Rail Passenger Safety: Equipment and Technologies

DETAILS

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AUTHORS

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RAIL PASSENGER SAFETY: EQUIPMENT AND TECHNOLOGIES

This TCRP digest summarizes the mission performed October 13–October 28, 2006, under TCRP Project J-03, "International Transit Studies Program." This digest includes transportation information on the organizations and facilities visited. This digest was prepared by staff of the Eno Transportation Foundation and is based on reports filed by the mission participants.

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INTERNATIONAL TRANSIT STUDIES PROGRAM

The International Transit Studies Program (ITSP) is part of the Transit Cooperative Research Program (TCRP). 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 2005 by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users. 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). TCRP is managed by TRB and funded annually by a grant from FTA.

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 for teams of public transportation professionals to visit exemplary transit operations in other countries. Each study mission focuses on a 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, professionally challenging two-week mission, after which they 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 States. Study mission experience also helps transit managers to better evaluate current and proposed transit improvements and

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can serve to generate potential public transportation research topics.

Study missions are normally conducted in the spring and fall of each year. Study teams consist of up to 14 individuals, including a senior official designated as the group's spokesperson or team leader. 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-03 Oversight Panel endorses the selection.

Study mission participants are transit management personnel with substantial knowledge and experience in transit activities. Participants must demonstrate potential for advancement to high 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 sponsoring employer. Travel expenses for participants are paid through TCRP Project J-03 funding.

For further information about the study missions, contact Gwen Chisholm Smith at TCRP (202-334-3246; gsmith@nas.edu) or Janet Abrams at the Eno Transportation Foundation (202-879-4718; janet.abrams@enotrans.com).

About This Digest

The following digest is an overview of the mission that investigated European rail safety programs. It is based on individual reports provided by the team members (for a team roster, see Appendix A), and it reflects the observations of the team members, who are responsible for the facts and accuracy of the data presented. The digest does not necessarily reflect the views of TCRP, TRB, the National Academies, APTA, FTA, or the Eno Transportation Foundation.

RAIL PASSENGER SAFETY: EQUIPMENT AND TECHNOLOGIES

Led by Tom Margro, General Manager of the San Francisco Bay Area Rapid Transit District, the mission team included representatives of state, local, and regional transportation agencies as well as the federal government. Over their two weeks in Europe, team members visited organizations and facilities in Berlin and Hennigsdorf, Germany; Reichshoffen and Paris, France; and London and Crowthorne, Berkshire, United Kingdom. They participated in a variety of meetings and tours hosted by national rail regulators and operators, local public transportation authorities, transit and commuter rail operators, safety directors at major rail corporations, and independent rail safety researchers. Opportunities were also afforded to team members to ride on a variety of rail programs, visit testing and manufacturing facilities, and interface with numerous public, private, and educational leaders knowledgeable about rail safety and operations (for a list and selected descriptions of host organizations, see Appendix B).

GENERAL OBSERVATIONS

After returning to the United States, team members reflected on the mission as a whole and developed consensus around the following general observations:

- There is a predominant European philosophy that emphasizes passenger rail and, to that end, provides a remarkable contrast to American rail program emphasis and management. In part due to emphasis directed through the European Union (EU), a variety of passenger rail connectivity, safety, operating, and infrastructure issues not only receive priority for planning, but for funding resources as well.
- The EU has developed a series of directives that the participating European nations must address through regulation and implementation. Examples include train control, driver platform standardization, passenger access and safety, operating safety, and many others. It is this approach, pursued in a spirit of cooperation, which helps underscore the emphasis placed on passenger transportation. For example, as one might suspect, strong national interests in Europe are easily identified by native language. But in the case of transportation infrastructure development and international travel, the language barriers are reduced by requiring that employees be fluent in the languages of the travel pattern of the passenger rail services.
- Conversely, the EU and the supporting national infrastructures, although making huge strides forward, are still in the formative stages in the development of a multinational integrated passenger rail program. It was apparent that the translation of EU directives to the national programs in each of the three countries visited was taking different courses, and at differing pace.

Developing national oversight and direction, translating directives into action, and integrating technologies at all levels is a complex and time-consuming activity. To the credit of the organizations visited by the mission team, the recognition of the milestones to accomplish these tasks was seriously taken.
- Similarly, public/private partnerships and private participation are key ingredients to EU transportation successes. The willingness of EU to actively encourage the public sector and the private sector to engage in partnerships in testing, operations, planning, manufacturing, and regulatory development provides a multinational, intergovernmental approach that brings the best thinking to the table.
- Geography and population density play significant roles in the development of a passenger rail philosophy in Europe. As compared to the United States, the large land area states of Texas and Montana are comparable in size to France and Germany. Significantly different though are the population comparisons, where the European countries are over six times more populous (Texas = 23 M; Montana = 1 M; France = 63 M; and Germany = 83 M). As a result of these densities, coupled with the historical nature of transportation infrastructure growth in Europe, significant differences in automobile emphasis and affordability, effects of World War I and World War II, and many other reasons, the transportation investment philosophy in Europe is dramatically different when compared to the United States. The lifeblood of many smaller European communities is the connection to larger communities primarily for employment. Without passenger rail connections, those smaller communities are cut off from the employment opportunities because other transportation infrastructure does not match the U.S. state and federal highway system investment philosophy. So, investment philosophy comparisons between Europe and the United States must be carefully considered.
- An undertone to the organizational structure of many programs studied by the mission is, in American terms, privatization of operations and services. Sometimes called liberalization, it is clear that there is an effort to engage the private sector to perform the operating, manufacturing, testing, and other activities to sustain rail operations and meet safety thresholds and goals.
- Finally, there was genuine interest on the part of mission hosts in sharing technology, philosophy, operating, and other passenger rail issues. Both public sector and private sector interests recognize the importance of information sharing as a means to moving forward together with legitimate ideas and valuable resources.

This digest presents information acquired by the mission team on European efforts to ensure the well-being of passengers in the areas of standards and regulations; rail operations/shared use; and specific safety measures.

STANDARDS AND REGULATIONS

Background

To understand how safety is managed in the European Union, it is important to understand the evolution of mainline railway national and European policy since the early 1990s. Historically, the national railway networks in the United Kingdom (British Rail), France (Société Nationale des Chemins de Fer Français [SNCF]), and Germany (Deutsche Bahn AG [DB]) were 100% owned by the state (in this instance the state means the national government) and heavily in debt. In addition, much of the technology and infrastructure was unique to the state (nation) in which it operated. The signaling systems, equipment design, and power provision were all different. The European Union countries realized that to revitalize the rail network, and open it up to competition (and attract private capital), they needed to jointly address companion concepts. These key concepts are interoperability, which is the ability of equipment to operate anywhere in the EU countries, and harmonization, which is the development of standards, regulations, norms, etc., which technically promote the concept of interoperability.

With harmonization and interoperability comes the requirement for individual states to ensure that their safety regimes and methods of authorizing vendors, contractors, and manufacturers are consistent. The European Commission had set targets for access to networks and improvements in competition for high-speed rail in 1996 and the conventional rail network in 2001. With the goal being that the national railways were no longer to be solely statewide entities and technology and infrastructure were to no longer be state-specific, it became clear that as the railway systems across Europe evolved, so did the safety and regulatory structure; the concept of harmonization had to apply also to these two vital areas.

The European Commission created the European Railway Agency (ERA). The agency's main task is to create measures for development and implementation of technical specifications for interoperability and a common approach to questions regarding safety. As concerns rail safety, the member states are required to establish both national safety authorities and an independent investigative body for crashes. In the three countries visited by the ITSP mission, those national safety agencies are the Eisenbahn-Bundesamt (EBA) in Germany, the Établissement Public de Sécurité Ferroviaire (EPSF) in France, and the Office of the Rail Regulator in the United Kingdom.

The mission met with the EBA and EPSF staffs and, as expected, both had very similar roles and responsibilities including the following:

- Acting as the government's safety regulators (although in some instances regulations are actually published by a government entity such as the Ministry of Transport)
- Reviewing and authorizing railway undertakings (such as new operators) and infrastructure managers ensuring compliance with all regulations and standards
- Certifying new or modified equipment and maintenance practices
- In some countries, licensing train operators
- Ensuring compliance with European rules related to interoperability
- Publishing technical recommendations
- Coordinating the relationship with the ERA and the other national safety agencies created in the other EU countries

In most cases, the national safety agencies are funded by taxes paid by railway sector companies or fees levied for activities undertaken by the agency.

It is clear the role of these agencies is evolving as new EU directives are implemented, new technologies overwhelm the capabilities of staff, new expertise is required, and interoperability and harmonization issues become more complex. In France, in particular, there is also discussion as to whether EPSF will also take over regulation of metros and tramways, which are currently being regulated by the state.

Standards/Research

The regulatory agencies EBA and EPSF also have a role other than that related to safety functions, which is ensuring compliance with European rules related to interoperability. To ensure interoperability, designs and functionality need to be standardized.

In general, European standards are developed with a hierarchy generally overseen by the ERA. At the top of this hierarchy are European directives, which present a set of mandatory requirements for the functions being examined. From those directives come Technical Specifications of Interoperability (TSIs), which create an overarching framework for EU members and are mandatory applications where interoperability is an issue. Last in the structure are norms, which support the TSIs and normally are written by the railway or manufacturers and are voluntary. In a complementary path, EU members can set national standards unique to their domestic railways as long as interoperability TSIs do not apply. The regulatory national agencies use these two frameworks (safety and standards) to fulfill all of their other roles, which includes certifying equipment technology to be proposed for service; a new system must work its way through this structure of requirements or standards before it is authorized by the national regulatory agency.

These TSIs are then translated into standard rolling stock and rail infrastructure designs through collaborative European projects that involve research think tanks such as Forschungs- und Anwendungsverbund Verkehrssystemtechnik (FAV) Berlin and educational institutions like the Technical University of Berlin, as well as manufacturers including Bombardier, Alstom, and Siemens, all of which were on the itinerary of the study mission program. European initiatives such as SAFETRAIN and MODTRAIN have funded research to develop the safest standard designs for particular parts of rolling stock including the operators' cab, truck design, and internal safety lighting, to name a few. Once adopted, these designs are aimed at modularizing production leading to an overall safer and standardized European fleet. One benefit is also the fostering of competition for the production of the modularized fleet. This approach of standardization is largely followed in France and Germany.

England clearly is following its own path with regard to rail standardization. Following the privatization of the railways in the early 1990s, some important lessons were gleaned. Not the least of which resulted from an inquiry into a major collision that resulted in 2003 in the formation of the Rail Safety and Standards Board (RSSB) in the United Kingdom. RSSB became independent in 2003 and since then has acted as the primary rail standards body in the United Kingdom. It is an independent nonprofit company that is owned and funded by major stakeholders in the U.K. rail industry including Parliament, railway companies, etc. The major charter of this body is to carry out research and development for the rail industry and provide technical analysis and advice with regard to standards setting. A major contributor to that research is DeltaRail Group, a frequently retained major think tank and research laboratory located in Berkshire.

This is not to say that there is no interface between European standard setting and that of Great Britain. However, there does seem to be a distinct philosophical difference (either perceived or real) between the application of the Railway Group Standards (RGS) that are the standards of the U.K. rail industry and TSIs that govern standard setting in both Germany and France. TSIs appear to have two purposes, the primary of which is to elevate safety in the European rail industry. The companion goal is to make the rail industry more competitive through economies of scale and market opening. In contrast, it is the goal of RGS to simply improve safety; they do not have broader applications.

Regulation

Germany

EBA is the federal rail regulator in Germany. Its charter is to authorize the safety of new rail infrastructure as well as monitor the safety of the existing infrastructure. It also provides crash investigation in the event of an incident. It is a body that was established in 1993 and generally has concerned itself with: (1) the merging of the two state railways that existed in Germany prior to unification; (2) investigating ways of dealing with the debt of railway systems; (3) making sure that German railways comply with European directives; and (4) ensuring a high level of safety is maintained though the privatization efforts that are now being embarked on. These European directives are then translated into technical specifications and adopted into federal law. EBA is then responsible for making sure that the law and technical specifications are complied with. As an example, DB, the national rail operator, will propose an improvement in rolling stock or infrastructure. That improvement cannot be implemented until the EBA authorizes its compliance with national law. In this manner there are checks and balances.

France

Regulation in France is not unlike that in Germany. Regulation occurs on many levels, primarily handed down through European regulation and then translated into state law. In France strict regulation is handled by the Ministry of Transport, but the French sister agency of the German EBA, the agency that is responsible for the authorization of transportation infrastructure, is the EPSF. This agency is responsible for regulatory oversight of the national railway. In many respects, the EPSF has the same charter as the EBA. In France there is a progression toward privatization that requires this oversight and there exists a separation of the transportation function from the infrastructure management function. Additionally, as in Germany, there exists the need to comply with the European rail directives to harmonize technologies to attain interoperability while maintaining a high level of safety. It is the duty of EPSF to oversee this regulatory function. The role of EPSF is to authorize new systems and training centers while providing safety accreditation and certification to infrastructure managers and rail operators. It also publishes technical recommendations and provides a vital link between the national rail concerns and the European regulatory bodies.

United Kingdom

In the United Kingdom, as in France, direct regulation of the rail industry is handled through the transportation ministry. There is however a major role that the RSSB plays in the setting of those regulations. When regulations are set at the international level, the RSSB reviews existing standards to ensure compliance with those regulations. The role of the RSSB is often to review crashes and use its findings to provide input to the regulatory review and setting process.

RAIL OPERATIONS/SHARED USE

Rail operations and shared uses have become an important area of focus for rail operators and regulators for a variety of reasons. Capacity or the ability to increase capacity places a large demand on existing systems and thus impacts safety. The goal is to operate as many trains, at the highest possible operating speed, and at the highest operating headways as the system will safely tolerate. The need for capacity drives technical solutions such as advanced signal and train communication systems. Maintenance of infrastructure also plays a role, particularly when capacity limits are pushed—more maintenance is required and time windows to conduct maintenance are shortened. Shared use of rail right-of-way is also an issue. Historically, freight and passenger rail service have shared rail right-of-way and infrastructure. However, in the United States, there is an increasing demand for passenger rail use and the challenge is interoperability—to jointly operate a variety of train equipment from an increasing number of rail operators using the same right-of-way and infrastructure. Also an issue is the crashworthiness of the various vehicles operated on the same tracks or in a common right-of-way on adjacent tracks—for example, freight or passenger locomotive versus a light rail vehicle. In Europe, where passenger rail is more dominant than freight rail, operation and shared use presents similar challenges. The most pressing of which is cross-border interoperability.

Stations are the primary interface between trains and passengers and many issues contribute to safe operations. The most basic interface is the station platform/train interface which becomes more challenging with the variety of train equipment that serves each station and the variety of train service (express versus local and freight traffic expressing through the stations at high speed). Stations that allow freight traffic have clearance issues that make station platform/passenger train interface design more challenging. Another issue is the ability to maintain platforms on tangent track (not having the platform on a curve). It is the platform/train interface that drove the slogan “Mind the Gap” in London’s Underground. Other issues affecting safety of stations are the complexity of station use, for example, multimodal stations have more complexity and require attention paid to movements or transfers between modes; communications; capacity; emergency preparedness and evacuation; disabled patrons; and security.

Germany

Operating in a similar fashion to the State Safety Oversight Program in the United States, the EBA presented information on how the regulatory environment affects safety. One of the main goals of the European Rail Directives is to address harmonization or interoperability of cross-border train traffic. Currently, train equipment and infrastructure limitations prohibit cross-border train traffic throughout Europe. Harmonization requirements will drive standardization of train equipment and infrastructure that will safely allow additional capacity, interoperability, and cross-border rail traffic. Securing of grade crossings is also an important regulatory concern. In Germany, railways have priority. New grade crossings with train speed of greater than 160 km/h must be grade separated. There are currently 22,881 grade crossings in Germany, which is down from 28,682 in 1998. Fifty-one percent of grade crossings have no technical protection while 49% have technical protection consisting of lights, signs, and gates similar to U.S. gated grade crossings. Grade crossing crashes are usually the fault of others and not the railways. In Germany, residents do not mind the train horn use at crossings because they realize the train horn is necessary for their protection.

Two challenges facing European railways are capacity and efficiency. Freight is expected to triple while passenger rail is expected to double by 2020. FAV is involved in research projects regarding standardization, particularly the European Driver’s Desk (EUDD), the MODTRAIN, and MODLINK projects. Their realization not only will improve safety through greater interoperability and reducing human factors, but will also build economies of scale. Regarding shared use, temporal separation (operating freight at night) is common practice. Other shared-use discussion regarded stations, specifically the relationship between the door/platform interface and the fact that mixed traffic (freight and passenger) comes through stations. In addition to freight traffic expressing stations, clearance is also an issue. Station standardization is a significant money issue.

Deutsche Bahn AG

DB is the state-owned railway of Germany with the primary focus on passenger transportation. Approximately 350 private companies operate on the DB rail infrastructure network. DB stated that the key to maintaining operation efficiency is control of infrastructure and operations. DB also stated that it would be very expensive to modernize historical stations. Mixed-use operations provide quite a few challenges. For example, high-speed passenger rail requires specialized infrastructure. Freight operations are also necessary and are particularly hard on infrastructure requiring additional maintenance. To address mixed use, DB uses temporal separation operating passenger service during the day and freight at night. DB also utilizes special passing tracks, but on a limited basis due to the inability to construct passing tracks in tunnels. Freight traffic typically does not operate on the high-speed passenger infrastructure; however, high-speed passenger service does utilize freight tracks and does so at lower operating speeds. The InterCity Express (ICE) network is the high-speed train network in Germany. ICE trains currently operate only in Germany with a few exceptions. This is primarily because of a lack of interoperability in infrastructure and train vehicles. For example, for ICE trains to operate on the high-speed Train à Grande Vitesse (TGV) network in France, retrofits are necessary to ICE trains for signal system compatibility. Similarly, for TGV to operate in Germany, compatibility retrofits are necessary.

DB is currently wrestling with capacity issues relating to both passenger and freight services. At present, only a small percentage of freight is transported by railway in Germany and the EU as a whole. Therefore, freight trains in Germany, and the EU, tend to have short consists composed of cars carrying lighter loads than their counterparts in the United States. However, due to highway congestion problems, and concerns about fuel costs and the environment, attempts are being made to shift more freight from trucks and onto the railroads. Transportation officials are looking to increase the hauling capacity of the railroads. Modern freight equipment is being designed to carry heavier loads. Future freight trains may be longer, with increased service frequencies on existing rail infrastructure.

Stations

Metro stations in Berlin are modern, well-lit, well-maintained, and planned. The fare system is on-board proof of payment; the stations do not have fare barriers or turnstiles that are typical of subway metro systems. Signage is good including next train variable message signs. Information kiosks where patrons can push a button for assistance are present in the station areas. Ticket vending machines are prevalent and allow the purchase of group tickets to speed up ticket purchasing. Security is good with the use of video surveillance. Mirrors are present at the platform ends to allow train operators to view the platform/train interface.

The trip included a tour of Berlin's new multimodal railroad station—Berlin Hauptbahnhof. The largest train station or crossing station in Europe, this multilevel station serves all types of passenger train service in Berlin including approximately 1100 long-distance, regional, and rapid transit trains. The station has 14 platforms on two levels which serve ICE trains, EuroCity trains, InterCity trains, and the S-Bahn rapid transit trains. Transfers between levels are accomplished via elevator, escalator, or stairs. Of particular interest are the glass fronted panoramic elevators which allow a full view into the elevator and elevator shaft. Video surveillance cameras are located throughout the facility. The tour guide stated that security is heavy, but many of the security measures are not visible to the public. It is interesting to note that trash and recycle receptacles are located throughout the facility. Signage is exceptional including next train variable message signs, clocks, and even Braille along handrails. One platform is built on a curve and has an innovative approach to safety. Since the platform serves long train consists, video surveillance is installed and used in combination with a platform attendant. A bank of video monitors allows the attendant a view of the entire train/platform interface. The attendant can verify that the train doors are clear and then use a key to presumably allow the train to depart the station. The station also has a myriad of services available including shops, lounges, food courts, and customer service centers for the various train lines.

A stop in Braunschweig, Germany, afforded utilization of the train station which is a multimodal station serving ICE trains and regional trains. Outside the station, connections were provided to bus and light rail or tram service. The bus and light rail platforms are separate, but adjacent to one another, so no circulation conflicts are present. Light rail or tram stations in Braunschweig are of simple design consisting of median near-end platforms (meaning the platform is before the road crossing). The platforms have railing on the street side for safety.

France

EPSF is the national safety authority of France and it operates similar to the EBA of Germany. There are two types of rail networks in France: the national (or open) network and the closed network. The national network consists of infrastructure owned and maintained by the Réseau Ferré de France (RFF) and operators like the SNCF. It is an open network; any European operator can operate on the network if the operator meets the standards and requirements (authorization). The open network challenge is cross-border interoperability because rail systems were developed nationally. The closed network is for metros and tramways. There is no separation between infrastructure and operators. The Régie Autonome des Transports Parisiens (RATP) operates in Paris; however, in other cities operators compete for public transit.

EPSF does not make regulations; its role is to authorize rail operators, control or enforce authorizations through audits, and make technical recommendations. Regarding its audit function, its goal is to audit the entire authorization or certificate within a 5-year period because that is the timeframe of the authorization or certificate. This is similar to the 3-year audit cycle conducted by state safety oversight agencies in the United States.

Société Nationale des Chemins de Fer Français

Similar to DB in Germany, SNCF is the state-owned railway of France with the primary focus on passenger transportation. In 1997, the SNCF decided to split or separate operations and infrastructure, allowing it to focus on its core activity of operating trains. RFF is a public agency responsible for the development and maintenance of infrastructure. RFF contracts out maintenance which is, oddly enough, performed by SNCF. SNCF pays access or operator fees to run on the railway network. Approximately 20% of the TGV ticket revenue goes toward access fees.

To assure safety and infrastructure maintenance, independent quality audits are conducted. The TGV network in France is the largest high-speed network in Europe representing about two-thirds of the European high-speed network. The network is expanding and the goal is to connect all the major capitals of Europe, which raises cross-border interoperability issues. France prefers staying with the TGV network as opposed to mag-lev technology because of the unique infrastructure required for mag-lev. Traditional infrastructure allows for greater network connectivity as the TGV operates on freight infrastructure but at slower speeds. Similar to the DB in Germany, freight trains do not operate on high-speed track in France primarily because of schedule and maintenance issues. SNCF is also working on increasing the capacity of the existing TGV network through improved signaling (going from 4-min headways to 3-min headways) and use of double-decker trains and by coupling train sets together. For TGV, SNCF is also considering a moving block system instead of its current fixed block system. However, the TGV is already at safe breaking distance as it approaches 3-min headway. Safe breaking distance is the limitation on capacity for the TGV, not the signal system technology capability of advancing to a moving block system. The TGV operates with cab signals; the rest of the French rail signal infrastructure is wayside signals with train stops or positive train control.

In France, as in the rest of Europe, integration and interoperability is an issue primarily between passenger and freight, old and new, and cross-border. In addition to equipment interoperability issues, there are cultural challenges. For example, in Europe, there is no common language for train control like there is for air traffic control. Behavior also varies country to country. For example, in considering level or at-grade crossings, some countries are more disciplined and follow safety rules, while others are not so disciplined, making standardization difficult.

SNCF initiated crash testing as early as 1937; however, two major crashes in 1988 were the impetus for today's focus on crash energy management. Equipment engineers stated that there is no substitute for active safety; however, there is always the possibility of collision outside the control of the railway as with level crossings. SNCF uses two methods of validation: dynamic crash tests and digital simulation. Passive safety devices perform better for low-speed (less than 125 mph) or conventional operations. Active safety must be applied to high-speed operations (greater than 125 mph).

Régie Autonome des Transports Parisiens

The RATP site visit began with a tour of line #14 or the Meteor line. The Meteor line is a driverless, automated metro line. It operates 100-s headways during the peak and 3-min headways off peak. It is capable of 80-s headways. The Meteor line vehicle is unique because from the interior it is one long car. Station platforms are equipped with doors on the platform edge that close prior to the train doors closing and the train leaving the station. In this manner, no one can get caught in the train doors and the platform edge doors assure that the interface between the train and platform is clear. In addition to the automated platform edge doors, there are manually operated platform edge doors for use in case of emergency evacuation. These doors can be activated with a push bar if the main doors were to fail. Since the line is automated, video surveillance transmitted back to the Meteor train control center is heavily used and relied on both for the station platform and inside the vehicle. RATP's experience with automation has been good and RATP is working toward more automation through modernization of the metro network.

RATP has begun the modernization of line #1 to a fully automated line. This will be the first automation of an existing line in Paris. The idea is that automation will increase safety through the use of platform edge doors and continuous speed control. The platform/track interface is important to protect because of the crowded nature of the platforms. The platform edge doors will also decrease the large number of suicides (approximately 100 per year) that occur on the system. Platform edge doors also prevent people from getting into tunnels, which is not only a safety issue, but also a security issue. In addition to improving safety, platform edge doors will increase efficiency. Approximately 72% of delays are due to passengers, of these 68% will be controlled by platform edge doors. Additionally, automation will utilize computer-based train control. RATP will use a phased approach attaining full automation in 2010. One concern RATP has is the response full automation will have operating in an outdoor environment under differing environmental conditions. RATP expects a 9-year return on investment on the modernization of line #1.

RATP also developed a safety action plan as a result of a crash that occurred in August 2000. The plan focus areas are recruitment of operators, more rigorous training, a 1-year probationary period, and a follow-up program for new operators. There has also been an emphasis on the enforcement of rules.

Stations

Two main types of train stations are predominant in Paris: large regional train stations or terminals, and Metro stations. The large terminals serve regional and high-speed trains and have modal connections to the Metro and bus lines. These stations are predominantly stub-in stations. Just as in Germany, there was no passenger security screening except for the Eurostar service to London via the tunnel. Security screening for the Eurostar is similar to air travel using metal detectors and baggage X-ray.

Metro stations in Paris are equipped with fare barriers and turnstiles that utilize a variety of fare media including a smart card like pass (scan in and scan out). Similar to systems of like age, the station platforms are tight and crowded. It appeared that, in the Paris Metro, individual station platforms served one line. This made it simpler to navigate and helped with crowd control as passengers waiting to board were not left on the platform while the alighting passengers exited the platform. Signage and maps are good making it simple to get around in the system. Patrons simply need to know the terminal station in their direction of travel to identify which platform and which train to take. Larger stations were connected by a series of pedestrian tunnels. One of the French presenters stated that French behavior does not respect safety and people cross the tracks to make trains even with high platforms and the third-rail subway environment. To discourage crossing between the tracks, certain stations are retrofitted with center railings and fences between tracks. The most unique safety feature of Metro stations is the platform edge doors in use on the Meteor line.

United Kingdom

Rail Safety and Standards Board

The RSSB provided a variety of interesting presentations. The Safety Management Information System was of particular interest. Using this system, a rail operator can develop a quantitative safety risk assessment. This assessment allows the operator to understand the nature of risk and subsequently conduct cost benefit analyses regarding risk or hazard resolution. Similar to what is being done in this area at the London Underground, this level of quantitative risk analysis is impressive. The tool is preloaded with various types of information and data that allow relatively complex information to be analyzed. The tool is not publicly available; however, U.S. transit systems could benefit from its implementation.

London Underground Ltd.

The Kings Cross fire in 1987 provided the impetus for the London Underground to establish key safety principles based on risk assessment. Additionally, the Health and Safety Act of 1974 provided objective- or performance-based regulations to reduce risk to as low as what is practical. The regulations describe three areas in regard to hazards: unacceptable (1 in 10,000 chance of fatality), tolerable (1 in 1,000,000 chance of fatality), and broadly acceptable (negligible risk). If the risk is in the unacceptable range, it must be addressed. If the risk is in the tolerable range, the agency has to balance cost versus risk to determine if a solution is practical. If the cost of resolving a particular hazard is three times or more the benefit, then it can be determined impractical to resolve the hazard. This model also applies to fatalities. The United Kingdom has determined that a fatality has an associated cost of 1.4 million pounds. Thus, if the cost to mitigate a fatality risk is greater than 4.2 million pounds, then it can be determined impractical to resolve or mitigate the risk. There is also a formula for estimating equivalent fatalities: 10 major injuries equal 1 fatality or 100 minor injuries equal 1 fatality. This is safety at a reasonable cost model. Regulations also require a metro operator to have a safety management system that ultimately makes a "safety case" to the government that the system is safe to operate. Once approved, the safety management system is subject to audit by the regulating agency.

The London Underground utilizes a quantitative risk assessment matrix to determine their top risk events. For example, some of their current top risks are platform/track interface–related and escalator incidents. This assessment is conducted yearly and then a business plan is developed to address the risks. Safety performance is measured and the overall assessment is modified and updated. The Underground stated that risk has been reduced by eleven times since 1992. Their major risk events in 1992 were flooding, station and fire risks, and train collision.

The Underground also summarized safety objectives for public/private partnership. The Underground currently operates trains on infrastructure that is maintained by others. The infrastructure group is also responsible for designing, engineering, and building new infrastructure. There are incentives in the contract for operating and safety improvements. The Underground is also involved in configuration management, meaning that changes made to existing infrastructure must be approved by the Underground. The contract also has provisions for enforcement and intervention if standards are not met.

Regarding emergency management, the London Underground has a hierarchy of plans. The Network Emergency Plan addresses large events that affect the entire underground system. Line emergency plans are also in place for events that affect specific lines. The emergency plans are structured parallel to the London Incident Command System so the plans match emergency services (police, fire, and emergency medical services).

Stations

Similar to Berlin and Paris, two main types of train stations are predominant in London: large regional train stations or terminals and metro stations. The large terminals serve regional and high-speed trains and have modal connections to the metro and bus lines.

London Underground staff stated that its stations are old: the first station, 1 Baker Street, was built in 1864. Similar to systems of like age, the station platforms are narrow and crowded. Individual station platforms also serve multiple lines which contributed to the crowding of platforms. For example, passengers waiting to board one line remained on the platform while passengers from a different line boarded the train and exited the platform. This contributed considerably to platform crowding and the main problem the Underground faces, the platform/track interface as the train departs a crowded platform. To assist in reducing station dwell times, the Underground added platform attendants on the platform to assist passengers, make announcements, and signal train operators. Originally placed for operational improvements, these attendants had a big impact on safety.

The system has good signage and maps and is rather easy to navigate. Variable message signs including next train information are prevalent and assist passengers by communicating the line and destination of the train that is arriving next. Similar to the Paris Metro, patrons simply need to know the terminal station in their direction of travel to identify which platform and which train to take. Larger stations are connected by a series of pedestrian tunnels and in many cases these tunnels are narrow. The system is barrier protected with turnstiles that utilize a variety of fare media including the oyster smart card. The oyster card is a loadable smart card and fare is deducted from the card per each use by scanning into and out of the system. Video surveillance is also in use. A number of stations appeared to be built on slight curves. It is unknown if the stations were originally built this way or extended at a later date. There are both horizontal and vertical gaps, which is the reason behind the widely known "Mind the Gap" campaign.

SAFETY MEASURES

Various presentations discussed the concepts of active safety and passive safety. Several presenters mentioned active safety and its importance; however, the focus of most presentations was on passive safety. Passive safety is the ability to reduce the severity of the consequences of a crash. When applying passive safety, the focus is not on crash prevention; passive safety assumes that crashes will occur. Therefore, to improve safety, emphasis is placed on reducing severity or the consequences of a crash both in terms of injury and property damage. Active safety focuses on crash prevention—the ability to reduce the probability that a crash will occur. The new European rail regulations are directed to improving safety with a focus on both active and passive safety.

To better understand the concept of rail passenger safety and particularly the definitions of active safety and passive safety, it is important to define and explain the concept of system safety. System safety is the application of management and engineering principles applied to a system throughout its lifecycle to eliminate or reduce hazards to the most practical level with the use of available resources. There are several key pieces to this definition: management and engineering principles; system; lifecycle; reduction or elimination; and available resources. Ultimately, it is about risk management and being practical. The concept is to begin applying safety at the earliest stages of a project—in planning and design—designing and engineering hazards out instead of having to manage hazards in later lifecycle stages like operations. Managing hazards in the operations phase relies on human factors. Unfortunately, most crashes occur as the result of human factors.

System safety focuses on reducing the reliance on human factors to prevent crashes by applying the system safety precedence or hazard reduction precedence. Simply stated, the hazard reduction precedence is to

- Design for minimum risk,
- Incorporate safety devices,
- Incorporate warning devices, and/or
- Develop polices/procedures.

Designing for minimum risk, or designing hazards out, is the priority. If hazards cannot be designed out to an acceptable level of risk, incorporation of safety devices is the next desirable approach. If the risk is still undesirable, incorporation of warning devices is appropriate. Lastly, policies or procedures can be developed to help reduce risk. This is the least desirable option because it relies completely on human factors. In looking at this precedence, the reliance on human factors is the least at the top (design) and continues to increase toward the bottom (procedures). The goal is to minimize the reliance on human factors.

Rail/roadway grade crossings, or level crossings as they are commonly referred to in Europe, offer a perfect illustration to apply the hazard reduction precedence. The most desirable approach is to grade separate the crossing and thus eliminate the hazard altogether (design the hazard out). However, grade separation may not be feasible for a variety of reasons such as cost, land availability, and geographical constraints. It is particularly difficult to revisit or retrofit an at-grade crossing once it is built and operational. The next option is to incorporate safety devices to reduce the probability or severity of a crash. Crash energy management is a good example of incorporating a safety device to reduce severity. The next option is to incorporate warning devices such as flashing lights, warning bells, and crossing gates. If additional hazard reduction is necessary, a rail operator could develop a rule stating that trains stop and proceed at the grade crossing. Each step of the precedence relies more on human factors to observe, comply, and respond accordingly.

Vehicles/Crash Energy Management

Rail equipment crashworthiness is a topic of discussion and research on an international level in the rail industry. Crash energy management is the safety topic of rolling stock that seems to be receiving the majority of funding and research in Europe. Rolling stock manufacturers Alstom and Bombardier discussed crash energy management systems that were installed on equipment that they had supplied or were designing for rail operators, including mission hosts DB, SNCF, RATP, and Transport for London (TfL). Safety oversight and research organizations Transportation Research Laboratories, DeltaRail, RSSB, EPSF, EBA, and FAV all talked in length about the current activities in which they are involved to improve vehicle crashworthiness.

Presentations and discussions during the mission provided detailed information on equipment that exists or is in the design phase that may protect the crew and passengers at speeds up to approximately 30 mph. It was suggested that it is not practical or possible to cost effectively limit injuries at moderate-to-high speeds. That being said, a great deal of work is underway to save lives and limit injuries at speeds up to approximately 30 mph. Most of this work falls under the category of crash energy management.

Crash energy management systems are designed to control energy absorption during a collision, and as a result, limit structural deformation of the train and maximize occupant volume preservation. Part of the strategy is to build or equip trains to begin deformation at lower speeds than that of conventionally built trains. This will enable the collision forces to be transmitted and absorbed in a manner that will lessen the negative consequences to the crew and passengers on board during the collision. This is accomplished with the introduction of equipment that is designed to deform in a specific way during collisions. Some of the equipment discussed included: push back couplers, load distributors, roof absorbers, sliding sills, enhanced operator cabs and end frames.

Equipment that stood out as the major contributors to the reduction of injuries to the crew and passengers was the push back coupler, load distributor, and the enhanced operator cab. Push back couplers are designed to deform and absorb energy at speeds over 5 mph, while the load distributors absorb much of the energy that exceeds the capability of the coupler during the early phase of the collision, enabling the other system components to react as designed to absorb the balance of energy requiring dissipation. The enhanced operator cab's primary job is to protect the driver of the train, and provide an opportunity for him to escape. Presenters provided statistics and videos of collision testing to qualify their claims of the positive outcomes that are expected when the methods and equipment discussed above are used. The companion topic to crash energy management is mitigation strategies for secondary impact velocities.

Secondary impact velocities must be limited to minimize injuries to the crew and passengers as they are thrown from their seats during a collision. Methods to address this included airbags for the driver's cab, seat belts for drivers and passengers, orientation of passenger seats, and railcar table designs. Minimizing body decelerations for passengers seems to be the most difficult aspect of improving on the current ability to limit injury during collisions. Seat belts do not seem to be practical, and it is extremely difficult to model crash dummies for the numerous passenger configuration scenarios. A few of the presentations touched on research that was underway to develop crash dummies that can more accurately simulate the actions of rail passengers during collision tests.

Our mission hosts appear to be making much progress in these areas as they work toward the development of international standards for providing safe passenger rail service throughout Europe with their work on international safety standards. Mission hosts who manufacture trains, Alstom and Bombardier, are deeply involved in crash energy management and shared a great deal with our team during the mission.

Alstom

Alstom devotes many of its resources to crash energy management in order to limit the costs of the trains it manufactures and maintain a minimum crashworthiness standard that meets worldwide standards. Alstom has presence in the United States for crash energy management through its participation in the U.S. Acela project that provides the U.S. version of high-speed train service. It gave presentations on crash energy management at its Reichshoffen facility in France. Its ability to be innovative was evident when it discussed and displayed its crashworthiness test bench Dynaccess.

This test bench enables it to simulate a train collision to test its crash energy management system, allowing the crash energy management system to experience the forces that are expected to occur during a collision. The crash energy management components suffer actual deformation and destruction damage. The test bench incorporates the use of explosives in order to generate the required forces to simulate train collisions from past crashes or scenarios that may occur in the future. The ITSP team was able to examine the actual equipment that is used to perform the tests, and viewed videos that had recorded previous tests.

The Alstom tour also included a look at a car overhaul project where new crash energy management operator cabs were being installed on 30-year-old trains. Alstom's engineering safety team did an excellent job at presenting information on crash energy management.

Bombardier

Bombardier representatives gave an excellent presentation on crash energy management along with an exceptional bogie (truck) design and operation presentation. They also provided a tour of their manufacturing facility in Hennigsdorf, Germany. The sprawling facility included test tracks that permitted vehicle testing at speeds up to 140 km/h, enabling Bombardier to deliver vehicles to European customers ready to run, unlike the United States where testing on the operator's rail infrastructure is usually required before providing service to passengers. During the facility tour the ITSP team was able to see work underway on projects that included trams, light rail vehicles, metros, and high-speed trains. Bombardier also permitted the group the opportunity to examine equipment involved in the European standardization and harmonization effort, MODLINK EU cab and EUDD. Bombardier is a member of the international team that is working to create European standards for safety. Transportation research organization FAV plays a lead role in this effort and was also a mission host.

FAV

FAV is in the role of facilitator for the harmonization and standardization effort in Europe. The goal of this initiative is to define and implement uniform safety rules and regulations for the continent of Europe. FAV is involved in numerous projects that are looking for ways to improve safety for all modes of transportation worldwide. FAV's presentation provided a breakdown of its organization and showed its involvement in transportation safety activities at an international level.

MODLINK EU cab, EUDD, Modbogie, Modpower, Modcontrol, and MODLINK Door Portal and Train crew interface were projects included in the presentation. Some of these projects are designed to enhance safety, while others may enable rail operators to reduce equipment costs by making major system components interchangeable, forcing more competition from vehicle manufacturers. Another mission host active in the standardization projects is Technical University of Berlin, Germany.

Technical University of Berlin

Technical University provides college-level instruction in land and sea transport systems. It has a comprehensive offering of rail-specific courses. We toured its labs and attended presentations. Projects that explored safe wheel/rail interfaces, truck noise abatement, and energy absorption couplers were discussed. The existence of this school and others like it provides Germany with an excellent resource of young qualified professionals who are anxious to begin work in the rail industry.

Transportation Research Laboratory and DeltaRail Group

While in the United Kingdom the ITSP team also visited with hosts, Transportation Research Laboratory (TRL) and DeltaRail. They are British companies involved in research activities to improve rail passenger safety. Their presentations represented them as collaborators working on projects that focus on crash energy management and the safe egress of passengers during crashes or equipment failures that create unsafe conditions. TRL also performs work as a rail crash investigating body. Some of its work uses the latest available technology or equipment, including its use of laser scanning equipment for crash information retrieval and the use of lower-limb cadavers for secondary impact deceleration testing.

TRL performs rail crash investigations in the United Kingdom using laser scanning equipment that captures critical evidence from the scene while rescue activities are underway. This is an improvement from the conventional method where evidence collection would occur after the rescue effort, resulting in some of the evidence being compromised or lost during the rescue effort. Its use of cadaver limbs in the building of its crash dummy enables it to more accurately simulate the dynamic action of the lower leg of a seated train passenger during collision tests. Innovative efforts like these provide a glimpse of the creative activities that are underway in the United Kingdom that may make passengers safer when they travel by train.

The daylong visit at the TRL facility included a tour that showed crash test equipment and emergency lighting products. Emergency lighting was included in the discussions on passenger egress in emergency situations. The recommendation for passengers who are on board a train during a crash is to stay put until emergency rescuers arrive, because the environment outside of the crash vehicle may expose the passengers to a more dangerous situation. The visit with TRL and DeltaRail provided unique information that other mission hosts had not discussed. Some of their presentations included references for statistics or information from the last host we would visit on the following day, RSSB.

Detailed information, descriptions, and images of selected safety measures discussed by hosts and the mission team may be found in Appendix E.

MODTRAIN

In order to ease the way through the above process, the EU countries are working together to integrate research centers, operators, manufacturers, and subsystems suppliers into consortiums that will work together to eventually create a set of European standards based on TSI-compliant designs. The EU is funding many of these integration projects and relying on the actions above to come to consensus on the right approach to take.

A prime example is the Modular Train concept, which was started in February 2004 with a total project duration of 4 years and a budget of 31 million euro. MODTRAIN (Innovative Modular Vehicle Concepts for an Integrated European Rail System) is a coordinated effort to "design, specify, and test the modules and interfaces for the next generation of intercity trains and universal locomotives in Europe," according to FAV Berlin. The aim is to examine the various major elements of a rail set and

- Develop a requirement database which meets the latest TSIs and European norms;
- Define standard interfaces;
- Demonstrate modular solutions;
- Include suppliers who will provide the module solutions;
- Create standardized elements so that economies of scale can work; and
- Identify parts and subsystems that can be standardized on a plug-and-play basis.

The advantages of the MODTRAIN process to the operators will be reduced maintenance costs, reduced training costs, and a structure other than from the operator itself, to demonstrate innovative and coordinated research and development (previously the 100% state-owned railways did all of the research and development, sometimes with vendors). The MODTRAIN process will result in an industry standard, which will eventually become EU norms as well as a requirements database, which can be used for future tenders.

Many of the agencies visited by the mission were part of the MODTRAIN consortium partners as system integrators (Bombardier/FAV Berlin, Alstom Transport, Siemens TS), as rail operators (DB and SNCF), or as research centers (Technical University of Berlin).

The MODTRAIN program has many on-going projects which will result in future standards or EU norms. Included are individual projects on passenger compartments; couplers; train control; power systems; and bogies (called trucks in the United States) and their design, prototype, layout, and verification.

The most advanced MODTRAIN project at this time is the EU cab, which is coordinated by Bombardier and FAV Berlin. The following EU cab status and deliverables as described by Bombardier are an example of similar expectations in all of the project areas:

- Main goals
  – Modular cab
  – TSI compliance (e.g., crash)
  – EUDD
- Status
  – Requirements analysis
  – Concepts/analysis/layout
  – Mock-up construction
  – Driver interviews in mock-up
- Next steps
  – Checking latest requirements from operators
  – Functional demonstrator for EUDD
  – Proposals for European standards
  – Readiness for tender

All of the projects will go through a similar process identifying the legal, normative, and operational requirements up front and then go through a design, prototype, and verifying process to come up with a harmonious design, which can be used as an industry standard, an EU norm, and a requirements database for future EU tenders.

MODTRAIN is only one step in an ambitious program to define and conduct rail research strategy for the next 20 years. The EU countries anticipate a tripling of freight ton-kilometers and a doubling of passenger-kilometers by 2020. To accomplish these goals and improve the economic-ecological and political environment that promotes rail transportation, the rail system must improve the quality, frequency, and reliability of today's rail system. The European Rail Research Advisory Council (ERRAC) has developed a program called EURNEX which is devised to overcome a disconnected European research program by creating partnerships between industry, operators, authorities, and research and setting benchmarks so there is an efficient technology transfer between EURNEX scientists, operators, and industry. As the notion of interoperability has been put forward as a requirement to grow and expand rail services, the EU nations also know that coordinated research, beginning with the MODTRAIN program and expanding into the broader EURNEX research program, is intended to make the rail system, now and in the future, a competitive mode of transportation throughout the European continent.

Grade Crossings (Level Crossings)

Unlike the United States where passenger rail is concentrated in urbanized areas with mostly limited rail connections between such areas, the European countries have invested in and grown their conventional and high-speed rail network. Frequent and reliable passenger trains are traveling between major urban countries often several hundred miles in length and increasingly between European countries.

With the increase of rail traffic comes a heightened awareness and concentration on grade separation policy and grade crossing protection. At least in the continent countries we visited (Germany and France), both with currently 100% state-owned railways, there are policy, political, and regulatory efforts to grade separate all crossings on all high-speed rail (HSR) corridors similar to the Federal Railroad Administration (FRA) regulations in the United States. Because of historic countrywide, government-owned railways in Europe and centralized funding, financing of grade separations has been part of national policy. In the United States, prioritization of grade separations and their funding is principally a local or state issue.

Because of this national policy perspective, regulating agencies such as the EBA in Germany examine grade separation and grade crossing improvements by way of a classification process that assists in identifying the type of crossing/separation required at any one location. Railways at crossing locations are defined by the number of tracks and whether the railway is a main line or branch line. There is a linkage to roadway traffic at the same crossing location based on volume of traffic, for example, fewer than 100 vehicles/day is weak volume; greater than 2,500 vehicles/day is heavy volume. From this analysis, each crossing is classified as requiring technical protection (active) versus nontechnical protection (passive). In addition, it is common, particularly at grade crossings, that line-of-sight analyses are done to ensure there is sufficient clear distance for both the train operator and roadway vehicle operator to see each other.

To understand the magnitude of the issue, the DB reported that in Germany with 22,000 level crossings, half have nontechnical protection. In the United Kingdom, of the over 7,600 level crossings, over 6,000 have nontechnical protection.

In the United Kingdom, RSSB has committed to significant research in the area of level crossing risk where more than 7,600 level crossings of various types exist. In the overall context, although less than 7% of all system risk is in level crossing, the United Kingdom recognizes that more than half of all grade crossing crashes involve pedestrians, with the second largest group (25% of all grade crossing crashes) involving "road users." Overall, this category is viewed as their biggest risk and is attributed to misuse error (as compared to violation error and proper use). Overall, the United Kingdom, as compared to other EU countries, is very safe, rating near the lowest in the category of fatalities per 1000 crossings.

The United Kingdom, through the RSSB, has a multistep analysis approach as follows:

- Accessibility: focuses on those with hearing and other impairments
- Data/risk: focuses primarily on modeling incidents by crossing types
- General categories: focuses on internal and external research outcomes
- Economics: focuses on the cost of change, either upgrade or elimination
- Human factors: focuses on understanding human behaviors
- Technology: focuses on technological solutions

The RSSB created the National Level Crossing Safety Group in 2002 to review level crossing legislation and to encourage cooperative planning between rail, highway, and crossing users. The RSSB has completed three formal inquiries on significant crashes over the period beginning in 2002. And, the RSSB has an aggressive research agenda having completed 6 topics, currently investigating 8 topics, and scoping as many as 10 or more additional safety program topics. Similarly, it has completed work on six relevant railway group standards. All in all, this is an impressive effort.

An important set of conclusions are a part of the RSSB "Level Crossing Safety in Great Britain" Summer 2006 Update. It concluded

- Road user violations, misunderstanding of signage, complacency, and underestimation of risk are the primary factors in level crossing crashes;
- Level crossing legislation is fragmented, outdated, or complex and does not recognize the shared responsibilities of rail and highway entities;
- Risk management is not approached from a holistic assessment basis;
- Legislation is required to eliminate or close current crossings;
- Improved planning guidance is required to assess likely effects of crossings;
- Greater participation by planning authorities is required;
- Treatment applications require driving tests; and
- Although response to investigations has resulted in technical improvements, overall innovation and modernization has slowed.

Arguably, these topics may have applicability in nearly all level crossing situations, regardless of country or operator.

The RSSB research efforts are coordinated with a new project initiated in July 2005 (in which FAV Berlin is one of the coordinating entities) called SELCAT (Safer European Level Crossing Appraisal and Technology). According to EURNEX's September 2006 Newsletter No. 4, the purpose of SELCAT is to ". . . collect, structure, cluster, analyze and disseminate existing world-wide research results and to stimulate new knowledge exchange in the area of level crossing safety."

Train Control/Signals

This section discusses fundamental aspects of train control systems within the EU. At this time, all high-speed and conventional railroads operate manually on a fixed block system with a driver at the controls of locomotives. One of the most complex tasks during the creation of an integrated railway system within the EU will be the development of a unified signal system that will be accepted by all of the nations of Europe. Different types of wayside signals and methods of controlling and monitoring those signals exist in Germany, France, the United Kingdom, and other EU members. One manual system and one automatic type of train control system will eventually be decided upon for operation throughout Europe.

Point-Based and Linear-Based Signal Systems

DB representatives noted that there are basically two different types of systems that are being utilized by railroads within Europe. These are classified as point-based and linear-based systems. Both are manual systems that require an operator in the locomotive.

The point-based system is over 80 years old and is utilized on conventional passenger and freight railroads. It is a fixed block system that enables only one train to be within a particular block during a specific period of time. The wayside signal communicates to the driver whether or not a train is in the block ahead (Figure 1). A restricting signal may restrict speed entering a block. In this case, the driver must acknowledge the signal by activating a button in the cab and placing the train into a braking mode until the train has reduced speed. If a signal actually prohibits entry into the block, the driver must acknowledge the signal and apply the brakes to stop the train. In either case, failure to apply locomotive brakes and acknowledge the restrictive signal will result in an automatic brake application. Locomotives and tracks are equipped with magnetic devices that interact and control the movement of the train. All movements are recorded in the cab of the train, and any operational discrepancies are investigated.

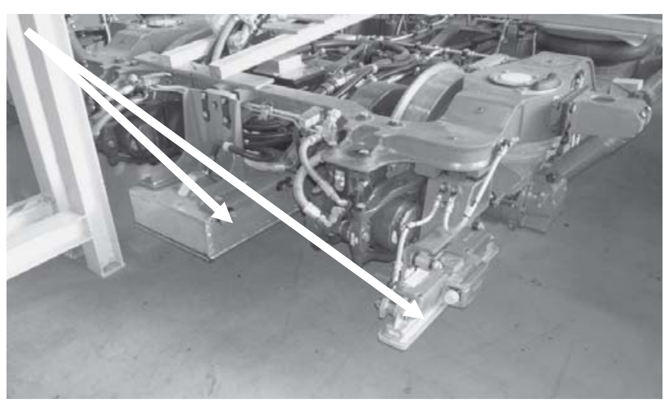


Figure 1 Signal pick-up arms (utilized on a point-based fixed-block system) on the truck of a locomotive that operates in Germany and the Netherlands

The linear-based system is utilized on high-speed lines within Europe. This system provides the locomotive with a cab signal display that indicates signal aspects on a constant basis to the driver of the train. Electrical currents are passed through the track and are received by a pick-up device on the locomotive. As with the point-based system, the linear-based system is fixed block. Restrictive signals affect operation of the train much the same way as does a point-based system. A restrictive signal may require the driver to slow down or stop the train entirely. The cab signals must be acknowledged in the cab with a button. As with the older system, failure to apply locomotive brakes and acknowledge the restrictive signal will result in an automatic brake application.

Signal Standardization—Goal for an Integrated EU Railway

Siemens representatives stated that engineers from the various EU members are working on the development of a standardized signal system. Whether there will be linear-based or point-based systems or automated systems included is under determination. Because signals provide a critical active safety element of train control, designers are ensuring that all systems and their components and subcomponents are thoroughly tested for functional reliability. EU signal designers are aware of one critical fact: testing can only reveal the absence of errors not their presence. Therefore, all products must be continually tested under realistic conditions to ensure that there are no software or hardware errors present before they are placed into revenue service. Because of this critical reality, the signals testing group has been given independence and autonomy from the influence of other members of the railroad integration exercise.

Signal component testing will be overseen by both EU railroad integration professionals and the manufacturers of products and equipment. The testing of components for a new integrated signal and train control system will include a product test, integration test, overall systems test, and final simulation and operational tests.

Automatic Train Control

Siemens engineers are looking at the application of automatic train control (ATO) with an automatic train protection (ATP) safety system on an integrated EU rail system. London Transport and RATP representatives noted that the Victoria line in London and the Meteor line in Paris are being operated by a fixed-block ATO system. Moving-block ATO or communication-based train control (CBTC) is under consideration for high-speed lines and metros. The primary benefit of this moving-block system is the ability to increase line capacity utilizing existing infrastructure.

The function of an ATO system is to regulate train riding comfort and smoothness during acceleration, coasting, and braking under corresponding train control commands. ATP is the safety system which ensures that trains remain a safe distance apart and have sufficient warning to allow them to stop so that the complete train is in the platform. This is important for systems that employ platform doors. ATP continually checks to confirm that the line ahead is clear before allowing the train to proceed forward.

The London Jubilee line and Paris Meteor line ATP safety system continually checks the speed of the trains as they leave stations, coast, and enter the next stations along a route. The Paris line is a driverless system. It is designed to automatically prevent doors from being opened until the train is fully docked in the station. After a predetermined time, the doors automatically close and the train is automatically started, accelerated, speed maintained, and braked as it comes into the next station. There are wayside signals present, and a manual control board is available for manual operations in the event of an emergency. Trains are automatically relayed at terminals and turned for another trip. The ATP safety system continually monitors all movement to prevent contact with other trains.

ATO/ATP Multihome Signaling

The London line has fixed-block systems with very closely spaced blocks. This has enabled the close following of trains and very frequent intervals. A multihome signaling system with ATO and ATP are utilized by these lines. A series of sub-blocks are provided in the platform area. These impose reduced speed braking curves on the incoming train and allow it to run toward the platform as the preceding train departs, while keeping a safe braking distance between them. Each curve represents a sub-block. Enforcement is carried out by the ATP safety system monitoring the train speed. The station stop beacons still give the train the data for the braking curve for the station stop but the train will recalculate the curve to compensate for the lower speed imposed by the ATP safety system.

Communication-Based Train Control

Siemens engineers noted that CBTC is essentially an ATO system with ATP system safety controls. It is different, however, in that it is a moving block system. With CBTC technology, intelligent-based systems are aboard the trains. An on-board system computes the train location; protects train movement in the various operating modes, including ATO mode; and computes the train's speed profile. CBTC also supervises and monitors train traction, including acceleration and braking functions. A system zone controller is in charge of wayside CBTC functions, ensuring a vital tracking of trains, fully bi-directional capability of trains, and moving-block anticollision protection. An automatic train supervision (ATS) system functions as a part of the CBTC network, monitoring and supervising trains and wayside equipment, regulating traffic, enforcing the schedule, setting routes, tracking trains, and managing the interfaces with other systems (i.e., public address, on-board train computer information screen, etc.).

The Paris Meteor line is the ancestor of the currently designed CBTC systems, which are based on high-transmission rate radio communication allowing exchanges of a high density of information. The Meteor line utilizes inductive loops as permanent communication support; therefore, the quantity of information is more restrictive than when utilizing radio transmissions. Therefore, on this particular line, true moving blocks requiring real-time information are replaced by very short virtual blocks, independent from signaling, with a layout allowing operation similar to what is found with true moving blocks. Therefore, instead of being variable, space between trains is a changing quantity of very small quantum.

APPENDIX A—STUDY MISSION TEAM MEMBERS*

Thomas E. Margro (Team Leader), General Manager, San Francisco Bay Area Rapid Transit District, Oakland, California

Steven Adkins, Senior Technical Project Manager, Massachusetts Bay Transportation Authority, Light Rail Engineering, Newton, Massachusetts

Michelle Bouchard, Manager, Rail Transportation, Caltrain/San Mateo County Transit District, San Carlos, California

RoseMary Covington, Mass Transit Administrator, District of Columbia Department of Transportation, Washington, DC

James Dickey, Director, Public Transportation Division, Arizona Department of Transportation, Phoenix, Arizona

Susan Duffy, Manager of Rail Operations, Utah Transit Authority, Midvale, Utah

David Genova, Manager of Public Safety, Regional Transportation District, Denver, Colorado

Ronald E. Hynes, Deputy Associate Administrator, Office of Research, Demonstration and Innovation, Federal Transit Administration, Washington, DC

D. Austin Jenkins, Light Rail Manager, King County Metro, Metro Transit Division, Seattle, Washington

Paul Messina, Superintendent, System Safety, Metropolitan Transportation Authority, New York City Transit, New York, New York

Carter Rohan, Director of Capital Programs and Construction, Municipal Transportation Authority, San Francisco, California

David Solow, Chief Executive Officer, Southern California Regional Rail Authority (Metrolink), Los Angeles, California

Thomas Tupta, Superintendent of Transportation, San Diego Trolley, Inc., San Diego, California

Ralign Wells, Director, Metro Operations, Maryland Transit Administration, Baltimore, Maryland

Janet Abrams (Mission Coordinator), Vice President and Chief Operating Officer, Eno Transportation Foundation, Washington, DC

*Titles and affiliations are at the time of the mission.

APPENDIX B—STUDY MISSION HOST ORGANIZATIONS

Host Organizations

Host organizations in each country are listed in the order they were visited by the mission team:

Pre-Mission Activities in Washington, DC

- Transit Cooperative Research Program
- Washington Metropolitan Area Transit Authority
- Embassy of France

- Embassy of Germany
- Embassy of the United Kingdom
- Eno Transportation Foundation

Germany

- Eisenbahn-Bundesamt
- Forschungs- und Anwendungsverbund Verkehrssystemtechnik (FAV) Berlin/Technologiestiftung Berlin (TSB) Transport Technology Systems Network
- Technical University of Berlin
- Bombardier
- Deutsche Bahn AG (DB)
- Siemens AG

France

- Alstom Transport
- Siemens Transportation Systems
- Société Nationale des Chemins de Fer Français (SNCF)
- Régie Autonome des Transports Parisiens (RATP)

United Kingdom

- Transport for London (TfL)
- Transport Research Laboratory (TRL)
- DeltaRail Group
- Rail Safety and Standards Board (RSSB)

Descriptions of Selected Host Organizations

Germany

Eisenbahn-Bundesamt. Eisenbahn-Bundesamt (EBA) is the regulatory and authorizing authority for the federal railways and for foreign railroad traffic companies for the territory of the Federal Republic of Germany and is charged with looking after the safety of railway passengers. This is accomplished by

- Supervising all construction activity,
- Inspecting and approving all rail vehicles, and
- Monitoring the condition of the railroad operational network and operations.

The supervision of the nonfederal railways is implemented by the EBA for 13 federal states. The EBA actively supports the improvement of railway transport, and over the last 10 years, the EBA has validated more than 40 billion euro in federal funds which were made available to it for new construction, upgrading, and maintenance.

Three main focuses within the mandate for EBA are the regulation of safety, the implementation of safety, and securing of grade crossings. All crash investigations work is independent of the EBA and is used to advise the transportation industry.

EBA currently has over 1,250 staff, an operating budget of 75 million euro per year, utilizes external testing resources, and receives 60 million euro per year in income. If the number of tracks or the speed on the tracks rises, the railway operation is responsible for providing financing for the upgrade work. If the car volume or car speed rises, then the transportation authorities and/or municipal authorities are responsible for providing the financing.

FAV Berlin/TSB. The ITSP team was briefed by the managing director of FAV Berlin. The FAV has functioned as an initiative of the Berlin University of Technology and the Berlin Technology Foundation, which utilizes the Berlin Senate for the development of sustainable solutions for the growing railway network. The group acts as a neutral mediator between local and international players involved in the railway markets.

In Europe rail spends 20% of total sales in research and development, as compared to the automotive industry which spends 12% to 14% and the aeronautics industry which spends 20%. Much of the spending is concentrated on harmonization of the many existing networks which are being integrated. The research and development also takes into account greater levels of safety and security.

The EURNEX European railway research network of excellence is managed by the FAV. As part of managing this network of excellence, the FAV has concentrated on specific core competencies such as modular cockpits, standardization of mechanical and human interfaces, and data and communication networks in the railcars and between trains.

The EUDD plus is currently the fastest locomotive in the world which runs at a speed of 357 km/h. At higher speeds rail traffic has to have high-end information systems in place. Berlin is proud of the fact that it has one of the best functioning real-time monitoring systems, which allows greater flexibility in integration of freight traffic and passenger traffic.

As a result of the efforts of FAV, there are currently approximately 600 researchers, and over 60 institutes utilizing private investments and public grants to study railway system technology, transport telematics and logistics, automotive technology and engineering, and aeronautics.

Technical University of Berlin. The ITSP team visited the Institute of Land and Sea Transport Systems. The university studies cover transportation specifics dealing with integrated transportation planning, transport systems planning and transport telematics, rail vehicles, electric railway systems, and track and railway operations. The visit started with briefings on sound studies being undertaken by the students dealing with car airborne and impact sounds. The noise reduction studies include noise analysis and the impacts of low-noise construction. Noise prediction models were discussed using software analysis and calculation. The students have reviewed rail friction modifiers and rubber primary systems on bogies. The ITSP team was then taken into their laboratory to see the types of testing that the students conduct.

The students demonstrated the sound-optimized bogie frame of the new Berlin S-Bahn BR 481. The students were working on improving freight transport through an increase in productivity and reduction in sound emission of bogies. They advised that they were working on developing a new bogie using light-weight construction, reducing wear by the incorporation of radial steering, and using telematic systems. The ITSP team was then taken to a small laboratory and shown a demonstration of a model nose crash test and then participated in discussions on how the input data for the simulations are used and validated.

Bombardier (Hennigsdorf). Bombardier Transportation has supplied new generation trains ranging from the Autorail Grande Capacite (AGC) for regional high-seating capacity used in France to double-deck coaches used in Germany. The company focuses on attractive vehicles that achieve a high level of comfort. Currently Bombardier Hennigsdorf is producing rail cars for China, specifically the Shenzhen Movia Metro cars and the Metro cars for Shanghai and Guangzhou. Most of their car bodies are aluminum, but the industry is progressing toward alternatives. Once the car bodies are produced and the vehicles are assembled, they are transferred to testing and commissioning facilities.

Bombardier is involved in producing vehicles and vehicle systems for more than 40 countries worldwide across all continents. They stay abreast of the industry markets by optimizing products and services. In the European market harmonization is key and there is a supervisory board that assists in negotiations for harmonization. Bombardier participates in proposals for European standards in car manufacturing.

Bombardier teamed with Siemens to produce the ICE 3+ electrical trains for the Dutch and German railways. Currently these trains are being used on the Deutsche Bahn high-speed Frankfurt to Cologne line. These high-speed trains run at speeds up to 330 km/h. Bombardier has also teamed with Alstom to produce very high-speed trains and cars are being delivered currently for France's TGV system. The SNCF is seeking to increase the order. In general, all of the Bombardier rail cars have high seating capacities and customized interior layouts.

The ITSP team heard briefings from the car body design team leader and took a tour of the production factory, including a look at the EU cab mock-up train cab which was designed to include a EUDD that is TSI compliant. All Bombardier designs are based on being functional, consistent, standard, and fully integrated.

Deutsche Bahn AG (Berlin). DB's core business is rail; however, they also focus on air and other land and sea transport. DB is working strongly on improving freight and passenger rail transport. For its current sales figures, passenger transport makes up 45%, freight traffic makes up 49%, and the remaining 6% is for infrastructure. The infrastructure is used by many companies. Currently over 350 companies use the DB infrastructure and they pay for the use. DB believes that railways need to become more internationally competitive and acquire the same capability of crossing borders that aviation and roadway traffic now enjoy. The issue of harmonization of rail equipment, systems, and infrastructure is the key.

DB currently employs over 230,000 people of which 76% are dedicated to rail. It is an international entity with 80% of its workforce being in Germany and 20% abroad. There are currently over 7,000 DB staff members in the United States dedicated primarily to sea and air freight traffic. DB utilizes the European Train Control System.

Its European service passenger traffic is the first priority during the daytime hours. During the nighttime hours freight traffic takes the priority. As passenger traffic is a priority in the daytime, passive safety systems are a focus of DB. The design of bogies must respect the special requirements for passenger versus freight service. DB has had over 12 years' experience in promoting vehicle passive safety. As such, crashworthiness is of high importance. DB is currently working on "Sicher Reisen" ("Safe Journey"), which is a crashworthiness project that is tasked with improving passenger safety. The areas of focus with the intent of improving equipment are

- Front car safety,
- Bogie safety, and
- Between-bogie safety.

DB has found that 90% of all rail crashes are caused by human error, and the remaining 10% are due to equipment failure. One particular concern that the DB team is working on is the reduction of problems at level crossings. Currently, of the more than 22,800 level crossings, 10,735 are passive crossings in meadows and rural areas.

The ITSP team was taken on a tour of the Hauptbahnhof (Berlin Central Station). The multimodal station boasts five levels, on a footprint of 430 m^2, with connecting rail traffic from local and national networks, six glass panographic elevators, and heavy-duty escalators throughout; all bound by commercial and business spaces. Visitors to the station can shop, conduct business, and travel to all parts of Europe. The station utilizes a proof of payment fare system with no fare gates.

Siemens AG (Braunschweig). Siemens AG in Braunschweig is the largest plant for rail automation in the world. Currently there are more than 2,800 staff working on efficient solutions to rail automation. Siemens produces: track vacancy detection and locating equipment, electronic interlockings, operations control systems, automatic train control systems, and advanced telecommunications systems.

Siemens is a market leader in rail automation. They deliver railway signaling and automation for transit, operations control systems, and rail communications systems. They operate under the fail-safe principle and all designs incorporate full features of safety. The Trainguard MT communications-based train control system is a modular train control system that is fully scalable and can function from simple supervision and control operation to the more complex unattended train operation systems. The train control system supports the rail car driver with automatic functions.

In the operations control arena, electronic interlockings and relay interlockings can be controlled and monitored by remote control. Control- and safety-related facilities are monitored by electronic interlockings that are containerized by design. The SICAS S7 electronic interlocking is a solution for scalable automation of control and monitoring functions. It includes high-performance CPUs with standardized components driven by fail-safe digital interface boards.

The SICAS S7 has the ability to communicate over wireless LAN technology with no physical connection between components. It has the ability to host a website directly in the local control panel which allows for remote monitoring from any authorized computer. It is capable of vital and nonvital TCP/IP communication.

In the area of closed circuit television (CCTV)/video monitoring, Siemens has developed an advanced video monitoring system—"RailProtect." RailProtect software performs intelligent video processing from real-time input and produces alerts when specific events occur in the coverage zones. It logs the events and dispatches personnel to manage the event.

The ITSP team was taken for a tour of the Siemens factory. The rail automation factory was viewed. The system test center was visited.

France

Alstom (Reichshoffen). Rail transport is a core business for Alstom. It is a worldwide supplier of rail products, services, and systems, with 5.1 billion euro in annual sales and 25,781 employees worldwide. Alstom has 48 safety management personnel covering rail passenger interlockings worldwide.

In the Alstom transport facility in Reichshoffen, its team studies crashworthiness. Alstom is working on several projects dealing with collision passive safety. The intention is to complement the activity of existing safety-related projects and ensure that the work is aligned with the strategic research objectives of the European railway system through these projects: SAFETRAIN, SAFETRAM, and Safe Interiors.

Briefings were conducted on European standards on passive safety. The TSI set out a number of essential requirements for interoperability, which include safety, reliability and availability, health, environmental protection and technical compatibility, along with others specific to certain subsystems. The TSI defines the technical standards required to satisfy those essential requirements. The development of the TSIs are the responsibility of the ERA, which was established as part of the second railway package.

There was a review of crashworthy trains produced by Alstom: TGV Duplex end trailer, XTER, ATER, and the B6D. Safety and crashworthiness are key to the design of signals, braking systems, and other rail car components. The ITSP team was taken to the dynamic test bench to view the coupler retreat system in the front car nose. The design absorbs the crash. In tests with freight trains all of the shock was taken by the coupler and no damage was visibly present in the train carriage used in the test. The team then moved to the dynamic test facility where the tests had been conducted. Alstom created a special launching platform to create the speeds necessary for conducting the crash testing.

SNCF (Paris). SNCF is a public company assigned the role of holding the legal ownership of rail infrastructure, and organizing and supervising sustainable development. In 1997 SNCF was assigned the role of operating the railway and providing management services with respect to public infrastructure. SNCF pays railway circulation fees. It is a state-run company operating under French law. The SNCF group is made up of 726 companies covering trucking, logistics, station services, and all services complementary to running rail service. The total staff for the group is 206,000 people and the group sees 21 billion euros in turnover per year. They manage 31 km of rail, over 13,000 freight and passenger trains, and run over 1 billion passengers and 108 million tons of freight per year. Regional transport is their primary focus and will have a direct positive impact on regions through investment in upgrading rail stations, infrastructure, systems, and trains.

The ITSP team was shown video clips of crash testing including tests run on train-on-train head-on collisions and barrier collisions such as a crash with one train standing still and a collision between a train and an obstacle on the right-of-way.

EPSF (Paris). EPSF is a public body that operates under the authority of the Minister for Transport. It levies a tax for a small percentage of the fees charged for network access for use of the railways. This is its major budget contribution which comes from 0.5% of the fee paid for use of the rail network. This accounts for 80% of its working budget. The income is supplemented by fees charged for examining applications. Currently EPSF has approximately 80 staff, of which 60 are railway experts. The group is principally charged with guaranteeing safety levels throughout the rail system to all rail passengers, all local residents, and all personnel when it comes to rail service regardless of the operator. Even so, the crash investigation body is independent from the EPSF. It performs safety audits both with documentation and in the field on operators. The audits are mandatory every 5 years and include random surprise audits annually.

EPSF is also responsible for preparing all technical documents and recommendations concerning rail safety and for assisting state bodies. Overall the French government remains responsible for publishing safety regulations. Its purview covers safety systems, signaling systems, electric current, and language. It has experts on staff to certify new technology for the railway. The certification process includes sending the package to independent experts for first review; then the EPSF staff analyzes and completes the certification review process.

RATP Group (Paris). The RATP Group runs public transportation and urban mobility services in the French markets. It is a public sector industrial and commercial organization that is geared to provide passengers reliable, user-friendly daily service that carries approximately 10 million passengers daily across France's multimodal network. RATP is France's leading operator controlling 78% of the systems. It currently operates 13 Metro lines, 1 automatic Metro line, 330 bus lines, and 2 train lines, with 14,228 employees. This includes 300 Metro stations and 67 stations in outlying areas.

RATP constantly improves its systems and equipment. In 2005 the communications network was modernized with a new radio network that provides a platform for constant data exchanges between vehicles and fixed servers. RATP is currently working on improving the digital radio network as well as the improvement of computerization of station equipment. Additionally, RATP is working on two new surveillance centers in the Metro that will assist in providing remote guidance for communications, conveyance, station mechanical and electrical systems, payment counters, and ticket vending machines.

RATP briefed the ITSP team on the success of the Meteor Line 14 project implemented by Siemens. It was RATP's first step in implementing a driverless train line. The line functioned with an on-board communication-based train control with zone controllers that took charge of wayside functions for vital tracking of trains, authorized movement and direction management, and utilizing moving blocks for anticollision.

Siemens Transportation Systems (Paris). Siemens Transportation, a subsidiary of Siemens France, built a train operation automation system offering an adaptable service featuring greater responsiveness, increased line safety, and greater train on-time consistency. The Siemens project team briefed the ITSP team on the implementation of the Metro driverless train project.

The Metro line #1 was chosen to be fully automatic (driverless) because it is the busiest in Paris (over 160 million passengers per year) and has the best possibility for interconnectivity. Siemens provided the complete design of equipment, systems, and facility renovations to implement the Metro line #1. The Metro has had a high rate of suicides, particularly in areas where the rubber-tired fleet is used, due to the guarantee of death when a car runs over a passenger. The new line utilizes platform barrier gates for increased passenger safety.

The ITSP team was given a tour of the new stations used on the line, a ride on the driverless train, and then a tour of the new driverless train command control center. Real-time demonstration of the fully automatic train control features was given. The Trainguard MT technology utilizes moving-block continuous communication which allows for short headways and optimization of train speed.

United Kingdom

Transport for London (London). TfL focuses on passenger safety, comfort, and reliability of equipment. It is currently investing in CCTV monitoring, enforcing bus lanes, uncovering illegal and unsafe minicab operations, and handling unruly passengers. It seeks to improve passengers' journeys by improving personal security on and around the public transport system, improving bus journey times and decreasing congestion, increasing compliance with fare regulations on buses, increasing public transport use by under-represented groups, and delivering high value for fares spent to utilize the system.

Currently 5% of the rail is controlled by TfL and it sees 30% of the overall passenger traffic. In 2003 TfL took over responsibility for the London Underground, which was established in 1864. Safety has become a major player in conducting business. There are more than 400 route kilometers with 275 stations and more than 500 peak trains with 3.25 million customer journeys per week day. In all of this it experiences an average of one death in 180 million customer trips.

In 1975 the Underground experienced a major train crash where 43 people died; due to safety standards implemented, there has not been a death on a train since then. In 1987 there was a major fire at Kings Cross. The fire started on an escalator. The response had failings at every level and damage and injury was high. As a result 7 billion pounds were invested on safety and major safety physical improvements were made. In addition legislation demanded changes to improve safety and training for management and staff, process, and procedures.

TfL currently uses safety risk modeling and it allows "what if" scenarios to guide safety analysis and improvements. Safety is managed by TfL personnel supported by three professionals in risk management. Based on their modeling they know that the base value of avoided fatalities is 1.4 million pounds. TfL is working to ensure that transfers between services can be made safer, quicker, more convenient, and secure. It believes that this will make the network more attractive to new passengers and improve the passenger journey. It also will greatly improve the overall integration and flexibility of the network, which in turn makes the network operate more efficiently. There are nearly 600 interchanges in the Greater London area that are being focused on for redevelopment.

TfL's Network Response Manager then took the ITSP team to its command control and response center for briefing and demonstration of safety and security monitoring activity. The control center is tied into every station and wayside through real-time CCTV systems. They are directly connected to local policing jurisdictions for a fully coordinated response to any events that may arise.

Transport Research Laboratory/DeltaRail (Crowthorne). TRL applies research and consultancy into all aspects of infrastructure including design, maintenance and assessment of pavements and structures, whole life costing, and environmental impacts and management for road and airfield pavements. It develops sustainable solutions and management procedures for assets and resources; assesses the condition of infrastructure; and analyzes material behavior for fatigue, impact loads, dynamic and static testing, non-destructive testing, and the understanding of long-life deterioration. TRL regularly advises on policy and assists governments with standards both in the United Kingdom and overseas.

Its state-of-the-art facilities in Crowthorne offer the latest technology to meet the needs of research. The facilities include

- A private test track and road network to test out the latest developments in vehicles, environments, and systems;
- A virtual driving simulation center hosting a full-mission car driving simulator;
- Technology used to develop human-body modeling suites and crash test dummies;
- Impact test facilities that enable vehicles and vehicle components to be tested in a wide range of conditions; and
- A structural testing facility to measure behavior of materials.

TRL's library and data resources provide a wide range of knowledge and cutting-edge research databases. Its testing is supported by photographic, multimedia, and broadcast video services.

The briefings conducted for the ITSP team included occupant protection in rail car cabs, crash investigation, crash testing techniques, development of crash test dummies, driver protection analysis, passenger seating scenarios, and an overview of testing and validation information. Additionally, the briefing included discussions of vehicle elements that contribute to the overall safety of passengers, such as windows and emergency lighting. The ITSP team was taken on a tour of TRL's crash test laboratory.

Rail Safety and Standards Board (London). The RSSB acts as an independent not-for-profit company owned by major stakeholders. It was established in 2003 under parliament's recommendation for an independent industry safety standards setting board. The RSSB services include safety policy, risk and safety intelligence, railway group standards, research and development, U.K. rail industry involvement in Europe, systems interface management, industry initiatives, and formal inquiries. Balancing safety risk and health is its focus. RSSB core objectives are to

- Lead and facilitate the railway industry's work to achieve continuous improvement in health and safety performance;
- Facilitate the reduction of risk to passengers, employees, and the affected public; and
- Aid in compliance by service providers.

RSSB currently is undertaking projects with new technologies that will improve system performance and passenger safety. RSSB envisions results of research to provide real-time knowledge of train positioning and speed. Currently the on-train issues are being addressed and the control of the network and the traffic will come later. The RSSB head of engineering research briefed the ITSP team on crashworthiness research.

The technology on which existing U.K. railway voice radio systems are based is outdated and, because of the dated nature of the technology, maintenance will become increasingly difficult. Renovation of the train communications systems will make possible a significant improvement in the quality of voice and data communications across the entire network and all applications will be managed within the one system. The new radio system will continue to provide secure voice communications between trains and signalers and will also provide a more consistent method of operation than the current legacy systems.

APPENDIX C—LIST OF ABBREVIATIONS

APTA	American Public Transportation Association
ATO	Automatic Train Control
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
CBTC	Communication-Based Train Control
DB	Deutsche Bahn AG
EBA	Eisenbahn-Bundesamt
EPSF	Établissement Public de Sécurité Ferroviaire
ERA	European Railway Agency
ERRAC	European Rail Research Advisory Council
EU	European Union
EUDD	European Driver's Desk
EURNEX	European Rail Research Network of Excellence
FAV	Forschungs- und Anwendungsverbund Verkehrssystemtechnik
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HSR	High Speed Rail
ICE	InterCity Express
ITSP	International Transit Studies Program

MODLINK	MODTRAIN project focused on man-to-machine and train-to-train interfaces
MODTRAIN	Innovative Modular Vehicle Concepts for an Integrated European Rail System
RATP	Régie Autonome des Transports Parisiens
RFF	Réseau Ferré de France (French rail network)
RGS	Railway Group Standards
RSSB	Rail Safety and Standards Board
SAFETRAIN	EU initiative to devise manufacturing standards to maximize vehicle crash-worthiness and occupant survivability
SELCAT	Safer European Level Crossing Appraisal and Technology
SNCF	Société Nationale des Chemins de Fer Français
TCRP	Transit Cooperative Research Program
TfL	Transport for London
TGV	Train à Grande Vitesse
TRB	Transportation Research Board
TSI	Technical Specifications of Interoperability

APPENDIX D—SELECTED VEHICLE SAFETY MEASURES

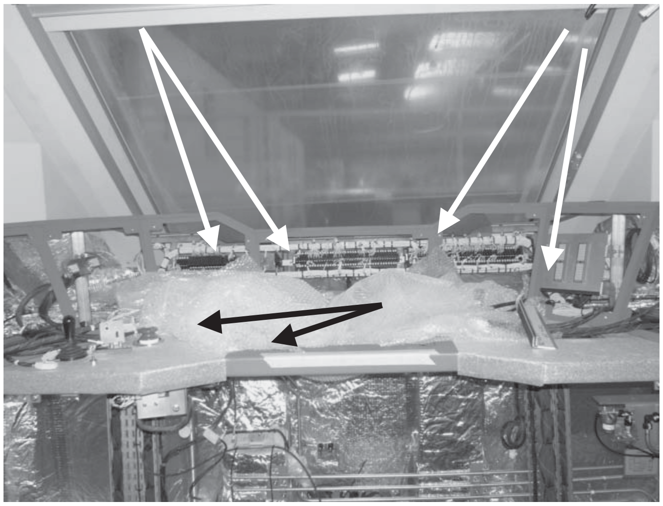
Active Safety

Cab Design

Bombardier and FAV representatives discussed cab design and its importance concerning crash avoidance. EU cab designers have studied the eye, hand, and foot movements of locomotive drivers and have developed a control panel and seat arrangement that is ergonomically superior to past configurations. Of utmost consideration is the fatigue and repetitive actions that a driver encounters while operating a locomotive. Elimination of these operational detriments will optimize driver performance and accomplish a major goal toward crash prevention. The new control panel is being considered as a future standard for locomotives that will be operated on an integrated EU railway system. All control instruments have been functionally grouped to ensure quick response concerning acceleration and braking modes of the train. Designers have incorporated a one-hand operation through which a driver can place the train into a propulsion or combined electro-pneumatic train line brake mode utilizing one handle. The cab itself has been designed with day and night vision taken into consideration. The new vision glass provides an enhanced view of the front of the locomotive with no obstruction. For night driving, a new digital display provides a bright, easily readable instrument that enables the driver to monitor all locomotive and train operating characteristics. The seat can be adjusted for driver height.

Truck (Bogie) Design

Bombardier representatives discussed the critical importance of trucks. Rail vehicle trucks include wheels and axles; primary and secondary suspension systems including springs, hydraulic shocks (dampers), and air bags; and braking equipment including air piping, calipers, tread brake units, cylinders, brake shoes, and traction motors (on powered trucks). Trucks are the most critical components on a rail vehicle, for they guide the vehicle along the right-of-way. These components are also subjected to the greatest wear-and-tear on the vehicle as they are subjected to continual lateral and vertical forces from the track and bar body. During operation, it is imperative that an efficient wheel/rail interface is maintained.



New EU modularized cab features a control panel with functionally grouped instruments, a one-handle locomotive operation, digital display, and a large windshield that is free of obstacles.

Modular cab design.

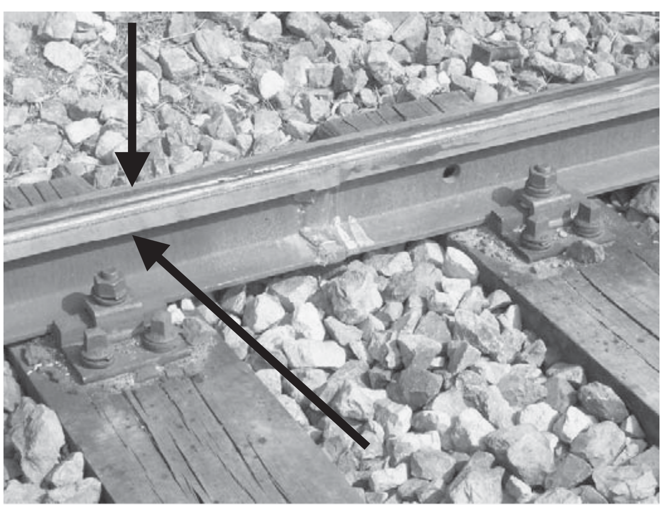
Bombardier and Alstom designers have been working to improve the durability and reliability of passenger car trucks to ensure that a high level of safety is maintained and enhanced on future car designs. Ultimately, their designs are focusing upon the prevention of derailments. Truck durability is particularly critical considering the fact that future rail cars on an integrated European system will be traversing tracks on different national railroad tracks. For high-speed trains (ICE, TGV), this will include tracks that were designed with critical tolerances for exclusive high-speed operation, and conventional tracks where a combination of passenger and freight traffic cause roadbed conditions where excessive lateral and vertical forces may be encountered.

Bombardier representatives discussed lateral and vertical forces that are placed on the truck during motion, and their critical importance to the engineering calculations required for the design of a truck. The lateral force and vertical force on the wheel, as well as the wear condition on the gage face of the rail, can cause wheel climb.

Passive Safety

Crash Energy Management

In the event that all active safety variables fail and there is a head-on collision between two trains, passive safety devices must be designed into rail vehicles to mitigate injuries to the train crew and passengers. EU rail car designers are working to incorporate crash energy management (CEM) characteristics into present vehicles that are being rehabilitated and new future designs.



The determinate of the likelihood of derailment is defined mathematically as the ratio of lateral to vertical wheel set force acting upon the head of the rail.

Lateral/vertical ratio.

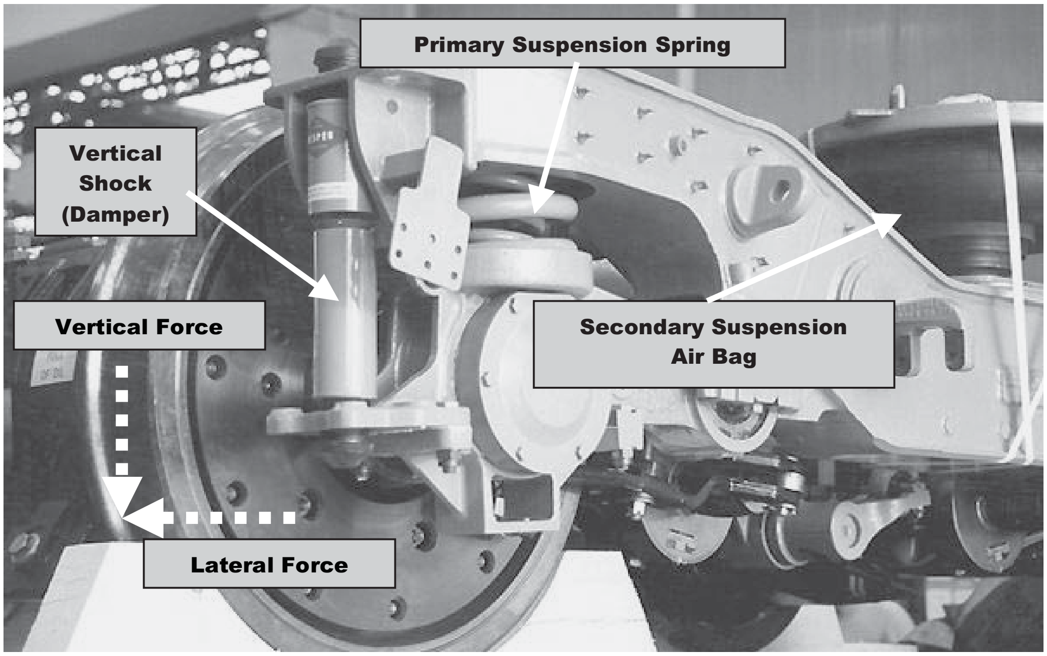
Representatives of various state agencies and manufacturers, including the Technical University of Berlin, Bombardier, DB; Alstom, and SNCF; the Transport Research Laboratory (DeltaRail); and the RSSB discussed the importance of incorporating CEM into the design of new rail vehicles. CEM is a design concept that absorbs energy that is generated when a rail vehicle or a train consisting of several rail vehicles comes into frontal impact with another object. This design considers the longitudinal dynamics of the train, distributing collision energy among cars in a train consist. CEM rail cars can more efficiently absorb collision energy, as this energy is transferred to the front end of the locomotive and to the following cars within the train. Key to the CEM design is the incorporation of a series of crushable elements into locomotive and car designs. In the event of a collision between a train of rail cars and another train or object on the right-of-way, the resulting vertical and lateral motions of the vehicles in the train are limited. Thus, coupled car interactions are controlled, and the saw-tooth buckling and consequent overriding and derailment of the cars in the train can be successfully minimized. Most importantly, CEM maintains the occupant survival space and structural integrity of the locomotive and cars in the train consist, thereby reducing serious injuries and fatalities.

Bombardier and Alstom rail car designers have considered several scenarios during crash tests. Parameters of weight and speed were developed for each of the following:

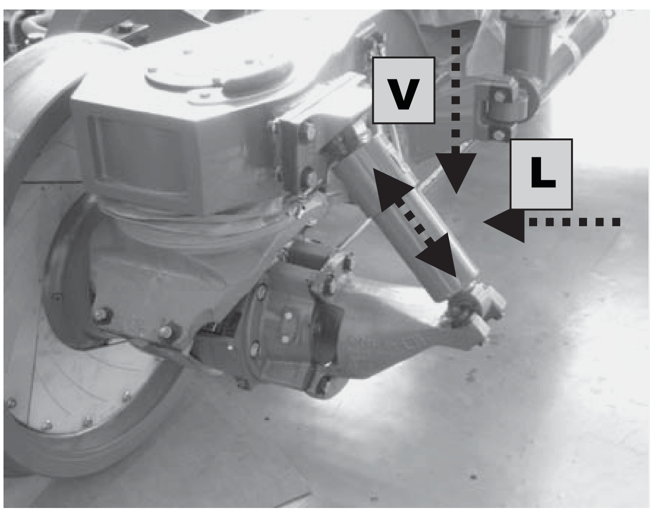
- Front end impact between identical trains
- Front end impact between a streamlined passenger locomotive or rail car and a freight car with side buffers
- Impact with a truck on a railroad crossing
- Impact with a low obstacle on the right-of-way or a small auto on a crossing

The passive safety focus is being considered for the following types of EU rail vehicles:

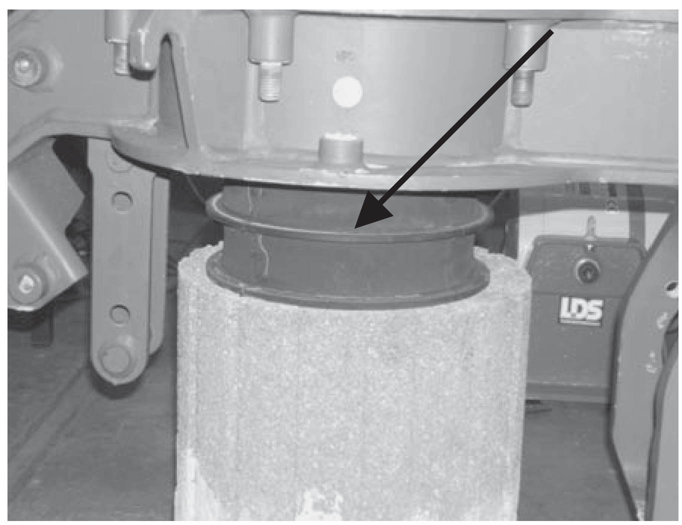
- High-speed and conventional locomotives and coaches
- Metro (subway heavy rail vehicles)



Components that stabilize a truck during operation, absorbing the lateral and vertical forces of movement along a track, are the primary suspension springs, secondary suspension bags, and dampers. Advanced EU truck designs incorporate suspension devices that employ the latest technology, assist with truck tracking along the rails, and provide an improved rail vehicle ride for passenger comfort.



Shock (damper) that stabilizes the truck against both vertical and lateral movement.



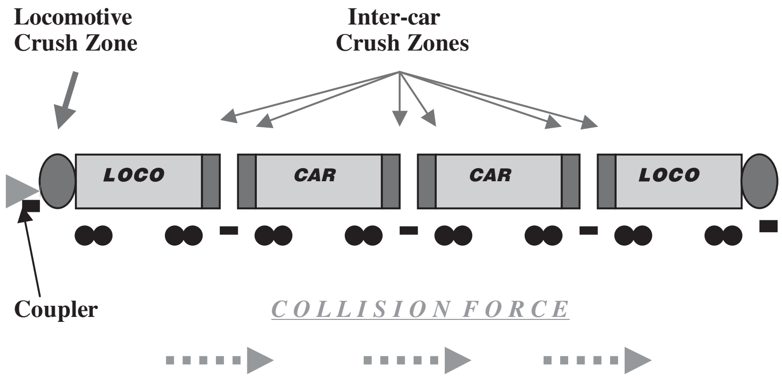
Primary suspension spring

Components that stabilize a truck during operation.

- Tram trains and interurban (periurban) vehicles
- Light rail (tramway, local street) vehicles

Locomotive Cab Design

In the locomotive or operating cab car, the primary concern is the protection of the driver. In the event of a collision, the driver must be able to survive the initial impact and have a means of escape. EU vehicle designers have been working on a monocoque cab construction design that will absorb the major stresses created as the result of the impact of a head-on crash. The cab is designed with the driver's seat mounted on a platform. This platform moves under



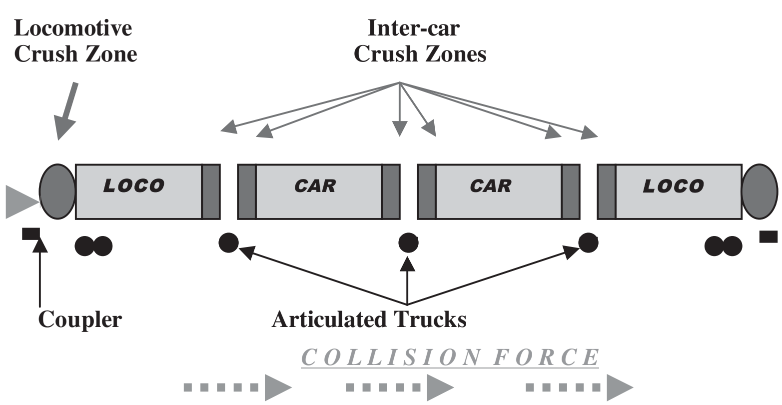
As the train encounters an obstacle on the right-of-way and strikes the obstacle, the force of impact is absorbed largely by the buffer absorbers in the locomotive coupler and is then transferred to the locomotive crush zone. The longitudinal force is then distributed through each of the inter-car crush zones.

A train consist of individual linked cars with their own trucks.

the extreme forces that are exerted in a collision. The seat is resultantly pushed away from the front of the locomotive toward the rear of the cab.

Special consideration has been given to doorways on the car body structure of the locomotive that lead to the engine room. These doorways provide a means of emergency egress for the driver and have been re-enforced to ensure that frames do not buckle in the event of a collision. Doors can then be quickly and easily opened for escape. Designers are concerned about the opening motion of the doors and have considered doors that can be opened in either the inward or outward positions enabling the driver to either pull or push the doors open quickly. This is a concern for designers because the driver may need either to push or pull the door open. As an example, analysis indicated that the forces exerted upon the driver and door of a quickly braking train will make it virtually impossible for a driver to push a door against the direction of deceleration, because deceleration makes it easier to pull the door open. Also, there is a concern that damaged components in the engine room may make it impossible to push the door open. Pulling may provide the only alternative for a means of escape.

As noted earlier, the CEM design is being incorporated into the construction of locomotives and passenger rail cars because it limits the deceleration rate, reduces the risk of derailment, reduces the risk of overriding (particularly on the front end of the locomotive), and maintains the integrity of each vehicle's car body



Through tests, EU designers have found that articulated cars (cars that share a truck between each of the individual units) have less of a tendency to derail. If they do derail, it has been determined that the articulated trucks usually remain within the confines of the two rails of the track, preventing saw-tooth buckling.

A train consist of articulated cars that share trucks.

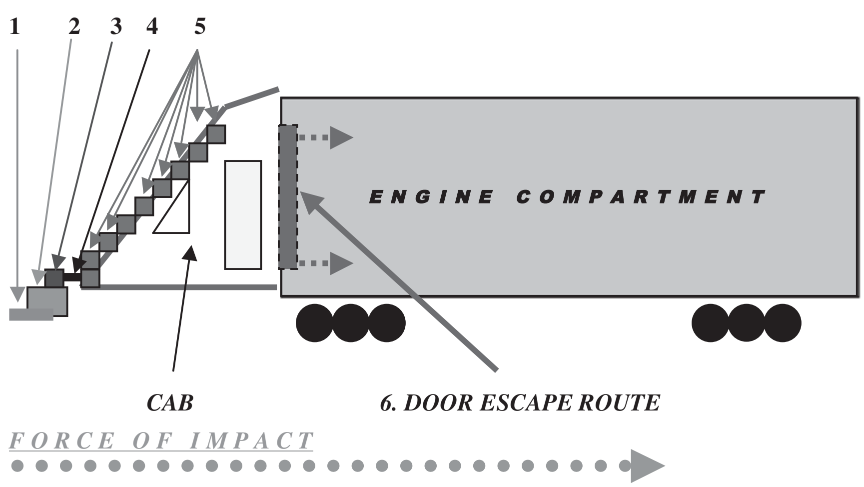
structure, thus maintaining the survival space of the driver, other crew members, and passengers.

Passenger Car Design

DeltaRail Group representatives discussed EU SAFETRAIN and Safe Interiors, and gave an in-depth look at several aspects of the projects. These are projects through which EU vehicle designers have been working to enhance the interiors of passenger rail vehicles. Work is being conducted with the following objectives in mind:

- The preservation of survival space
- The prevention of the intrusion of foreign objects from entering the passenger compartment, either from the undercar section, the roof, or the windows
- Prevention of ejection of passengers through the windows or doors
- Fire prevention—in the event of fire, inhibiting its spread throughout the compartment
- Prevention and mitigation of passenger injuries while seated and standing
- Escape aids in the event that passengers must evacuate for their safety

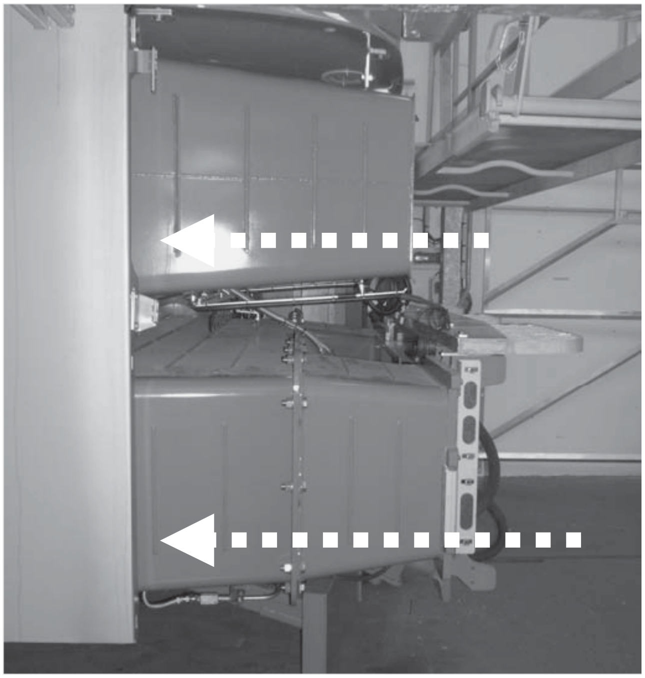
DeltaRail engineers have been determining and recommending relevant criteria and design requirements for passenger accommodations in order to achieve the maximum vehicle crashworthiness and improvement in passenger safety. The study of past railway crashes revealed that secondary impacts within a rail vehicle seldom result in fatalities. However, passengers have received major injuries while seated or in a standing position during a collision. Studies have revealed that the speed of vehicles and their interior components reduces rapidly after a collision. However, the velocity of a projected occupant remains relatively constant. They will impact a table or the back of another seat while seated, or a pole, wind screen, stanchion, or other object within the car before coming to rest. Engineers have utilized the science of biomechanics to study specific injuries that are sustained to the body when subjected to a collision with an obstacle within a rail car. Through actual tests conducted on crash dummies, 18 body segments have



In the event of a collision, the locomotive or operating cab car front end is the first point of contact and will absorb the initial energy.

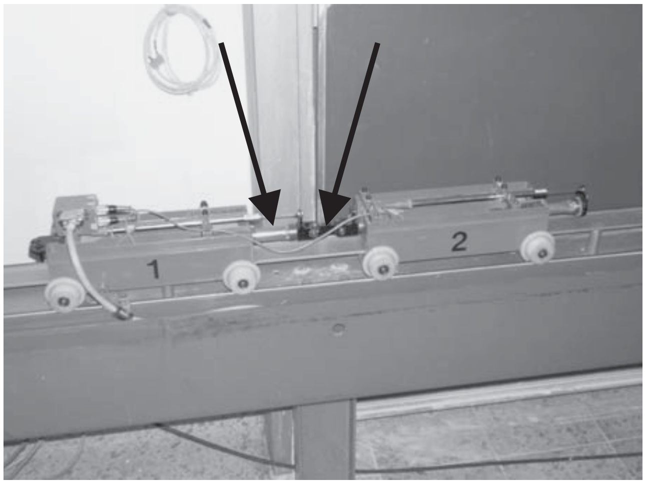
1. Coupler comes into contact with the object and is pushed back into the buffer.
2. The front end coupler buffer will slide back and crush honeycombed type construction materials.
3. When this buffer has reached its full stroke, it will compress a second buffer. When this compression is completed, the buffer will be resting and inline with the frame of the vehicle car body.
4. The anticlimber device prevents the colliding trains from telescoping.
5. The load is then transferred to the crush zone of the engine cab.
6. The driver escapes through the cab door into the engine room. The frame of the door is constructed so that it is protected from any crushing or warping. The door can be opened either way.

CEM design for locomotive cab car.



The front end coupler buffer will absorb the initial collision force and slide back. When this buffer has reached its full stroke, a second buffer will absorb energy and compress. These buffers dissipate the collision force before it reaches the locomotive or cab car crush zone.

Tests are conducted on actual rail cars and locomotives. A gas-fired rail car is propelled at high speeds into locomotive and car ends that employ various types of crash buffers.



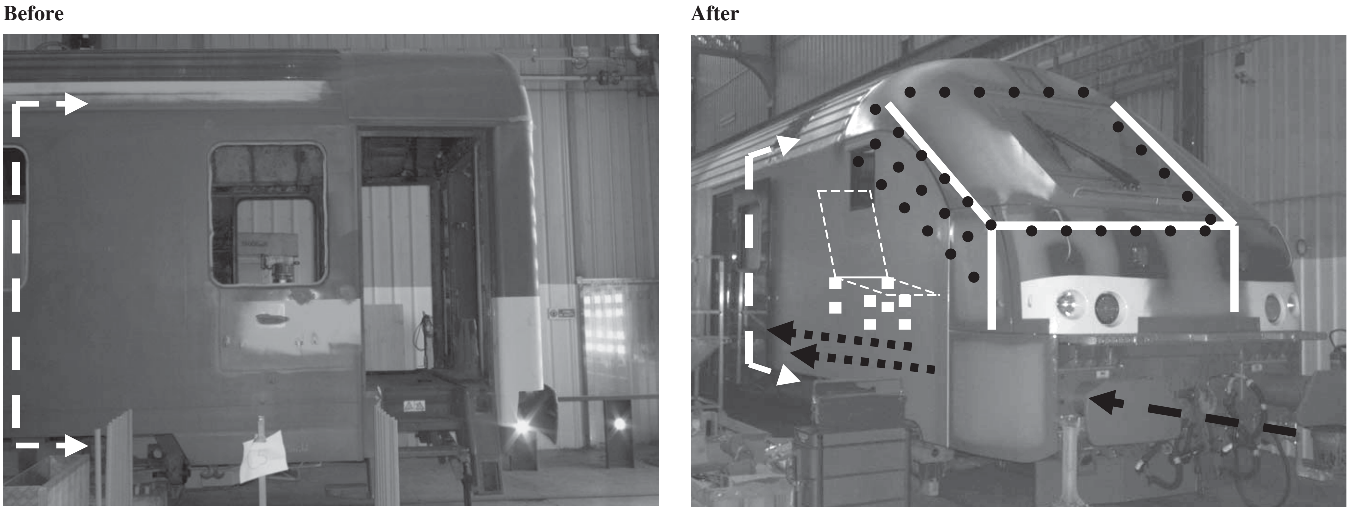
Simulated crash energy management tests are conducted utilizing models. These models have scale crash bumpers.

CEM tests conducted at the Alstom facility.

been studied—head, two arms, two forearms, two hands, two thighs, two feet, and the vertebral column including five segments. Computer simulations have been developed through which dummies wired with sensors have simulated human injuries when subjected to collisions with objects within a rail vehicle.

Seats and Tables

Designs. Crash data revealed that occupant impact with seats represents the main cause of secondary impact injuries. Seats, however, also provide the most efficient way to restrict the bodily movement and therefore, minimize the seriousness of any in-



The impact force is initially absorbed by the buffers in the coupler. The cab structure is strengthened by collision posts (solid lines). The force is then absorbed by the crush zone (dots). Note that the drivers seat is p ushed back by the force of a collision to increase the survivor's space.

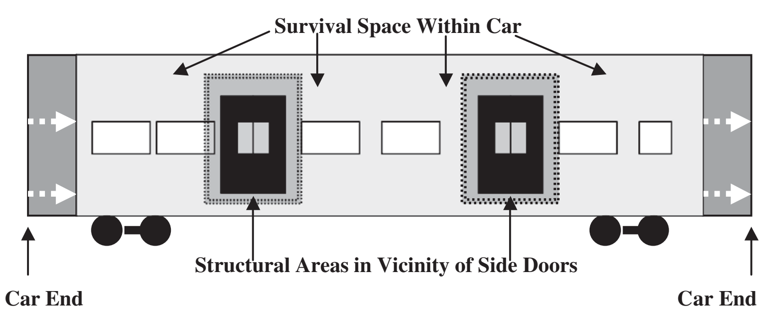
Operating cab car before and after modification.

flicted injuries. Concerning the arrangement of seats, it has been determined that

- Unidirectional seating is best for injury mitigation.
- The second best arrangement is an open bay with table. However, the table must possess thick round edges that have crush zones embedded into the table structure. The table must be firmly attached to the floor of the vehicle to prevent it from becoming a projectile.
- The third safest arrangement is an open bay without a table.

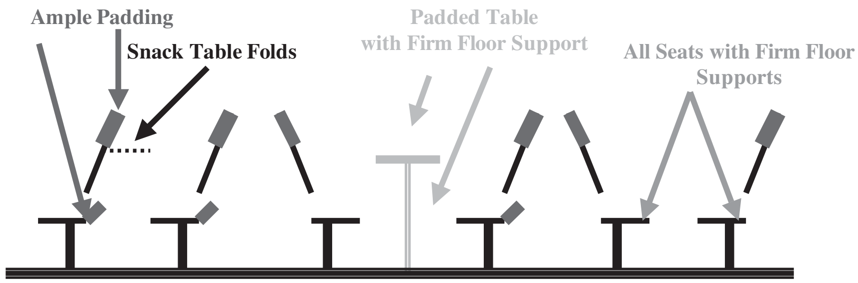
Engineers have determined that the design of seats must satisfy several requirements, including the following:

- Seats must resist the impact forces occurring on collision.
- Seat backs should be sufficiently high and well padded on both the front and back sides so as to afford proper support for the head and neck of a rearward traveling passenger and not to cause face or neck injuries to a forward traveling passenger who impacts with the seat ahead.
- On a unidirectional seat equipped with a folding snack table, the table should be designed as to not constitute an injury hazard. Tables that automatically lift or fold in an accordion manner are being studied.
- The low back side of a unidirectional seat should also be equipped with an energy-absorbing padding element for the protection



CEM design considerations are given to the preservation of survival space within a passenger car. The ends of the car will absorb some of the impact. Note that EU designers have designed the front ends of locomotives and cab cars to absorb the highest percentage of a collision impact. The ends of the cars within a consist will also act to buffer the collision impact, spreading the longitudinal force of the impact throughout the train. Note that serious considerations have been given to the preservation of structural vehicle areas in the vicinity of side doors.

CEM design for passenger car.



The unidirectional seating shown (on left) is the safest. Open bay seating with a table (in center) is the second safest. Open bay seating (on right) is the third safest.

Seating Configurations

of knees and lower legs of the passenger in the seat behind.

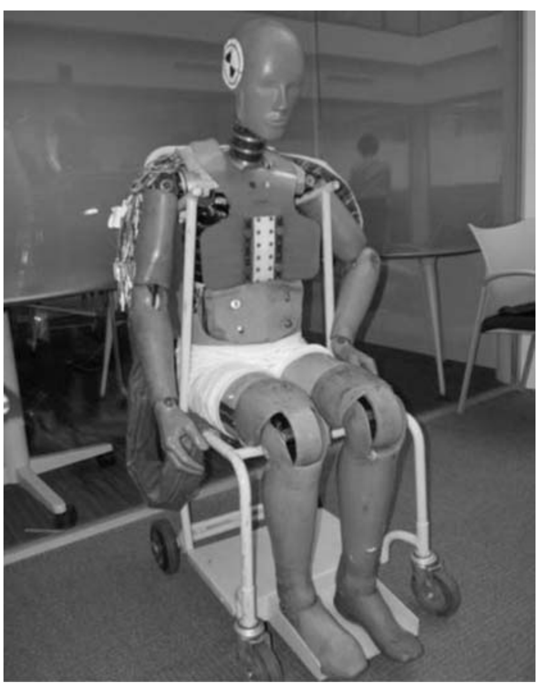
- Finally, seats must be firmly mounted to the vehicle floor to prevent dislodging during the initial collision and secondary impact of passengers striking the seat.

Seat belts were considered. However, it has been determined that they do not provide the utmost in desired protection. This deduction was made taking into account that all passengers would not wear seat belts. In a unidirectional arrangement, passengers not wearing seat belts would become projectiles that would collide with the seat ahead of them. If occupants in the forward seat were wearing the seatbelts, they would be thrown forward with the compounded weight of the non–seat-belted passengers who were projected forward from behind. Their injuries would be compounded. Studies are still being conducted concerning this and other seat considerations.

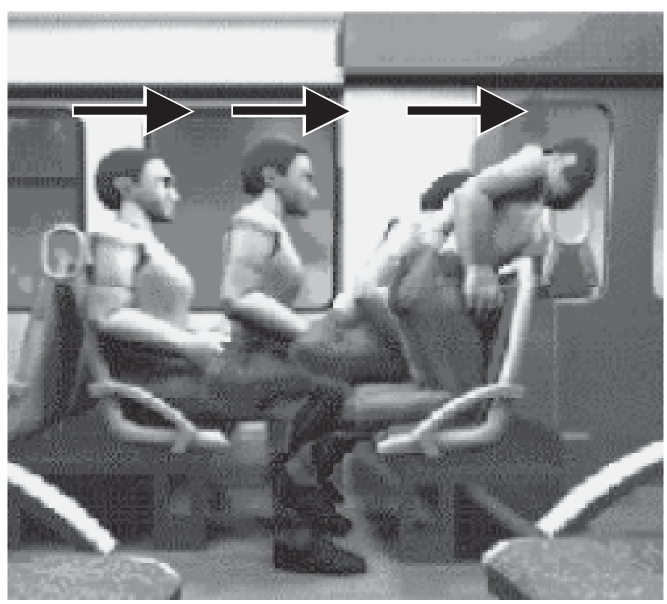
Fire, Smoke Retardation. DeltaRail engineers are looking into seat, tables, and other interior equipment materials that have a lower tendency to spread flame, with lower smoke toxicity. This is a special concern as they look for additional padding on seats and other interior equipment.

Windows

DeltaRail engineers have studied past crash scenarios and have analyzed the effect of windows on



Crash dummy used to study injuries to the body.



Without any restraint, a passenger in the open bay will continue moving as the vehicle slows down.

Movement of a passenger's body in an open-bay seating configuration during the force of a collision.

passenger fatalities and serious injury. Considering the results of the studies, they have had two primary concerns:

- Prevention of passenger ejection when windows break
- Prevention of foreign debris from entering the passenger compartment when cars leave the right-of-way, saw-tooth buckle, and turn over

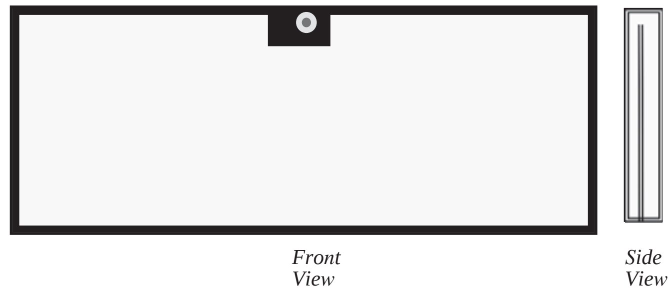
The designers have determined that, in the event of an emergency, it is best for passengers to remain within the confines of a vehicle until first responders arrive. This is the case if the car structures are sound and there is no fire or smoke.

Therefore they have determined the following:

- Hard glass windows must be impervious to hard projectiles that may be thrown against windows during a collision/derailment.
- The windows must contain passengers. Passengers must be persuaded not to exit through windows. Doors must be used for exit when available.
- Windows must provide egress as a last resort and must enable entry by first responders.

Doors

Doors are important on a rail vehicle because they provide a means of egress in the event of an emergency. As noted earlier, Bombardier and Alstom engineers are concentrating on strengthening the integrity of the car structure around door areas to ensure that they are not deformed in the event of a crash. Any



Present train car window designs incorporate a small section (dot within dark rectangle) that can be struck with a hammer to break the pane from the interior of the car. The side view indicates a laminate with two panes of glass separated by a plastic piece that will prevent entry of foreign materials. The outer pane is struck by first responders. The plastic is then cut and the second pane broken for emergency passenger egress.

Window hardened to prevent foreign objects from entering.

deformations in the side- and end-door operating areas could inhibit the sliding action of the doors.

As noted earlier in this report, windows must be considered the exit of last resort. Passengers are recommended to stay within a car structure and await the assistance of first responders. However, when absolutely necessary for safety reasons, passengers must utilize doors in the middle or ends of vehicles for exit. New designs include clear signage of luminescent materials that direct passengers how to operate doors in the event of an emergency where the electrical power is lost. On new cars, special emergency handles are being placed alongside doors with clear instructions for use. There are also buttons for direct communication with the train's crewmembers.

Actual emergency device in the interior compartment of the DB high-speed ICE train.

Emergency door controls and an intercom button aboard a new rail vehicle.

Lighting

DeltaRail engineers have given considerable attention to new emergency lighting technology. Studies of past crashes have determined that emergency lighting is essential to calm the fears of passengers who have been involved in the traumatic experience of a wreck. Passengers will be reassured by a well-illuminated car interior and will have less tendency to panic. It is preferred that passengers remain aboard vehicles and await first responders. An illuminated interior will provide a greater sense of safety than one that is totally dark. Illumination may persuade passengers to remain aboard for assistance. Well-placed emergency lighting fixtures must also direct passengers to available exits when evacuation is essential. Illumination will also help to reduce additional injuries to passengers as they negotiate vehicle interiors that may be clogged with debris and damaged structural areas. Emergency lighting must be reliable and have the following characteristics:

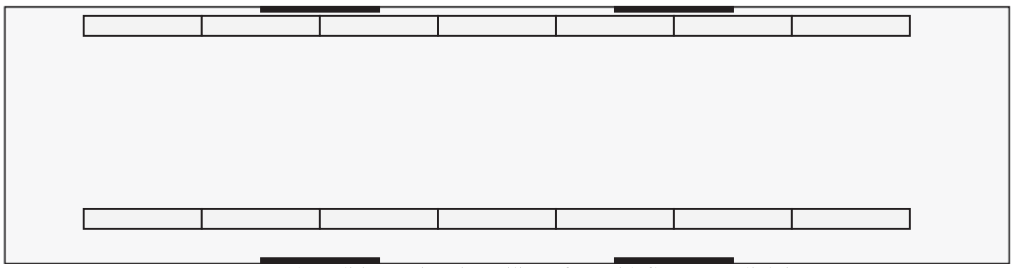
- Robust—fixtures must survive all forces exhibited in a crash
- Self-contained energy source
- Uniformity of lighting—no bright and shaded areas
- Very low voltage, amperage draw
- Last a minimum of 3 h

Paris Metro

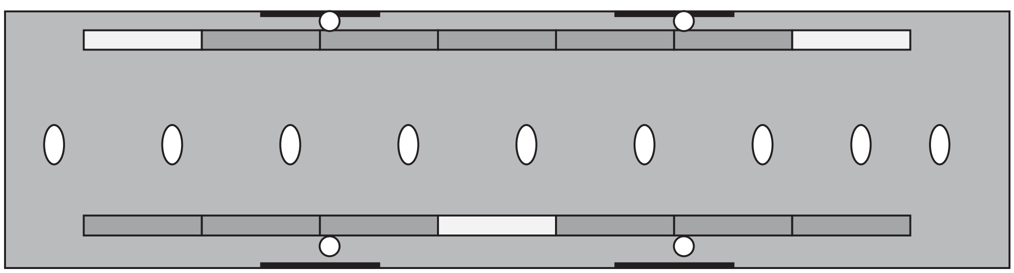
London Tube

Emergency alarms (without emergency opening mechanisms) in door areas of present Metro vehicles.

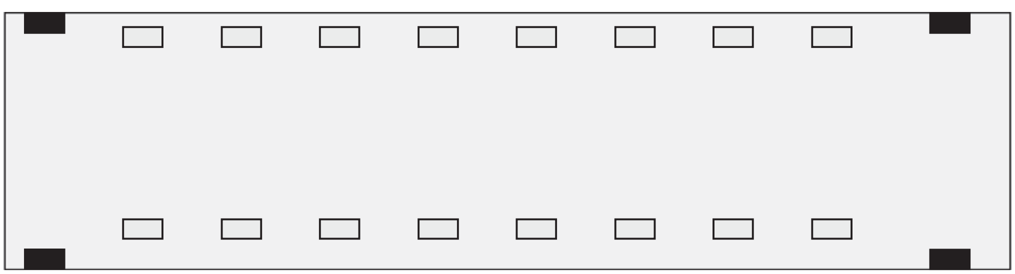
Light Emitting Diode Technology. Researchers investigated the utilization of light emitting diode (LED) technology for a new generation of emergency lighting. LEDs are low voltage, low amperage lights that are capable of emitting a bright light over an extended period of time. Technological advances have produced a new spectrum of white light that can be clearly seen. Fixture lenses disburse light uniformly over a wide area. Because of their low current draw LEDs will remain illuminated for long periods of time on battery-generated power. Fixtures can be manufactured utilizing hard plastic that makes them robust against external forces. Because of these attributes, designers have determined that self-contained LED fixtures are ideal for emergency lighting in EU rail vehicles. LED units can be installed in the interiors of new cars. Because of their self-contained power supply, the fixtures can also be installed in older cars without the expense, staff-hours, and maintenance entailed with wiring installations.



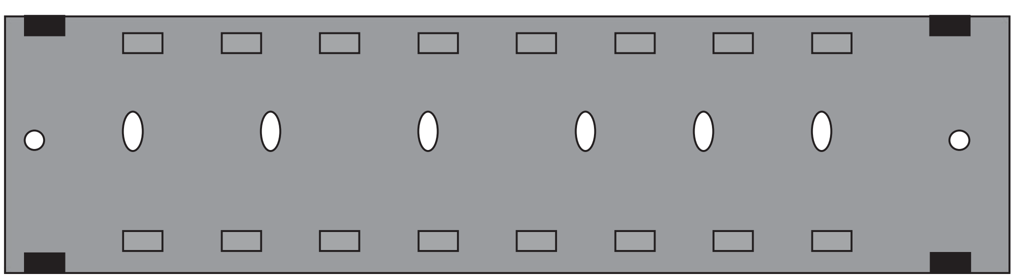
Normal conditions—interior ceiling of car with fluorescent lighting.



Emergency—LEDs emit white light in center of car and over doorways.



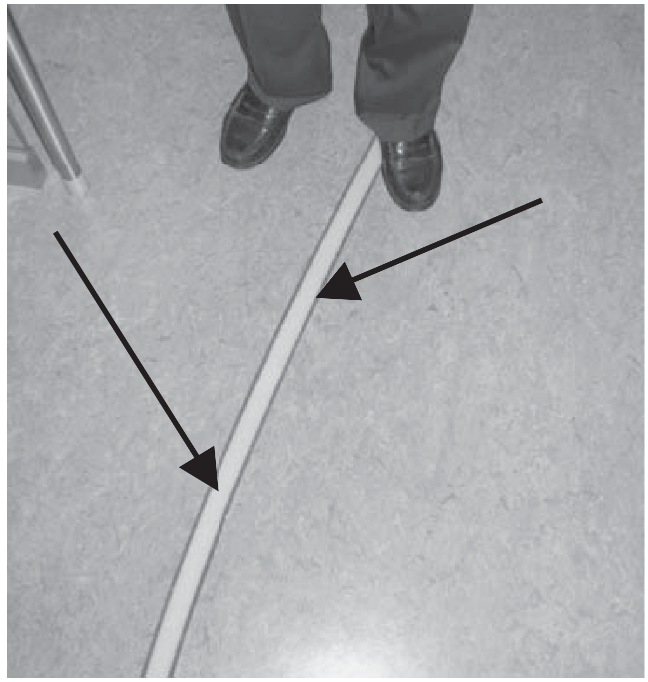
Normal—interior ceiling of older car with incandescent lighting.



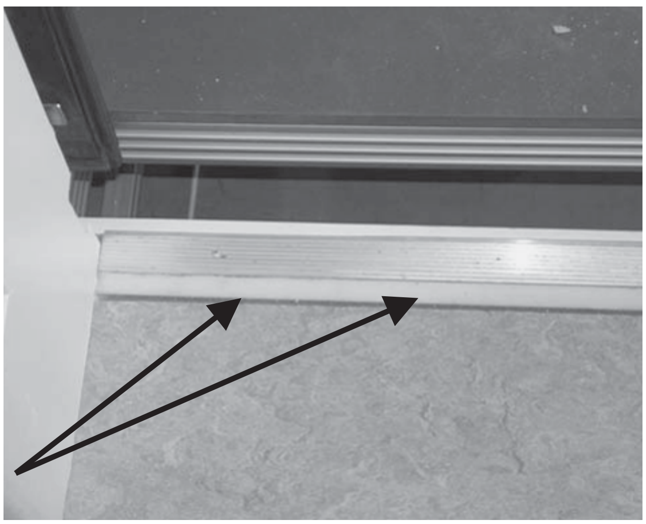
Emergency—LEDs emit white light in center of car and over doorways.

Normal and emergency lighting in cars equipped with fluorescent and incandescent lighting.

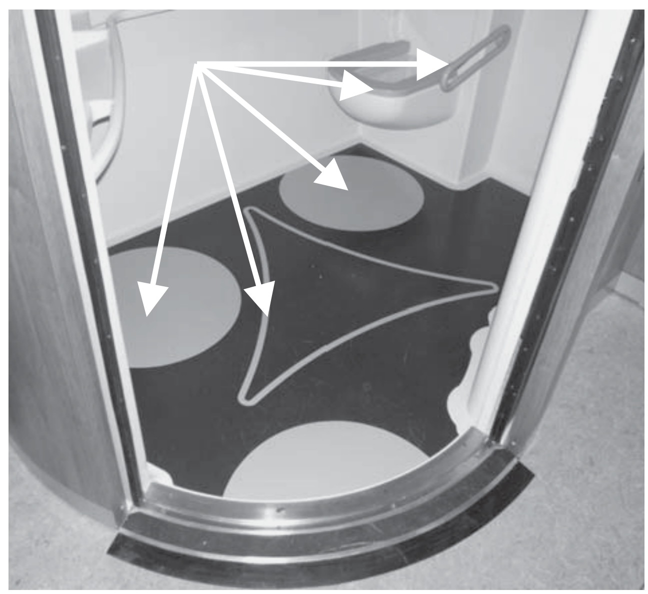
Luminescent Technology. DeltaRail engineers have also looked at chemical technology and the development of luminescent striping and signage to assist passengers in rail vehicles in the event that electrical emergency lighting totally fails and the interior is left in darkness. Strips can provide a low level of lighting in the passenger compartment, and guide passengers toward emergency exits. Luminescent signs can provide critical information concerning vehicle exiting, the activation of emergency doors, and other emergency apparatus. This technology is being installed in new railroad and Metro vehicles by Bombardier and Alstom.



Luminescent materials utilized along the floor.



Luminescent materials utilized at a doorway threshold.



Luminescent materials utilized in the lavatory of a new rail vehicle.

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