural rail lines (Cologne and Karsruhe).

riders used to be primarily automobile drivers, as compared to 3 percent of bus riders. In Dueren, average weekday transit ridership immediately jumped 38 percent after opening the new Rurtalbahn DMU system on former German Federal Railway lines; 5 years later ridership had increased fivefold on one line and over two times on the other. (Review Figure 10 bar graph.)

Strasbourg, like Saarbruecken and Dueren, had its original tram system dismantled in the 1960s. Bringing back trams increased the mode share for transit from 11 percent in 1989 to 19 percent in 1999. With two additional lines scheduled to open in fall 2001, officials anticipate the transit mode share will increase even further to 25 percent of all trips. In Kassel (pop. 200,000), transit officials touted a 100+ percent increase in transit use over 3 years with the new tram extension on existing railroad tracks. According to officials in Dueren, Saarbruecken and Strasbourg, operational, design and technology characteristics contribute to public support and increased overall transit ridership.

TECHNOLOGY

Technology Applications in Track Sharing

No startling breakthroughs in advanced technology were detected by study mission visits to seven European cities. The mission did find that technology is subtly integrated into state-of-the-art car propulsion and control systems, all encased in a proven, reliable and attractive car shell. German advanced transit technology efforts appear to be directed at incremental improvements to conventional transport modes, like LRT and not trying to invent new ones.

Advanced technology cannot substitute for poor operating discipline. The mission observed a highly disciplined operating forces in transit vehicles, control centers, and other facilities. On a previous study mission, Dr. Dieter Ludwig of VDV and KVV in Karlsruhe expressed German operating discipline and enforcement standards best when queried about S-bahn LRV operators who run red signals on shared track. He silently drew his finger across his throat.

The mission approached *technology and practice* as the two primary means of reducing risk of collisions between trains sharing a common track. Beyond avoiding collisions, practices and technology become tools for mitigating the effects of an unlikely collision. More directly, technology and practice seemed by the study mission participants to be the two areas with the most potential for application to North America. These, therefore, constitute the two last sections in this digest.

Mission participants were impressed with German regulators' and rail carriers' shared confidence in specific train protection measures and signal systems to justifying safe track sharing. Specifically, the INDUSI train protection technology is codified requirement in the regulations governing shared track, in combination with speed restriction practices. The INDUSI requirement therefore became the subject of intense interest by the mission participants. It is treated in somewhat more detail in this report.

INDUSI: An Inducement to Track Sharing

Germany's success in combining light and heavy rail in suburban corridors along with operating this service on city streets was not immediate. Several technical, operating, and institutional issues had to be resolved prior to its implementation. These issues included the different traction voltages, wheel and flange profiles, vehicle crashworthiness, dispatching routines and practices, and infrastructure standards to ensure the safe operation of trains. Once these issues were resolved, it became possible for cities to more effectively usse the available rail rights-of-way to solve their mobility issues.

It became clear after meeting with several successful joint use system operators that at least three technology-related requirements are needed to make track sharing both safe and credible. Stringently enforced operating rules are also required. The operators' message and that of the regulators and oversight agencies was consistent. They are as follows:

1. **Braking performance** and stopping distances for LRVs comparable with those of trams that operate in mixed vehicular traffic. As Dr. Dieter Ludwig of KVV has stated, 80 percent of train collisions are caused by insufficient stopping distance,
2. **Impact-absorbing rail car structures** to protect occupants in the unlikely event of a crash, and
3. **Train control or train protection** systems that override operator error and are proven to avoid accidents. In Germany (at speeds under 90 kph), that train protection system is INDUSI.

Regulating light rail and railroad equipment, operating, construction, and safety requirements was a key challenge to initiate mixed rail services on a common track. In the United States, light rail and so called "heavy rail" or rail rapid transit are nominally regulated by FTA and state safety oversight agencies. There are no detailed federal regulations on individual light rail or rapid transit operations. These are the domain of state safety oversight agencies, as long as joint use is not involved. The FRA regulates railroads. For purposes of redefining federal policy on shared track, FTA and FRA issued a joint policy statement. FRA issued its own more detailed separate statement of policy and supplements to CFR on issuing waivers. In effect, FRA regulates shared track and whoever operates on those rails. Germany has federal regulations for light rail and separate set of regulations for heavy rail, but they are regulated under a common ministry. BOStrab are the regulations governing the construction and operation of light rail transit systems. These regulations were issued on December 11, 1987, and cover operating management, operating staff, operational installations, vehicles, operations, procedural formalities and noncompliances, conclusion and transitional arrangements for light rail undertakings. Light rail systems are defined as either independent (on reserved track) or street running systems.

Joint use systems must meet the BOStrab requirements while operating as light rail and the "Special Conditions" while operating on joint use tracks. There is no national oversight agency similar to the FRA or FTA with respect to direct monitoring compliance of BOStrab, EBO, or Special Conditions requirements. Each German state is responsible for inspections and ensuring compliance with all appropriate regulations. However, these regulations have been approved by the EU and can only be changed with its concurrence. Where guidelines are given, changes cannot be made by each country without EU concurrence.

As outlined in *TCRP Report 52, "Joint Operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads,"* German regulations require that rail vehicles shall be provided with the train protection systems required for all joint use routes. In Germany, separation and intermittent train protection is usually applied to railroads. Wayside control is required in a BOStrab network if they are operating in joint use. If the vehicles mix with vehicular traffic in public streets, then sight distance rules prevail (excepting at major intersections where traffic signals control movements). The report also notes that the German Ministry requires that the train protection system utilized be compatible with the brake technology of the vehicles. The train protection system is key in joint use operations.

The INDUSI system provides the necessary protection to ensure that train to train collisions do not take place. Similar to automatic train control and positive stop systems in use in the United States, the INDUSI system forces a reduction in speed as required by a change in wayside signal indication and prevents a rail vehicle from being operated past a stop signal. The importance of this system is evident in that all light rail trains operating on Germany's "general railway system" tracks must be equipped with it. Any public transit undertaking that wants to operate a mixed use service must ensure that the equipment and the rights-of-way use an INDUSI system.

Each of the light rail systems visited during the study mission used the INDUSI technology with varying levels of sophistication and options ranging from the simplest at the Dürener Kreisbahn, to the more advanced systems in Karlsruhe and Cologne. In each of INDUSI's uses however, the main emphasis is the ability to prevent trains from exceeding prescribed speeds or passing a stop signal.

What Is the INDUSI System?

INDUSI is an acronym derived from Induktive Signalsicherung or Inductive Signal Protection. It is also referred to as Induktive Zugbeeinflussung, while its official name is "Punktweise Zugbeeinflussung," meaning "spotwise train control." There is also second, more sophisticated train control system used on the higher speed (160 kph+) Deutsche Bahn AG (DBAG), Linienzugbeeinflussing (LZB) or linear train control, which is similar to transponder-based positive train stop system currently being installed in several locations in the United States.

Developed by German Reichsbahn in the early 1930s, the INDUSI system is a modestly sophisticated (though not high-tech by today's standards) system. In summary, wayside receiving coupling coils are placed at specific intervals along the railway, the length determined by the operating speed and *stopping distance* required of the user trains. Recall how important a criterion stopping distance performance was in determining the certification of rail cars for sharing track.

Similar inductive devices were used in the first decades of the 20th century on U.S. electric interurban railways. There is nothing mystical or ultra high-tech about protecting train movements on shared track in Germany.

A speed measurement section consists of two of these coils. The signal received by the first coil when the trainborne equipment passes over it, starts an electronic timer, which is programmed for the permissible speed. If the train arrives at the next coil location before the programmed time allowance has elapsed, the system determines that the train is operating at an excessive speed and the brakes are automatically applied. Ignoring signals also produces and automatic emergency stop.

Contrasting INDUSI with LZB and Other Train Protection Systems

The INDUSI system communicates with trains only at certain locations at and between wayside coils, while the LZB system provides a continuous stream of information. The INDUSI system was introduced on the German national railroads at a time when most wayside signals were wire track circuit-operated semaphores. INDUSI is based on magnets/coils, which do not need a power supply; therefore, it is adaptable to a variety of operating environments and applications. The LZB system allow trains to operate at speeds greater than 160 kmh. Trains traveling at faster speeds would not have sufficient time to brake for a stop signal utilizing the INDUSI system. The speed constraints of the INDUSI system happen to coincide well with the capabilities and service requirements of LRVs and DMUs, since most of these cars cannot exceed 100 km/h. INDUSI can also allow for greater track capacity by reducing the distance between signals. It does so by not only showing the status of the next signal on a display in the operating compartment but also by showing signals up to 5 km in advance. The LZB system does not depend on wayside signals. It can, however, be "overlaid" on tracks, which already have the INDUSI system, allowing the use of either technology on the same track. Obviously, these two systems do not interfere with each other's functions. As a result, DBAG trains must, at a minimum, have the INDUSI system while any train operating over 160km/hr must also have the LZB system. LRVs in shared track service need only INDUSI equipment.

As described in detail in *Stadtbahnen in Deutschland*, published for the German Transport Ministry by the respected transit association, Verband Deutscher Verkehrsunternehmen), the INDUSI is an inductive train control system that operates on the resonance feedback principle via two inductively coupled resonant circuits. A change in the current based on the wayside signal activates various operations such as controlling the brakes. Improvements in the system allow for additional functions such as automatic route control and dynamic passenger information. The system can also be used to control speed by installing two transmission devices, usually magnets, as described above. This type of system is different than the automatic train control (ATC) system that is based on track circuits. In ATC, a continuous signal code is fed through the rails and changes as the wayside signal indication changes. Equipment mounted on the outside of the lead car or locomotive picks up the code and translates it into a device in the operating compartment, which alerts the locomotive engineer to the signal change. If the engineer does not reduce the speed of the train in a sufficient period of time, the brakes are automatically applied.

Magnets are placed to the right of the rail in direction of travel at three key locations. The first magnet with a frequency of 1000 Hz is located at the distant signal (the signal prior to the signal where a stop may be required). A 500-Hz magnet is located between the distant and the signal where a stop may be required (known as a home signal). A 2000-Hz magnet is placed at the home signal. The *distance of the 500-Hz magnet is based on the braking rate of the equipment operating over the track*. A magnet is also located on the light rail car, DMU, or locomotive. If the signals have a green or a clear signal indication, the magnets are inactive and the train can proceed at the required speed. However, if the distant signal indicates that the train is to either stop or reduce its speed at the next signal, the magnet is activated thereby activating the magnet on the light rail car. The operator is warned by a light (and sometimes an audible signal) and must press a button to acknowledge the warning within 4 sec or the brakes will be applied. The operator must also reduce the speed of the vehicle. The 500-Hz magnet is a type of safety check to ensure that the operator has reached a prescribed speed. This is monitored by use of a timer as described above. The 2000-Hz magnet located at the home signal will cause an emergency brake application, which will force the vehicle to a stop within a safe area beyond the signal (for example, prior to a crossover).

While the INDUSI system is a key part of the overall German train control system and mandatory for shared track, train-dispatching practice, grade crossing control, and operator training also play major roles. The following is a discussion of both the INDUSI system and other train control practices at each of the shared use properties

Operating Practices of Track Sharing

Of the seven cities visited during the summer of 2000, five had *active* track-sharing systems involving various types of mixed use by light and heavy rail vehicles. As understood by the study mission, the objective of these five cities was to use existing railway lines as a means to rapidly and cost-effectively initiate and extend their light rail systems, as an alternative to developing costly new rights-of-way.

Operating Service Objectives

Beyond that commonality, however, special circumstances in each city dictated individual objectives and design for their systems. Dueren wished to re-institute a flexible and affordable light rail service that could operate in urban and regional environments after having been a bus-only system since 1971 (DKB Meeting, June 19). For Dueren, its choice was light DMU cars on branch line railroads blended with freight service that it also operated. DKB operates no in-street tram-type trackage. Saarbruecken had a similar service improvement objective, but also wanted to address the severe automobile congestion problem that was developing in their downtown. For Saarbahn, their solution required light rail traffic priorities in pavement downtown and various types of railroad operation in its suburbs. Cologne, Kassel, and Karlsruhe all wished to extend their existing light rail systems to outlying regional areas where most of the population growth was occurring. Aggressive use of railroad tracks met the objective of these cities. Karlsruhe, in addition, wished to avoid forcing passengers to transfer between modes at their main train station, which was some distance from downtown. This concept, referred to as "through running," would allow a single vehicle to operate from the downtown city center to outlying regions located on main railway lines (Drechsler, 1991, p. 2).

These varying service objectives, and the regional railway resources available, have resulted in widely varying systems, in terms of size and ownership/access arrangements among the five cities. Dueren's single DMU service uses two existing railway lines purchased from DB Rail after the national railway had abandoned use of them (Dueren Meeting, June 19). Cologne Transit uses two railway lines still owned by DB Rail for extensions of two of its light rail lines, and pays access fees on a train-kilometer basis, as provided for by the railway legislation. It also uses tracks jointly with its sister rail freight operation servicing the Port of Cologne on the Rhine River. Saarbruecken's single light rail line also operates on tracks owned by DB Rail and the French SNCF (Saarbruecken Meeting, June 27). Saarbahn will also use an abandoned DB right-of-way on its north end. Karlsruhe operates portions of their light rail lines on seven different DB rail lines and pays track fees, though outright purchase is being contemplated where feasible (Karlsruhe Meeting, June 23).

Types of Shared Use Activity

Likewise, the type and level of track sharing varies greatly among the five cities. Dueren, Kassel, and Saarbruecken have the dominant use of the tracks for the light rail vehicles, with a very limited level of freight traffic also using the lines. Certain Karlsruhe and Cologne lines have their light rail vehicles sharing the tracks with significant levels of freight trains, as well as regional DB Railway trains. On the line between Karlsruhe and Baden Baden, the observed ratio of LRVs to freight and passenger trains was approximately 8 to 1 (Phraner, Supplement pp. 2.8-2.9). These factors affect the priority of trains versus light rail vehicles. While train priority was not addressed at each of the cities visited, the general rule seems to be that long-distance passenger and Intercity Express (ICE) high-speed trains take top priority, followed by regional DB trains and then LRVs (which often replace heavy rail consists in such services). Freight trains take last priority (Karlsruhe Meeting, June 23).

Operating Safety Reforms and Practices

Of course, safety is the most central issue of track sharing by vehicles of radically different weight and structural strength. In the United States, this issue has been at the center of the FRA's reluctance, up to now, to allow mixed use by FRA-compliant and noncompliant vehicles on the general railroad system. In contrast to the U.S. condition, there is less size and weight disparity between German LRVs and railroad trains, and both must meet buffing requirements. Germany has innovated in this area through a combination of train control and signaling technologies, communications systems requirements, vehicle safety design considerations, and personnel practices. These areas are reviewed below.

Train Control and Signaling

At the heart of German safety systems and practices that support track sharing (up to 100 kph), is a technology-based system of train separation. This system, INDUSI, was present in all of the cities with shared track applications, and involves the installation of both wayside and vehicle-based components. This system is a federal requirement in shared use systems and is referenced in the Transport Ministry Policy on Mixed Use discussed earlier. A summary of that policy statement says, in part: "The LRV must be equipped with a train-influencing [system] by which a train can be brought to a stop automatically" (Phraner et al., p. M-1).

This system is combined with an automatic train stop system using similar coils, which are interconnected with the main signals and which automatically stop the train if it passes a red aspect as described in detail above. In this manner, train speeds can be controlled and trains can be kept separated by an automated system (VDV, p. 305). This system is required on all low- to medium-speed trains that operate on main and branch railway lines, and is among the key operating systems making mixed use possible. No similar, *universally required*, automated system currently exists on U.S. railroads, though simple inductive train separation technology was used on some railroads and interurban electric railways in the United States during the early 20th century.

As mentioned earlier, the Transport Ministry requires that LRVs entering heavy rail lines comply with both EBO and BOStrab requirements, and this applies to the train signaling system also. Light rail systems operating in city environments in the cities visited all used either line-of-sight or light rail signal systems, integrated with the street traffic signals. However, on those lines where the LRV moved into shared use heavy rail lines, the signal system was that of the general railroad system, with traditional green, yellow, and red aspects and block signal operation. These were integrated with the INDUSI system described above. Thus, the operators of the mixed use LRVs must be cross-trained in both the tram system's signals and that of the general railroad system, and must observe both systems during the operation of each LRV trip. LRV drivers operate their LRVs on railroad tracks, but they are not certified to operate railroad equipment on railroad tracks.

Communications and Control Centers

Another safety aspect of train control and signaling, which requires adaptation of LRVs used in mixed traffic, concerns radio communications and control centers. The Transport Ministry's policy included a requirement that LRVs operated on railways, as well as the railway lines themselves, must be equipped with "train radio equipment for the transmission of emergency stop instructions and emergency calling for all lines used" (Phraner et al., p. M-1). In practice, this means that the LRVs have two radio communications systems on-board, one for communication with the owner of the rail line (e.g., DB Rail) and one for communication with the operator's transit system personnel, including other operators and control centers.

The German concept for control of shared track appears to have available as many possibilities for communication as feasible. Generally, the urban rail system vehicles stay on their normal radio channel but have the ability of immediate access to the railroad radio network, if needed. Where the operator was the same for both railroad and light rail modes (as in Dueren), the same control center handled communications for both modes. When two separate control centers were involved, it appears that the transit control center had not only voice contact but also access to train tracking data from the railroad system. In Cologne, where a local port railroad freight operator (under common ownership with KVB) was involved in the majority of shared track, the freight control center was in direct voice contact with the transit control center. Although train operators would call the transit control center, trains were monitored by the freight control center when in the shared track area. Control centers had little routine contact with trains. Urban rail operators were not required to report entering or leaving the shared track area, except in nonroutine conditions departing from the operating timetable.

While LRVs are operating with trams on reserved track, they use a train to wayside (TWC) system for route selection and train identification. There is generally no train protection provided in this mode. On the railroad tracks however, LRVs are under speed control and a positive train stop is provided as well as signal protection at interlockings. Without exception, all LRVs operating on the railroad system are equipped with the same signaling devices as used by the railroad freight and passenger equipment. Consequently, once off urban transit tracks, the same level of train control is provided to the LRV as is provided to the railroad type vehicle. Again, using the "INDUSI" system to provide both limited speed control and positive train stop is key to the concept of shared track in Germany. Redundant communications system is also regarded as essential.

In Karlsruhe, as a specific example, the LRVs communicate with a control center covering the entire LRV and tram system for service coordination, but they also have radio equipment on-board to communicate service problems to the railway owner. Figures 14 and 15 depict the modest AVG system Ettlingen Control Center near Karlsruhe and the large KVB system Cologne Control Center. Officials explained that the running of the trains is ultimately determined by the owner of the tracks (Karlsruhe Meeting, June 23). Likewise, Saarbruecken officials reported that, when an emergency occurs on the Saarbahn, the LRV operator notifies the owner of the tracks directly, but also contacts Saarbahn's control center. Dr. Keudel, the system's managing director, noted that he would like to have his agency take over this responsibility by owning the tracks themselves (Saarbruecken Meeting, June 27).

CONCLUSIONS DRAWN AND LESSONS LEARNED

The ideals of urban and transportation planning seem to be practical and working in Germany. In spite of aggressive suburban growth, sustainable and livable suburban environment seems achievable. Aside from chronic and ubiquitous graffiti, German railroads and urban transit present models of technical skill and operational achievement. On the study tour, observing first hand the "impossible" was exciting and eventually routine. One study mission participant reported "while waiting for a light rail train in Saarbruecken, a DB iron ore train passed the platform where I was standing, just minutes ahead of my arriving LRV on the same track."

The use of the tram-train concept or Karlsruhe track-sharing model appears to demonstrate these study mission-observed ideals dramatically. In spite of the successes noted in the seven overseas shared track cities visited, there are realities that must be considered in any initiatives to adapt German railway practices in North America.

Figure 14. Ettlingen Control Center in Karlsruhe which controls SI and SII LRV joint-use lines.

Figure 15. Cologne Control Center unifies right-of-way dispatch, voice communications with LRV's and buses, and security functions.

Obstacles to Track Sharing, Even in Europe

In spite of acknowledged benefits (in Karlsruhe alone, travel time savings could be in the region of $US 4.5 million a year), tram-train or shared track projects are slow to take hold outside of Germany and perhaps Britain. The reasons claimed are threefold (Jeffcott, M - Int'l Ry. Journal 5/01):

1. Tram-train projects are perceived as major capital investments that must compete with other public investment. If existing institutional structure and high-level commitment does not place a priority on public transport, other projects are selected over tram-train.
2. Tram-train proposals have difficulty securing political support. Successful projects typically have a single championing organization and in some cases an individual serving as super advocate and provide sustained support. Delivery of a new LRT system, even on shared track, most often exceeds the term of political office. Political successors get credit, originators take the heat.
3. National rail infrastructure providers (in Europe and class 1 railroads in North America) are reluctant to share their track because of concerns over safe operation and relative low crashworthiness of LRVs. At present in Europe, only Germany and Britain have published standards for acceptance of LRVs on to railroad tracks. France has completed a review of the German standards and appears on the threshold of developing and implementing its own standards. North American standards as published in the FRA statement of policy (Federal Register, Vol. 65, No. 132, July 10, 2000) permits tracks sharing, but discourages commingled operation.

The following is a short list of safety obstacles that are directly confronted by the German safety standards. They are couched however, as remedies to safety concerns. As such, they can serve as a checklist for prudent transit operators considering shared track, even in North America.

1. Maximum speed restrictions based on LRV stopping distance,
2. Automatic train protection with automatic train stop and signal spacing based on LRV stopping distance under various conditions,
3. LRV braking performance consistent with those of trams or streetcars that mix with vehicular traffic on the street,
4. Restrictions on simultaneous freight-switching operations,
5. Development of other standards based on risk assessments,
6. Rail car design based on broadly based survivability criteria, and
7. Operating regulations based on local conditions.

Planning Considerations

Unlike the United States, unfocused development or sprawl is almost nonexistent in Germany because of strong land use planning laws prohibiting it. There are other very fundamental differences between Germany and the United States, which temper the ability to make comparisons and exchange practices between the two countries. These differences include a relatively homogenous German culture dating back many centuries, scarce land, and a strong regard for nature, which all contribute to high-population densities in urban, suburban, and open rural areas, both sharply defined on the landscape.

Common to all areas the mission visited was the belief that track sharing in no way caused outmigration or sprawl. To the contrary, it was a tool for counteracting it. As Dr. Dieter Ludwig, often regarded as the German father of track sharing remarked, "people left the city long ago, and track sharing is bringing them back!" It was also evident that well-planned, high-quality transit service was an integral part of town planning and urban redevelopment. German law essentially dictates that transit plans be well coordinated with city planning. An important theme was that communities in regions were economically linked, and that track sharing combined with other institutions described above helped unite those regions.

Summary and Conclusions on Institutional Changes

It is evident that a variety of institutional changes and events created an environment conducive for the development of track sharing in Germany. These events had their roots in a fundamental federal government recognition of the need to improve public transit, particularly light rail transit, and subsequent federal action to fund it at a meaningful level. From the funding commitment demonstrated in Germany, it is clear that public transit and specifically rail transport is a national priority. Other actions follow from that national policy and are more remedial in nature.

Reorganization of the German national railway system opened up the network to third-party operators, including transit agencies that could offer more cost-effective light rail services in outlying areas than previous heavy rail, locomotive-hauled consist service. In-depth studies by the German Ministry of Railways on mixed use, including risk analyses, created the technical basis for track sharing and led to a national policy that spells out conditions required for this use of the railways. Next, the Regionalization Act transferred all planning and financing functions for public transport to the states, and, in many cases, ultimately to regional transit associations. These associations have a regional perspective on integrating transit services, which is a natural corollary to mixed use of railroads to serve suburban areas of growth. And finally, the current wave of deregulation and privatization sweeping Europe could create an inducement for more track sharing because of its inherent economies compared to building new rights-of-way, and its potential operating cost advantage over heavy rail in appropriate corridors. Bidding out transit services and dismantling regional public transit/utility combines may create new financial burden without the benefit of cross subsidization.

While all these institutional changes created the environment for track sharing in Germany, a host of operational reforms and practices were necessary to make it a reality. While the U.S. railroads are already privately held and have experienced two decades of deregulation, other different conditions influence domestic attitudes toward shared track. Among these is the loss of regional and most long-distance intercity railroad services. U.S. national policies on shared track and on public transit contrast with those of Germany. Finally, the gradual separation of U.S. domestic railroad business into separate (freight and passenger) entities has focused on the competition between different railroads for track space while overshadowing opportunities for rail transit to also compete, as in Germany.

Applicability of German Track Sharing to North American Rail "New Starts"

Transfer of German track-sharing practices to the United States can start with applying the same motivational forces that exist on both sides of the Atlantic. These common forces include a willingness to innovate and to change for the sake of improvement. Improve what? Energy, environment, personal freedom, and quality of life are commonly held social goals for improvement. Though the evolution of institutions, ownership, social policy and innovations are very different in the United States and Germany; the quest for financial and operational viability is the same. We also acknowledge each other's strengths. Germany admires U.S. freight railroad performance. The United States admires Germany's passenger railroads and public transit. Some professionals have declared that Europe and Germany are too different in too many ways to apply anything useful from their railroad or transit practice here in North America. Yet, most of the North American light rail rolling stock and much of LRT technology used here is German in origin. If we import their technology and apparatus, is it possible to also use some of the ideas and concepts from the same source? Finding the common ground is the first step to such a transfer.

Track-Sharing Case Study and Conclusions

Similar to the efforts to improve the performance of the German Railway through privatization, private railroads in North America are constantly looking for opportunities to improve their financial performance. In many cases, these opportunities include selling lower volume freight lines (branch lines) to short line railroads or in some instances to regional transportation agencies. In the case of a 1991 purchase of (now) Burlington Northern Santa Fe (BNSF) railroad rights-of-way in Southern California, three regional transportation agencies in three separate areas included acquisition of these branch lines for extensions of the planned commuter rail system or stand-alone light rail operations. While BNSF retained the right to operate freight over these branch lines, the purchase agreements give the right to the regional agencies to determine when freight service will be operated. Railroads will insist that their freight customers not be affected by introducing new rail transit service. Having considered that requirement, the proposed use of wireless LRVs or DMU is a popular option among the three areas.

Clearly there is the opportunity for public/private investment to benefit private freight operators and public transit agencies through the shared use of existing railroads. In exchange for use of the track, public transit agencies and freight railroads share in the cost of needed capital improvements. This practice is common among conventional railroads sharing track by assessing fees or using an index of use to proportion costs. Because the major freight railroads focus their attention and investments on the longer haul freight service, the proper maintenance of branch lines often suffers. Both track users must benefit from the shared arrangement for it to work satisfactorily.

Where branch lines have been sold to short line or regional carriers, often these new owners lack the financial capability to upgrade the infrastructure. And with the increasing weight of the freight cars now being used by the larger main line freight carriers, the short line operators are facing increasing maintenance expenses. Short lines are very inventive in finding new revenue or means of cost sharing. The experience described above is not very different from what was learned by the study mission at Dueren.

Common to many branch lines, the volume of freight is often low and car delivery flexible enough that time-separation of freight and passenger rail service is suitable to both occupants of the track. This eliminates one of the major safety concerns of a collision involving a light-duty passenger rail vehicle with the traditional freight equipment. Commingled operation is a moot point in such circumstances, and a waiver petition to the FRA will likely receive favorable action, as indicated in their policy statement (Federal Register, Vol. 65, No. 132, July 10, 2000).

Study Mission Participants' Statement of Concurrence on Findings

Study mission participants assembled at the conclusion of the tour to share impressions of what they observed. Their purpose was to develop a summary statement of findings for use by subsequent researchers and to suggest next steps in a research agenda.

Track sharing between widely varying types of passenger and freight trains was reintroduced in Germany in order to expand rail transit quickly and cheaply, and to attract suburban populations out of their cars. This was put into effect to counter growing vehicular congestion and its negative social impacts. This initiative is largely successful from our observations. Joint use of tracks, unrestricted by time of day, has yielded positive results. In such cities as Kassel, Karlsruhe, and Saarbruecken visited by the study mission, transportation officials report mobility gains *and* numerous social and economic benefits. This study mission visited the most innovative shared track cities—yet six of the seven cities had less than 300,000 population. The success of these operations and the benefits to the areas they serve has compelled other urban places to consider similar tram-train concepts in Europe, and now in North America. Again, these prospective shared track or tram-train cities are of a size traditionally considered insufficient to support light rail in North America. Track sharing can significantly improve the rail transit sufficiency of these candidate light rail locations.

The German experience has demonstrated that it is technically feasible to commingle rail transit and railroad trains of different weights, propulsion systems, and sizes in a manner that satisfies public safety and risk standards. German transit officials confirmed that there have been no major train accidents attributable to joint use over the last decade. This safety record is the results of rigorous safety analysis, train protection systems, and vehicle re-engineering to reduce the probability of accidents and to limit injuries. Given the often prohibitive expense of creating new rights-of-way and decreasing supply of surplus track space, track sharing appears to be a cost effective alternative for improving metropolitan mobility, even in the United States.

Admittedly, there are differences between Germany and North America regarding governance, track ownership, organized labor, and tort liability. The climate for shared track operations is more favorable in EU's new Europe. The most significant difference, however, is the way that mobility benefits and safety risks are balanced in both countries. In Germany, the mobility benefits of track sharing are achieved by application of policies, standards, training, and technology that reduce the risk of accident. In the United States, the near prohibition of track sharing of the types practiced in Germany has also reduced risk to acceptable levels, but at the potential loss of considerable mobility benefits. Responsibility for urban development, comprehensive mobility, and safety benefits are lodged in a single German ministry of transport, building, and housing, which may account for balancing these factors, as achieved in Germany.

The mission participants suggest that a cooperative multiparty effort at all levels of government, transit providers, and the private sector should develop a track-sharing research agenda as a cost-effective way to enhance mobility; that program should include, but not be limited to the following:

1. Publication of a multiparty policy statement, research agenda, and guidance for transit planners and operators on shared use operations;

2. Development or refinement of appropriate standards and guidelines addressing safety;
3. Suggested policies to support investment in technology to promote compatible operations;
4. Consideration of one or more demonstrations involving rail rights-of-way and tracks that are underutilized or are in public ownership.
5. Collaboration with existing shared use operators to prudently research ways to expand beyond temporal separations and to encourage new start managers to consider track sharing in their system planning; and
6. Initiation of more in-depth research on shared track experience in Japan and Europe.

Americans need more mobility options for the well-documented reasons of congestion, energy, and the environment. Experts agree that it will be impossible to provide enough new road capacity to accommodate future travel demands, in the manner that it has been provided in the past. Enhanced rail transit holds great potential if ways can be found to share existing facilities wisely and to their greatest potential.

APPENDIX A

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APPENDIX B

Glossary of German Technical and Institutional Terms and Abbreviations

Institutional Abbreviations

German transport operators, railways, authorities and associations are typically represented by three character abbreviations. The following list shows those institutions visited or experienced by the spring 2000 study tour. Each abbreviation is followed by the German name for the organization, followed by a rough translation in English and a short description. Several French titles are also included. Note that the German title uses the native spelling of the city, while the translation shows the Anglicized spelling.

AVG - Albtal Verkehrs Gesellschaft mbH (Albtal Transport Co.) Karlsruhe's regional railway / S-bahn operator.
BMV - Bundesministerium fur Verkehr Bau - und Wohnungswesen (German Federal Ministry of Transport, Building and Housing) comparable to FTA, FRA, and HUD combined. It regulates both railroads and streetcar operators.
BTB - Bus -Tram - Bunn (Bus - Tram - Railway) Luxembourg shared track plan.
CTS - Compagnie des Transports Strasbourgeois (Strasbourg Transit Co) franchise bus and tram operator
CUS - Communaute Urbaine de Strasbourg (Strasbourg Urban Co.) diverse utility holding company.
DB/DBAG - Deutsche Bahn AG (German Railways Corp) former national railroad now contract operator.
DKB - Dürener Kreisbahn (Dueren County Railway) public operator of light DMUs and buses.
GVFG - Gemeinderverkehrsfinanzierungsgesetz or German Municipal Transport Financing Act, that governs the federal share and how it can be spent.
KBE - Köln - Bonn Eisenbahn (Cologne - Bonn Railway) interurban railway now merged into KVB.
KNE - Kassel- Naumburger Eisenbahn (Kassel - Naumberger Ry.) regional freight commuter railway.
KVB - Kölner Verkehrs-Betriebe AG (Cologne Public Transport Co.) Cologne bus and tram operator.
KVG - Kasseler Verkehrs Gesellschaft GmbH (Kassel Public Transport Co.) bus and tram operator.
KVV - Kasseler Verkehrs und Versorgungs Gesellschaft (Kassel Public Utility Co.) holding company.
KVV - Karlsruher Verkehrsverbund GmbH (Karlsruhe Regional Transit Authority) regional authority.
SBS - Stadtbahn Saar (City Railway of the Saarland) the rail transit subsidiary of VVS.
SNCF - Societie Nationale de Chemins de Fer Francais (French National Railways).
VBK - Verkehrsbetriebe Karlsruhe GmbH (Karlsruhe Transit Co.) bus and tram operator.
VDV - Verband Deutscher Verkehrsunternehmen (German Public Transport Association) like APTA.
VRR - Verkehrsverbund Rhein-Ruhr (Rhine-Ruhr Regional Transit Authority) association of 25 operators.
VRS - Verkehrsverbund Rhein Sieg (Rhine/Cologne Regional Transit Authority) regional authority.
VVS - Versorgungs und Verkehrsesellschaft Saarbrücken (Public Utility & Transport Co. Saarbruecken).

Technical Terms (German, French, and North American terms defined)

APTA - American Public Transportation Association, a transit advocacy association.
AAR - Association of American Railroads, U.S. railroad sector advocacy group.
bahn - "railway" (frequently used in compound words such as strassenbahn *street railway*).
BOStrab - "Bau und Betriebsordung for Strassenbahnen" German uniform federal regulations or "ordinance" governing construction standards and operation of streetcar and rail rapid transit-type operations (as differentiated from railroad operations).
crashworthy - ability of locomotive or rail car body to retain structural integrity when subjected to the impact of a collision.
crash attenuation - ability of a rail car structure to absorb collision impacts through design of sacrificial voids in the car body, each void sequentially adding resistance as it collapses with the intent of reducing injurious impacts transmitted to the car occupants.
crash avoidance - ability of rail cars to avert (or minimize the effect of) collisions, usually through high-performance and redundant braking systems thereby shortening stopping distances.
DMU - Diesel multiple unit rail car. Self-propelled and sometimes capable of being operated by a single driver in the manner of an LRV. In the context of this report, DMU is most often used to describe a "wireless" light rail-type vehicle, diesel, or alternate fuel internal combustion engine-propelled, often low floor, being operated on interurban or railroad tracks in shared use and in common use in Germany.

dual power - A rail car or locomotive capable of operating by either on-board (such as diesel electric) or wayside (such as third rail electric) traction power sources.

dual voltage - A rail car , usually light rail, capable of running off two or more wayside traction power sources.

EBO - Eisenbahn-Bau- und Betreibsordnung. German federal uniform regulations governing operation and physical standards of railroads, interurban railways and certain regional S-bahns. (as differentiated from streetcar or rail rapid transit).

EU - European Union, an organization to unify Western European nations in a common economic bloc with uniform currency, immigration, finance, railroad, transport standards, regulation, and other features.

FRA - Federal Railroad Administration of U.S. Dept. of Transportation.

FTA - Federal Transit Administration of U.S. Department of Transportation.

"INDUSI" - Inductive signalsicherung" or "inductive signal protection," also referred to as "Punktweise Zugbeeinflussungssystem" or "spotwise train control system." It is an intermittent wayside and on-vehicle passive inductive 50- to 100-kHz system introduced in 1930s in Germany. INDUSI features automatic train stop and is required for all shared track operations up to 90 kph (and in some cases, 100 kph or 62 mph) in Germany.

land - a state or province (and governmental unit) in Germany.

light rail - A term relating to local railways and stemming from English law. "Light" usually, but not exclusively, refers to light construction standards, vehicles and/or duty assignment. Light rail may be freight or passenger; steam or internal combustion. Most recently, light rail is used to differentiate between (1) conventional streetcar or tram operating a modest speed in predominantly mixed street traffic and (2) LRV mode running predominantly on reserved track at higher speed and higher construction standards. In the United States, this contrast is most apparent in comparing the Portland Streetcar and MAX light rail operations in Portland, OR.

LRT - Light rail transit.

LRV - Light rail vehicle.

LZB - "Linienzugbeeinflussungssystem" or "linear train control system" uses transponder-activated technology applied to automatic train separation. LZB is required for train speeds in excess of 160 kph (100 mph) in Germany.

open access - A term describing an operating concept that assumes that the track owner and the operators of trains are separate enterprises. Use of tracks is available to any qualified train operator prepared to compete for schedule slots by paying a track user fee. This tenant-user relationship grew out of the reorganization and privatization of the German national railways. Open access is considered one of the foundations of shared track in Germany, because it enables qualified rail transit operators to compete as equals with other railroad operators for track space on the national railroad system.

rail bus - Called a "Schienenbus" in Germany, these "one-man" rail cars are typically light-weight bus or coach derivative vehicles. They have been used for over seven decades on branch lines in Germany as an economy measure or to preserve marginal passenger services. They operate in mixed rail traffic and have largely been replaced by DMUs.

S-bahn - In Germany, an S-bahn takes several forms, most commonly light rail as in Karlsruhe or Saarbruecken, elevated or surface rapid transit in Berlin and even DMU trains in certain other locations. S-bahn is thought of most frequently as "light rail."

schienenbus - see rail bus above.

stadtwerk - Literally "city works" or public utility works consortium under a common authority. These institutions may consist of bus, rail transit, phone, water, electric gas, waste disposal, parks, steam supply, and other components. Profitable components typically, cross subsidize the deficit operations like public transit). All the urban areas in Germany and France visited by the study mission had a form of stadtwerk. "Versorgungs" in the title of the organization usually denotes a stadtwerk type organization.

strassenbahn - streetcar or tram , a term widely translated as operation, infrastructure, or vehicle.

"tram-train" - A contemporary term to describe track sharing with trams operating on railroad track. It is believed to have originated in France where a number of cities including Strasbourg have expressed interest in the concept. Use of the term is becoming wider spread throughout Europe.

temporal separation - Time separation of railroad and rail transit operations to avoid any risks associated with simultaneous track sharing. Temporal separation usually divides into late night and day/evening permissive operating periods. Temporal separation is seldom practiced in Germany, but short blocks of time are assigned different carriers sharing the same track for purposes of managing congestion or because of capacity constraints. Peak period prohibitions of lesser priority train movements to avoid system congestion may be found in Germany, but this is not considered full temporal separation as practiced in the United States.

tram - A high-capacity, but low-speed streetcar or strassenbahn-type rail transit operation. This subtle distinction from light rail transit reflects the difference between traditional streetcar and modern LRT performance and construction standards. Portland's "MAX" light rail and its "Portland Streetcar "operation is a domestic example of this abstruse contrast.

UIC - "Union Internationale des Chemins de Fer" (International Association of Railways).

UITP - "Union Internationale des Transports Publics" (International Association of Public Transport), an international transit advocacy and professional association.

verkehrs - "traffic" or "transport" found frequently in compound German organization titles to describe transport enterprise.

verkehrsbetriebe - City or regional transport institution, enterprise, or operator.

verkehrsverbund - City or regional unified transport authority of oversight organization governing integrated fares and services for all transit operations within its domain.

verkehrsversorgungs – See "stadtwerk" above.

zug - train.

Appendix C
GERMAN CITIES WITH TRACK SHARING SYSTEMS
KEY OPERATING PRACTICES/FEATURES
(BASED ON HOST PROPERTY INTERVIEWS, TOURS, AND MATERIALS PROVIDED)

OPERATING PRACTICE/ FEATURE	DUREN (DKB)	COLOGNE (KVB)	KASSEL (KVG)	KARLSRUHE (KVV/VBK)	SAARBRUCKEN (VVS)
Service Objective for Shared Use System	Reinstitute flexible rail service able to operate in City and regional environments	Ability to cost effectively extend reach of City Tram system to region's growth areas, tie to downtown	Ability to cost effectively extend reach of City Tram system to region's growth areas, tie to downtown	Ability to cost effectively extend reach of City Tram system to region's growth areas, avoid transfers bet. modes in City	Reinstitute local tram combined with regional service to outlying communities, reduce auto congestion in central city
# of Shared Use Lines	2 line	2 lines	1 line	7 lines	1 line
Shared Use km of Track	70 km	58.5 km (interurban)	4 km	300+ (total km of lines with track sharing)	14 km current; 11 km extension under construction
Type of Shared Use	Limited freights and DMU's in mixed traffic	Significant freights (30-40 per day) and regional DB trains with LRT's	LRT's mixed with freight traffic	LRT's mixed with DB regional trains and freights	Limited freights with LRT's. Most DB rail sections no longer carry DB rail trains. 95% of traffic is Saarbahn.
Train Control Technology on Shared Use Tracks	INDUSI	INDUSI (separate systems for LRT's vs. freights)	INDUSI	INDUSI	INDUSI
Other "Equivalent Safety" measures	Freights operated by Dueren employees; new signal system	Reduced speeds for freights on shared lines. Common ownership of freight & transit operating company = shared interests		Short braking distance of LRT's; reduced maximum LRT speeds; crash attenuation in car design; longitudinal energy absorption	Improved acceleration and braking on LRT's; energy absorption features in car; added SNCF signal upgrades.

OPERATING PRACTICE/ FEATURE	DUREN (DKB)	COLOGNE (KVB)	KASSEL (KVG)	KARLSRUHE (KVV/VBK)	SAARBRUCKEN (VVS)
Priority of Trains				1. Long Distance and ICE trains 2. Regional DB Trains 3. Trams/LRV's	95% of trains are Saarbahn, rest are freight. LRT's have priority
Control Center	Basic train dispatch Ctr provides control of shared ROW, monitor of grade xings.	Control center unifies ROW dispatch, voice com with LRV's/Buses, Security.		Control Ctr coordinates LRV moves with DB rail in constrained schedule	Railway dispatcher coordinates shared track bet. Saarbahn and freights.
Vehicle Type/Mfg	Siemens Regiosprinter DMU, 70% low floor	Bombardier low-floor & Siemens Duewag high-floor stadtbahn cars	Bombardier (former DWA design), 75% low floor LRV	Siemens Duewag Medium floor dual power	Bombardier dual power 48% low floor
Platform Access System	Low floor access, deployable ramp for W/C	Low floor access	Low floor access, separate track for LRV's at stations on DB line	Medium floor with retractable steps with two height levels	Retractable steps on car to fill platform-car floor gap
Operator Training	Operators are cross-trained for DMU and freight equipment operation.	3 months training, 1 month in service on basic LRV's; one year in regular service before assignment to shared tracks. One additional month of training per shared-use line	4 extra weeks of joint use track training above tram training. Elements of BoStrab and EBO	LRV operators are cross-trained for railroad engine operations.	
Operator Enforcement / Discipline				Serious rule violation leads to dismissal,with no re-hire elsewhere. Override of INDUSI by breaking tamper proof seal results in dismissal	

APPENDIX D

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