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Report on the Spring 2005 Mission

IMPLEMENTING NEW TECHNOLOGIES IN MAINTENANCE SYSTEMS AND DEPARTMENTS IN EUROPE

This TCRP digest summarizes the mission performed April 7–22, 2005, under TCRP Project J-3, "International Transit Studies Program." This digest includes transportation information on the cities 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 most recently 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 2-week mission, after which team members return home with ideas for possible application in their own communities. Team members are encouraged to share their international experience and findings with peers in the public

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transportation community throughout the United States. Study mission experience also helps transit managers to better evaluate current and proposed transit improvements and can serve to generate potential public transportation research topics.

Study missions are normally conducted in the spring and fall of each year. Study teams typically consist of 14 individuals, including a senior official designated as the group's spokesperson. Transit properties are contacted directly and requested to nominate candidates for participation. Nominees are screened by a committee of transit officials, and the TCRP Project J-3 Oversight Panel endorses the selection.

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-3 funding.

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

About This Digest

The following digest is an overview of the mission that investigated the application of new technologies in bus and rail transit operations in Germany, Austria, and France. It is based on individual reports provided by the team members (for a roster of the team members, see Appendix A), and it reflects the views 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.

IMPLEMENTING NEW TECHNOLOGIES IN MAINTENANCE SYSTEMS AND DEPARTMENTS IN EUROPE

The theme of this study mission was "Implementing New Technologies in Maintenance Systems and Departments in Europe." Over a 2-week period, the study team met with senior officials and management staffs of transit agencies in eight major European cities: Berlin, Potsdam, and Dresden, Germany; Vienna and Linz, Austria; and Paris, Rouen, and Orléans, France (for a list of host agencies, see Appendix B). All of the cities visited are operating in environments with intense pressure to reform transit systems. Public subsidies in some localities are decreasing. In addition, the European Union (EU) has required that, by 2008, transit systems must demonstrate the ability to operate efficiently or be opened to free or controlled competition.

The transit agencies are rising to this challenge in part by turning to technology as a means for achieving necessary improvements in areas such as passenger service, maintenance, security, and ticketing. Consequently, the study team learned how these transit agencies are successfully implementing new technologies for more effective and efficient operations. They also learned how the systems are dealing with related issues including investment planning and decision making, funding arrangements, and staffing and training a qualified maintenance staff.

OVERVIEW OF PUBLIC TRANSPORTATION NETWORKS

Berlin, Germany

Berlin, located in the northeastern part of Germany along the Spree River, is the nation's capital and largest city. The city was divided into Eastern and Western regions from 1949 until the fall of the Berlin Wall in 1989. In the years following German reunification, Berlin has continued to be one of Europe's major industrial and cultural centers.

Modern-day Berlin covers 341 mi^2 and has a population of approximately 3.4 million. At the heart of Berlin lies the medieval core of the city, located along the western bank of the Spree. To the west of the medieval city is a formal grid of streets laid out on either side of Unter den Linden, a wide central avenue stretching from east to west and flanked with double rows of linden trees. Berlin's 12 city boroughs contain large areas of undeveloped land. Forests and farmlands cover nearly one-third of the city.

Almost one-half (47%) of Berlin households have no car, and 43% of households have only one car. Public transit is used by 27% of Berliners; 31% are pedestrians or ride bicycles, and 42% rely on automobiles. Surprisingly, recreational traffic accounts for 40% of the purpose of the journey on public transportation, followed by shopping at 24% and jobs at 19%. Transit ridership, however, has declined recently, matching losses in the city's overall population.

Berlin's public transportation system is city owned and operated by Berliner Verkehrsbetriebe (BVG), which employs 11,500 people. Sixty-one percent of BVG's operational costs are subsidized with taxes. The system comprises 161 bus lines, nine metro lines (U-Bahn), 21 light rail lines (S-Bahn), and six ferries. The four modes combined provide 180 daylines and 66 nightlines for 2.84 million rides per day.

BVG operates more than 1,500 buses that make 601 daytime stops and 1,504 nighttime stops and account for 1.24 million trips per day. The bus system speed is 12.1 mph. The U-Bahn, which operates 7 days a week, has 1,051 cars that make 170 daytime stops and 145 nighttime stops. The S-Bahn makes 377 daytime stops and 110 nighttime stops with its fleet of 602 cars. BVG has been working to spruce up its transit fleet by introducing new low-floor light rail cars and new H series metro cars, developed by Adtranz, that are capable of driverless operation. The new metro cars have more room for bicycles, wheelchairs, and baby carriages and feature unrestricted passageways throughout the train, without doors between individual cars.

Potsdam, Germany

Potsdam, capital of the German state of Brandenberg, is located 16 miles southwest of Berlin. The city has often been called "Germany's Versailles" for its many historic sites, large parks and gardens, and chain of interconnected lakes formed by the nearby Havel River. In 1945, the city was the site of the Potsdam Conference, which helped to shape post–World War II Europe.

Potsdam has a population of 145,000 and covers an area of 72 mi^2. The city's proximity to Berlin means that it has a healthy level of commuter traffic going to the German capital. However, there is also a large amount of leisure travel from Berlin to Potsdam.

The agency for Potsdam's public transit operations is Verkehrsbetriebe Potsdam (ViP), a fully owned subsidiary of the city authority. ViP is subsidized by the city at a rate of 40%. Transit services consist of buses, light rail, and a tram network that has been as much a part of the Potsdam's fabric for the last century as some of its most impressive monuments. Approximately 17 million passengers use Potsdam's trams and light rail vehicles each year. ViP also operates one ferry route.

Potsdam has a round-the-clock public transit system. Tram service generally operates between 4:30 a.m. and 10:30 p.m. each day, using 34 tram sets. One tram route operates 24 hours a day, along with a night bus network. Overall, ViP operates 36 buses, 17 of which are articulating buses, on seven bus routes.

The ViP tram network consists of five lines, with a total length of 15.8 mi, which converge on the city center Potsdam Stadt interchange with the Deutsche Bahn heavy rail terminus. The network's central hub has always been the main square, the Platz der Einheit, but over many years the system has been steadily expanded, largely to serve new residential areas. The tram network currently has 107 stops.

More than 50% of the tram network runs over dedicated tracks, meaning that there is no conflict with any other road vehicles. These dedicated tracks allow the city railway to achieve a top speed of 40 mph, relatively high for a city railway. (The average speed on all the tram lines is 13.7 mph.). All but 0.3 mi of the system is double track.

ViP is in the process of buying 48 new Siemens tramcars to replace its aging Tatra-built cars. The new tramcars are articulated, low-floor units designed to transport 70 to 100 people. They will also provide more impact protection for passengers in case of accident. The new tramcars will be introduced gradually over a 10-year period.

Dresden, Germany

Dresden, located in east central Germany, is the focus of one of Germany's largest metropolitan areas and is a major manufacturing, transportation, and cultural center. The city is a significant port on the Elbe River and its economy centers on port activities and the manufacture of high-technology items such as specialized medical equipment, business machines, and computers. The city covers 212 mi^2 and has a population of 1.2 million.

Dresden's public transportation system is owned by the city and is called Dresdner Verkehrsbetriebe AG (DVB). DVB, which has more than 1,700 employees, receives 10 million euros in operating subsidies each year from the city, the state of Saxony, and the German federal government. The public transit system transports approximately 138 million passengers per year.

The system comprises five modes of transportation: light rail (111 cars), trams (197 cars), buses (500 buses), cable cars (two cars) and ferries (five, including one car ferry). There are 12 tram routes and 28 bus routes with a combination of 650 stops shared by trams and buses. Overall ridership has risen despite a base fare increase from 0.08 euro to 1.70 euro since 1989.

In addition to traditional public transit operations, DVB offers a car-sharing service to some parts of Dresden that are not covered by bus or rail service. More than 2,000 private individuals, clubs, and companies make use of the program. DVB also offers taxi service for passengers who need to reach an area not covered by public transit during reduced service hours (e.g., weekends).

Vienna, Austria

Vienna, Austria's capital and largest city, is located along the Danube River in the northeastern portion of the country and covers 160.2 mi^2 with a population of 1.6 million. The city is by far Austria's most important manufacturing, banking, and insurance center, contributing roughly one-fifth of Austria's total industrial output.

Wiener Linien, a private company, is the public transportation authority in Vienna. Previously a public utility owned by the city, it was restructured in 1999 as an independent enterprise operating under private law. Today, it is an independent subsidiary of the Wiener Stadtwerke Holding AG, a share holding company that is currently wholly owned by the city of Vienna. The company, which has more than 2,200 employees, is subsidized by the city, the Eastern Austria regional government, and the Austrian federal government. Vienna's city government collects a special transport tax from employers who must pay 1 euro per month for each of their employees.

Vienna's public transit system made 721.8 million passenger trips in 2003 and provides for 34% of travel made within the city. The system comprises U-Bahn, S-Bahn, trams, and buses. The total length of the transit system is 144.5 mi, and the system operates with an average speed of 9.5 mph.

Vienna's trams and buses are worth particular note. Vienna is the only European city operating propane buses. Of the system's approximately 500 buses, 150 are articulated buses. The majority of the bus fleet and all new trams have a low-floor design to allow for easy accessibility for all customers, including seniors and those with disabilities. The Wiener Linien tram network, which has 2,000 tramcars, is the third largest in the world.

Surveys and other data indicate that use of public transit in Vienna is increasing. Public transportation was the preferred mode choice in a 2002 survey (private automobiles earned the top spot in 1993). Also in 2002, the transit system was carrying an estimated 1 million passengers per day, an increase of 500,000 per day from 1975 data.

Linz, Austria

Located in northern Austria, Linz is the capital of Austria's Oberösterreich (Upper Austria) Province and is Austria's third largest city, with a population of roughly 180,000. The city is situated along the Danube River and covers 37 mi^2. As one of Austria's main industrial cities, Linz is home to a large steel mill, the companies resulting from the split of the former Chemie Linz chemical group, and the company that created PEZ candy dispensers.

The city serves as an important transportation hub for Oberösterreich. In addition to being a hub to river transport along the Danube, Linz lies on Austria's main rail axis, the so-called Westbahn, linking Vienna with western Austria, Germany, and Switzerland.

Surveys indicate that public transportation is responsible for 23% of Linz's travel; pedestrians (32%), cyclists (4%) and autos (42%) account for the remaining shares. Roughly one-half of Linz residents are car owners.

Linz Linien is the public transportation provider for the city. Similar to Vienna's Wiener Linien, Linz Linien was a former public utility restructured in 2000 to operate as an independent subsidiary of Linz Holding AG, which is wholly owned by the township of Linz. The company, which has more than 500 employees, is subsidized at a rate of 65%.

Linz's public transportation system makes 87.6 million passenger trips each year. The system comprises trams, buses (autobuses and trolley buses), and a mountain railway. The system has 28 routes: three for trams, 20 for autobuses, four for trolley buses, and one for the mountain railway.

The tram network operates 21 new tram vehicles, called City Runners, and 28 old-style trams. All new trams feature a low-floor design. Bringing the City Runners into service required changes to Linz Linien's maintenance facility as the company did not have the infrastructure required to maintain the tramcars.

Figure 1 Two new City Runner trams in Linz, Austria.

The system uses sixty-one 59-ft buses, thirty-six 39-ft buses, and nineteen 59-ft trolley buses to provide bus service. The mountain railway operates six cars during most of the year and adds two cars during the summer season.

Paris, France

Paris, located in north central France along the Seine River, is France's capital and largest city. Known as "The City of Lights," Paris is world famous for its beauty and charm and is France's political, cultural, and economic center.

Paris covers an area of 41 mi^2 and is home to a population of roughly 11 million people, which means 20% of France's total population lives on 2% of its overall territory. As a result, population density in Paris is very high compared to most western cities. Statistics indicate that 61% of Parisians rely on public transportation; only 31% of city residents own an automobile; and 8% of Parisians bicycle or walk to their destinations.

The Régie Autonome des Transports Parisiens (RATP) is Paris's public transportation system. The RATP, which has more than 43,000 employees, is publicly financed at the city and regional level. The RATP provides 2.8 billion passenger trips annually, with 10 million trips each weekday.

The public transit system comprises city and suburban bus, subway, tram, and surface lines. City bus operations consist of 250 routes operating 4,000 buses out of 23 divisions and account for 310 million trips annually. Suburban buses, which are shared services and charter, account for 570 million annual trips. Subway operations represent 1.4 billion trips annually. The subway features 14 lines, 318 stations (including 37 connecting stations), and 2,950 rail cars. The subway and most of the system's buses are not air conditioned. The transit system also has a limited passenger space allowance, allocating four passengers for 1 m^2, which makes for a congested trip.

The transit system's rail operations include tram service and surface, or Réseau Express Régional (RER), rail. They account for 95 million and 405 million annual trips, respectively. The tram service has two lines, 99 trains, and 112 stations. RER has two lines, 334 trains, and 67 stations.

Paris faces a number of transit challenges. Traffic congestion on streets and boulevards is particularly heavy, negatively impacting bus service throughout the city. In addition, the Paris transit capital budget is 4 billion euros in debt.

Rouen, France

Located 84 mi northwest of Paris along the Seine River is the city of Rouen, capital of the Haute Normandie (Upper Normandy) region and France's fifth largest port. In addition to commercial activities connected to the port, Rouen is home to a number of universities and art schools. The city is perhaps best known for its Notre Dame cathedral.

The city covers an area of 112 mi^2 and is inhabited by a population of 394,000. Rouen and its 36 suburban communities of the metropolitan area form the Communauté d'Agglomération de Rouen.

Rouen's public transportation system, Transports en Commun de L'Agglomération Rouennaise (TCAR), is operated by private company Connex under a 30-year contract with the city. TCAR, which has more than 1,000 employees, combines trams, regular bus service, and dedicated bus rapid transit (BRT) routes to move city inhabitants and residents of the suburbs. The tram line, which is 9.3 mi in length, and the bus routes, covering 16.1 mi, provide for 40 million passenger trips annually and obtain 40% fare box recovery.

Rouen's tram network has 28 cars with a capacity of 118 persons per car. During peak times, the system operates 3-min headways, with an average speed of 12 mph. Trams are fully integrated into the downtown corridors. Significant parking is provided on the edge of the city to encourage use of public transportation.

TCAR operates 220 buses. Rouen decided to use BRT in place of trams to serve the city's outlying suburbs. The first phase BRT operates 38 articulated buses with some portions of the route dedicated bus lanes and the remainder integrated bus lanes and mixed flow.

Orléans, France

Orléans, capital of France's Centre region, is located in north central France along the Loire River. The city is a major commercial and transportation center. Orléans's economy is noted for industries including electronics, food processing, automobiles, pharmaceuticals, and cosmetics.

Orléans has a population of approximately 270,000. The city is closely tied to its outlying suburbs, which consist of roughly 20 communities stretching into the Loire Valley.

The Société d'Economie Mixte des Transports en commun de l'Agglomération Orléanaise (SEMTAO), a private company, operates the city's public transportation system, also known as SEMTAO. It provides service to city inhabitants and residents of Orléans's suburbs. SEMTAO provides 15% of all trips made in Orléans. Overall, the system provides for 24 million passenger trips annually. Passengers commuting to work make up 26% of transit users. The system, which has 700 employees, consists of one tram line (a second tram line is under construction) and 28 bus routes. Tram ridership has increased 18% over the past 3 years.

TECHNOLOGY

Many European transit agencies are exploring how technology can contribute to more efficient and effective transit operations in advance of the 2008 EU deadline. In the agencies visited, the study team encountered a broad array of technologies—ranging from cutting-edge maintenance and navigational systems to the latest smart card innovations—that are having a positive impact on day-to-day transit functions.

Vehicle Locating

Several of the transit agencies visited by the team are using vehicle locating systems to improve vehicle timeliness and provide better status information to passengers. In Paris, the RATP's automatic vehicle locator (AVL) system uses a combination of infrared sensors and radio signals to measure the real-time position of each vehicle. Data are then relayed to the transit system's control center so RATP personnel can monitor the location of buses and trams on every route. Data are also provided to a number of passenger information systems that can give transit users the most up-to-date schedule information.

Wiener Linien in Vienna uses an AVL system that relies on satellite signals and global positioning system (GPS) technology to locate its transit vehicles. GPS provides an accurate position of the vehicle using a satellite tracking system, which sends signals to the GPS receiver on board a bus or tram. The receiver then transmits location coordinates to Wiener Linien's communication center via a radio station. The communication center identifies the location of the vehicle and sends the information along to passenger information systems and other systems and transit departments that use the data.

Maintenance Tracking

Berlin's BVG has relied on the SAP maintenance system for 9 years to meet its maintenance tracking needs. SAP enables BVG to capture the life-cycle cost, reliability, availability, and safety information about vehicles and related transit equipment. Its capabilities for failure analysis help BVG to identify potential problems before they arise. The system provides BVG personnel mean time and distance between failures data that support this effort. In addition, SAP collects field data, such as how long the vehicle was inoperable or what parts are needed for repair, which BVG uses to conduct broader analysis to identify chronic or recurring defects in parts or equipment. BVG has also integrated the SAP maintenance system with its operations systems. This data sharing gives BVG more complete information and real-time updates about asset utilization and repair.

In addition to using the SAP maintenance system to track vehicle repair status, Wiener Linien in Vienna uses the system to log maintenance employee time records. Employees enter their time and progress on maintenance tasks into SAP, allowing Wiener Linien to better track the hours and effort required to complete different types of repairs.

Paris's RATP uses its fully automated On Board System (OBS) to make sure transit system buses are properly maintained. OBS software continuously monitors maintenance needs from four data sources: operator requests (driver enters a repair code into the system if s/he detects a mechanical problem while operating the bus); bus requests (the bus's own vehicle logic system automatically logs a fault code if it finds a problem); network preventive maintenance data (maintenance schedules are stored in the logic system's memory); and fuel-monitoring system data (records of fuel, oil, and coolant levels that are stored in the logic system and tracked).

Each day when a bus returns from its route, RATP personnel use wireless technology to download information from the OBS software into a shop information system, which analyzes the data and sends it to a shop dispatch system. The dispatch system then displays an electronic map of the bus parking yard, with each bus assigned to a specific color-coded parking spot. The color coding (red, yellow, blue, green) reflects the maintenance status of each bus. The dispatch system also generates work orders for the shop foreman. When mechanical work on a bus is completed, red, yellow, or blue status turns to green, and dispatchers are free to assign the bus to another route.

Information Systems for Passengers

The Dynamische Auskunfts- und Informations-system (Dynamic Enquiry and Information System, DAISY) in Berlin provides U-Bahn riders up-to-the-minute destination information and arrival times for the next two metro trains. The system, a combination of hardware and Oracle database software technology, gathers information from trackside sensors and calculates approximate journey times, which are then shown on LED display panels in all 170 stations. BVG also uses DAISY to provide real-time information about disruptions to normal service and to advise passengers on what to do in case of an emergency.

In Paris, data provided by the RATP's AVL system are used to give passengers real-time information on the travel status of buses, trains, and trams. Digital display panels containing this information are located in subway stations, bus zones, and even on the vehicles themselves. Information from the system is also provided to passengers through automated audio announcements. The combination of on-board display panel technology and automated audio announcements enables operators to concentrate on driving without the distraction of having to use the public address system.

Dresden's public transit agency, DVB, teamed up with private company AEG Mobile Communications to implement a passenger information system based on radio and wireless technology that provides real-time travel updates via transit agency Internet websites, mobile phones, personal digital assistants (e.g., Blackberries), and digital display panels at tram stops and aboard vehicles.

To generate real-time information with this system, tram operators key a location code into the radio at each stop. This sends a wireless signal that is received by DVB's central computer and vehicle locator application. The central computer uses the incoming data to construct a real-time "path" along that tram's route, projecting from the current location to the tram's registered destination. Forecasts of arrival times are then computed according to current travel conditions, and the data are electronically transmitted

Figure 2 The On Board System that helps to monitor the maintenance needs of transit buses in Paris.

Figure 3 A digital display to provide train arrival information to U-Bahn riders in Berlin.

Figure 4 Open passage between individual cars and digital information display screens for passengers in a tram in Dresden.

to the digital displays at each stop and the other information outlets, which assists passengers in making decisions about the mode of travel that will work best for them at any given time and location.

Operations Management

In Berlin, individual systems that provide for maintenance tracking, passenger information, and other key needs operate under the umbrella of one overall operations management system. BVG's "BERTA" is a completely integrated and comprehensive operations management system that covers the city's entire public transit network, from service yard to bus stop, driver workstation to traffic signal controls, and statistical data to passenger announcements. Although this enormously complex and expansive system was developed completely in-house, BVG relied on the services of a number of private companies including Alcatel SEL, AEG Mobile Communication, Siemens, Gedas, and IAV to help create some of BERTA's individual modules, such as the DAISY. In addition to connecting all the individual BVG systems used for various operations surveillance and control tasks, BERTA provides BVG personnel the capability to better assess and manage myriad streams of operational data coming into headquarters.

Traffic Signal Control

Wiener Linien has taken advantage of traffic signal control technology common to many streetcar systems to improve the on-time performance of Vienna's buses and trams. The technology permits transit to move through the city at a faster pace by allowing oncoming transit vehicles to trip traffic signals. In this manner, buses or trams are able to proceed without stopping. It is also enabling the transit system to run trains more frequently without delays. Currently, Wiener Linien controls 87% of traffic lights along transit routes. The agency plans to gain control capability for all traffic lights along transit routes in the near future.

Closed Circuit Television

Many of the transit agencies visited by the study team make extensive use of closed circuit television (CCTV) systems for security and to discourage attempts at vandalism. Berlin installed its Systemtechnik für den automatischen Regelbetrieb (STAR) camera system in 2000 in an effort to thwart vandalism that was forcing BVG to invest roughly $2 million annually in equipment repairs. Research and installation of STAR was a joint project between BVG and private companies Adtranz and Siemens.

When a vehicle's emergency brake is engaged, an alarm signal is activated that causes the STAR equipment to begin transmitting video images to the BVG control center for review. With STAR and the cooperation of the local police, BVG has enjoyed an 84% reduction in reported vandalism to its transit vehicles and seven parking facilities since the system has been operational.

Figure 5 Monitoring transit activities inside a control center in Paris.

In Paris, RATP has installed 10,000 video cameras at subway stations and aboard trams and transit buses. Four cameras are located in every 40-ft bus and six in every 60-ft articulated bus. The CCTV network is wireless for above-ground cameras and uses fiber-optic cables for underground subway station cameras.

Paris's CCTV system transmits image, voice, and data information. It has also been used to broadcast recorded audio to passengers. Each camera records continually for 72 hours with an image quality that is comparable to analog, at about 25 images/s. Although the RATP control center is constantly monitoring critical areas, vehicle operators can transmit alerts to the center about incidents occurring along their routes. Local police, fire departments, and the transit police can have access to the system's recorded files. The system is programmed to automatically notify the proper authorities in case of a technical difficulty. The RATP also ensures that a camera and wireless network support team is available 24 hours a day to maintain quality control and reliability. RATP officials indicate the system has improved overall security and helped to minimize graffiti and vandalism repair costs.

Smart Cards

Smart card technology is proving beneficial to transit customers in Paris. Riders can use their smart cards anywhere in the RATP system, eliminating the need for purchasing individual tickets for different bus, tram, or subway trips. Passengers simply swipe the card at any tram or subway station entrance, or at the fare transition processors located at the front door of every transit bus, and the smart card system automatically deducts the necessary fare amount.

The RATP's smart cards also feature a built-in "e-purse" chip that allows customers to add money to the card's value at transit stations and at non-transit facilities such as banks. The smart card also works as a debit card, to be used for purchases at venues such as coffee shops and restaurants. In the event of loss or theft, smart cards can be canceled or frozen. New cards are then issued to the cardholder reflecting the last current balance.

In Berlin, BVG took advantage of an upgrade in its ticketing systems to introduce smart card technology. When BVG decided to replace its fleet of more than 700 Ascom Transport Revenue ticket vending machines, it selected a new fare collection system that would make ticketing easier for passengers and reduce BVG operating costs. The system, which is capable of converting the German mark to the euro, allowed BVG to increase fare offerings to 800 basic fares from 40 and enabled Berlin to become the first transit system in Germany to dispense proximity smart cards. These smart cards allow a more complex regional fare structure, while simultaneously simplifying the transit experience for passengers, because a single fare ticket can be accepted by several interconnecting modes of transit. The cards also provide transit operators with more accurate ridership data.

Figure 6 Paris smart card technology in action.

BVG has found that individual transactions with the proximity smart cards are swift, taking place in about one-third of a second and thus making possible easy handling of high volumes of passenger traffic. An added benefit is that the cards are counterfeit-proof. Manipulation of paper tickets had produced significant revenue losses for Berlin's transit system.

Smart Garage

All three French transit agencies the study team visited use some variant of smart garage technology. The Smart Garage system is activated when the bus operator approaches the garage's entrance door. Based on input from a sensor, the door opens automatically and closes when the vehicle has entered the garage. When exiting the garage, the bus operator blinks the headlights four times within 10 ft of the door. The sensor detects the request and again opens and closes the door automatically.

Smart garage operates on the premise of assigned stall parking, regardless of whether buses are housed

Figure 7 Upgraded ticketing machine for dispensing proximity smart cards in Berlin.

in a covered or open-air garage facility. Each bus's parking stall is equipped with a smart plug that consists of an air supply, voltage supply, input signal, and output signal. After parking their vehicles, operators connect them to the smart plug. The plug gives the bus's suspension a constant supply of air and keeps the bus's batteries fully charged. The plug's input signal enables the dispatch center to identify the location of each vehicle and the condition of its electrical system. During cold weather conditions, the dispatch center uses the plug's output signal to activate heaters inside the vehicles 10 min before their scheduled departure times. This activation ensures the buses are warmed up and ready for operators and passengers.

Automatic Bus Guidance

In Rouen, TCAR has implemented an automatic bus guidance system to improve the transit system's efficiency in loading and unloading passengers. The system guides buses and parks them within approximately 5 cm of specially designed elevated platforms that TCAR has placed in more than 140 bus loading/unloading zones throughout Rouen. This system eliminates the use of the wheelchair lift and makes entering and exiting vehicles easy for physically challenged customers, as the platforms are designed to be at the same level as the bus floor.

When a bus enters a zone (indicated by guidance lines on the street), the operator removes his hands from the steering wheel, and the automatic guidance system takes charge of the vehicle, working with the steering mechanism to bring the bus alongside the platform. When the bus is ready to leave and the doors are closed, the automated system guides the bus out of the zone. After the bus has exited the zone, a horn sounds and control is given back to the bus operator who resumes manual operation of the vehicle.

Figure 8 A smart plug that is common to smart garage technology being used by many transit agencies throughout Europe.

Hydrogen Fuel Cell Buses

BVG is working with The Volvo Group, leading manufacturer of trucks and buses, to make Berlin the

Figure 9 Special street lines that are part of Rouen's automatic bus guidance system.

world’s first city to run transit buses powered by fuel cell technology using hydrogen, an extremely clean and efficient fuel source.

A fuel cell, or battery, uses an external fuel supply connected to an electric motor. Electrodes within the cell house a catalytic reaction where the fuel and oxidant are electrochemically transformed to produce direct current power, water, and heat. The buses will be powered by proton exchange membrane (PEM) fuel cells developed by Proton Motor, a German fuel cell manufacturer. As currently planned, the double-decker buses will be about 50 ft long and carry between 120 and 130 seated passengers. This attempt is BVG’s second at introducing hydrogen fuel cell technology to the transit system.

Although fuel cell technology is still at an early stage and the durability of fuel cell stacks is still limited in comparison to diesel engines, fuel cells benefit from not having moving parts. It is reasonable to expect that once the technology matures, vehicles powered by fuel cells may be more reliable and require less maintenance than those using internal combustion engines.

Fully Automated Subway Lines

Line 14 in Paris is RATP’s first fully automated subway line. The line, which covers a distance of 6 mi, has been operating since 1999. Trains using the line are operated from a central control room, where RATP personnel can control headway and add or remove cars as demand requires. A system display board shows train identification and location and indicates whether the train or platform doors are open, closed, or malfunctioning. The line operates on pneumatic tires and has automatic tire inflation sensors at two positions on the line that are capable of sensing low tire pressure. The control computer has full redundancy and is completely reliable, according to the RATP.

RATP plans to fully automate Line 1 in 2010–2011, without shutting down operations. Line 1 serves 700,000 passengers per day. The agency believes that the full automation of Line 1 and other lines will improve service quality and generate cost savings for the transit system.

Figure 10 A modern double-decker bus in Berlin.

Radio Frequency Identification

Dresden’s transit system is using radio transponders to improve its ability to track both vehicles and inventory. Transponders utilize radio frequency identification (RFID) technology to assist in tracking items, both in- and out-of-service. As a form of technology, RFID is relatively simple, low cost, and disposable.

RFID tags include a chip that typically stores a static number (i.e., an ID) and an antenna that enables the chip to transmit the stored number to a reader. When a tag comes within range of an appropriate radio frequency (RF) reader, a distance which can range from a few inches to several yards, the tag becomes powered by the reader’s RF field and transmits its ID to that reader.

There is little to no security on the RFID tag or during the actual communication. Any reader using the appropriate RF signal can get the RFID tag to communicate its contents. Typical RFID tags can be read easily in this manner and permit the easy tracking of vehicles and inventory. RF readers allow devices to wirelessly interrogate and write to minute data tags that can be embedded into any device, triggering the immediate transfer of the digitized information contained in them. RFID-enabled items can contain information such as what they are, where they have been, and where they are intended to go.

While Dresden is using RFID for basic vehicle and inventory tracking, transit operators may realize multiple benefits from the technology. RFID can contribute to automated real-time train position information to take system management to the next level of efficiency and safety. It can also help transit agencies lower labor costs through improvements to automated passenger information systems, thereby reducing required staffing levels for customer service representatives and station agents.

INVESTMENT PLANNING AND DECISION MAKING

Germany

Transit agencies visited by the study team in Germany operate under a policy framework established by federal, state, and municipal governments that shapes their planning and decision-making processes for investing in new technologies.

Germany's national transport policy is regulated by the country's National Transport Infrastructure Plan, or Bundesverkehrswegeplan (BVWP). The BVWP identifies future projects to be constructed according to the level of urgency. The BVWP covers planning for autobahns, interregional highways, long-distance railways, waterways, and airports. Regional transport policy is regulated by the Regional Development Plan for Transport, or Landesentwicklungsplan (LVWP). This plan directs transport planning within the individual German states. In some cases, municipalities can also carry out regional development. The LVWP covers planning for ordinary roads, regional railways, waterways, and airports with regional demand. All other projects are, as a rule, undertaken by the municipalities.

Projects with national or regional impact must be approved against guidelines established by the corresponding plan. The approval procedure generally consists of an analysis of the current situation, a prognosis for future demand, an assessment of available funds, and a final decision. The federal government selects projects after a pre-selection process is carried out by regional governments. Before the final decision is made, potential projects are assessed at roundtable conferences between representatives of the national and relevant regional governments.

To be assessed at the roundtable conferences, proposed projects must undergo an extensive evaluation process that includes examination of the project's economic, ecological, and urban planning implications. The economic evaluation includes a detailed analysis that weighs a project's costs (e.g., project implementation funding requirements) against possible benefits (e.g., employment). Each project receives an overall evaluation rating. Projects with higher ratings are more likely to get approved.

Transit agencies also seek to have projects approved through the Municipal Transport Funding Law. Known as the Gemeindeverkehrsfinanzierungsgesetz (GVFG), this is a fund for local transportation projects that is financed through a tax on petrol. The fund's current budget is 1.7 billion euros. Allocations from the GVFG can be carried out by either municipalities or states. There is a standardized GVFG evaluation procedure that involves obtaining objective criteria about a project's economic, ecological, and other impacts to allow for across-the-board comparisons and priority approval of the most urgent projects.

Potsdam's ViP conducts extensive planning and analysis before deciding upon the technology investments for which it will seek funding support. The agency researches new technologies through transit shows in Berlin, by reviewing literature available in print or on the Internet, and by conducting site visits to other transit agencies. Once ViP has completed its research and conducted a needs assessment, the agency has its in-house engineers develop specifications and issues a call for bids if the project is expected to cost more than 400,000 euros. The specifications require bidders to demonstrate how their proposals will be cost effective for the ViP. Specifications also include other types of criteria for proposal evaluation such as system up-time and life-cycle costing.

An outside agency evaluates each of the proposals received against a weighted set of criteria. In the meantime, ViP staff travel to transit agencies operating the proposed technology or equipment to gather information on its reliability and operational characteristics. The technology or equipment also undergoes a schedule of tests within a 2-week period of the evaluation. Once the test period is complete, items such as equipment wear and projections for time to failure are assessed. Using the weighted proposal evaluation criteria, information gathered from other transit agencies, and results of the evaluation tests, ViP then makes a final decision about which proposal to pursue.

Austria

In Austria, policymakers guiding the future of transit operations are aggressively responding to EU initiatives, the burden of large transit subsidies, and loss of passengers to automobile traffic. Consequently, governments at the federal, state, and municipal levels are pushing a number of public transportation reforms, backed by legislation, that have three key goals:

- To increase the cost efficiency of local and regional public transportation;
- To improve the quality of public transportation services and thereby improve the market

share of trips made using public transportation versus the personal automobile; and

- To increase local and regional control over public transportation policy, organization, and finances.

These goals are now driving the planning, funding, and selection of new transit technologies. To be considered viable for implementation in Austrian public transit systems, a new technology must provide for an increase in market share, a reduction in operating costs, or compliance with regulation.

Transit systems in Vienna and Linz use similar processes that rely on several components to identify and determine whether new technologies are worthy of investment.

Project Purpose

Because new technologies must increase market share, reduce operating costs, or provide regulation compliance, transit agencies are closely evaluating the purposes of actual projects. Vienna's Wiener Linien and Linz's Linz Linien report aggressively exploring every opportunity to improve the effectiveness and efficiency of their respective transit systems with new technologies. According to Wiener Linien, most new technology procurements are undertaken to reduce internal costs.

Needs Assessments

When a need is identified, the transit agencies conduct an assessment to accurately define the need and all related issues. The information gained during the analysis is then used to determine the best method of addressing the need. At Wiener Linien, the magnitude of the needs assessment is proportional to the expected outcome and potential cost of a project required to address the need.

Knowledge of Transit Technology

Wiener Linien and Linz Linien place a high priority on staying in touch with the leading edge of transit technology. These agencies continuously gather transit technology information through trade shows, literature, academia, transit associations, visits to other transit agencies, and visits to manufacturer facilities.

Customer Involvement

Wiener Linien has an excellent reputation for reaching out to customers to determine their needs and desired service levels. The system makes extensive use of customer surveys to help identify and rank actions that will improve the customer's transit experience. This approach has proven effective, as the agency's number of provided passenger trips has increased with improvements to service. New technology is often selected and implemented to provide enhanced customer service, particularly in on-time performance.

Project Evaluation

Using a cost/benefit analysis, the transit agencies rank identified technology projects according to their impact on market share, efficiency, and regulation. Projects are also evaluated in terms of their overall effect on transit system operations.

Implementation Planning

The transit agencies view implementation planning as a key element of technology investment decisions. Some of the biggest challenges Linz Linien encountered with its recent implementation of new tramcars included having to upgrade its facilities and introduce new technologies that were necessary for supporting the tramcars. The agency took the step of deliberately slowing the tramcar deliveries to make for a smoother implementation and minimize the impact on the organization. The slow rate of delivery allowed maintenance technicians to train on the first tramcars delivered while assisting with the required facility modifications.

France

At RATP in Paris, the bus division's bus and equipment group is responsible for buying new buses, testing new technology, and conducting technical research. Bus engineers are frequently sent to other transit agencies and manufacturer sites to gather information and learn about emerging bus transit technologies.

When replacing vehicles, detailed specifications are developed by the RATP and given to manufacturers. International tenders are issued for vehicle purchases. The RATP evaluates submitted proposals for compliance with the specifications and cost factors. No testing is done prior to contract award. Vehicle testing, and any testing of related technologies, is performed after the award. Testing continues until operational compliance with the specifications is achieved. Production of vehicles with the tested and approved designs proceeds upon notice of acceptance. The RATP typically experiences a 30% savings in operational costs with the delivery of new vehicles.

Little visibility into technology planning and decision-making practices is available for the privately operated transit systems in Rouen and Orléans. In Rouen, Eurolum, a subsidiary of Connex, conducts all transportation-related research and development that might affect TCAR.

FUNDING

Germany

All levels of government (federal, state, and local) in Germany regard the supply of public transport as a "voluntary function for living." Thus, the provision and regulation of transit have remained largely in the public sector.

Local authorities provide transit services directly or through associated companies. Often, German public transport agencies are structured with the city as the parent company and a holding company as the owner of the transit agency. Companies that provide services to the transit agency, such as electric power and telecommunications, also act under the direction of the holding company. All three German transit systems visited by the team operate in this manner.

Funding sources for the Berlin, Potsdam, and Dresden transit systems come primarily from revenue and fare collection and from city budgets. In Berlin, 61% of BVG's operational costs are subsidized with taxes. Potsdam's ViP is subsidized by the city at a rate of 40%. The DVB in Dresden receives an annual 10 million euros in operating subsidies from the city, the state of Saxony, and the German federal government. DVB has mounted efforts to generate additional revenue and decrease the level of subsidies it receives from its parent company. Efforts include developing an aggressive marketing campaign to encourage transit ridership and offering charter transportation services.

Austria

Like Germany, policymakers in Austria have long regarded public transportation as a social service and held fast to the belief that the public sector has a key role to play in ensuring that all individuals have a certain level of mobility. Transit services, as in Germany, are provided by local authorities, either directly or through public companies. The Vienna and Linz systems visited by the study team are both operated by subsidiary companies, under the umbrella of holding companies owned by their respective municipalities.

Overall, the public companies operating transit systems within Austria had provided services that attracted a high percentage of travelers at relatively low operational costs compared to other European transit agencies. During the 1990s, however, increases in public transportation subsidies far outpaced a substantial growth in public transportation patronage. The mounting subsidies have contributed to budget deficits at the regional and municipal levels.

Despite large deficits, both the Vienna and Linz transit systems continue to receive significant portions of their funding through subsidies. In Vienna, Wiener Linien is subsidized by the city, the regional government, and Austria's federal government. The subsidy rate is 60%. The city provides one-half of the total annual subsidy. Other dedicated funding comes from a monthly tax of 1 euro per month per employee that is collected from Viennese employers. This funding is used to support further construction of the U-Bahn.

While investments in new technologies are largely funded from Wiener Linien's overall budget, which includes fare revenue, the agency has obtained full government funding for technology investments that can demonstrate cost reduction and improvement of passenger experiences as their primary goals. For instance, the city government recently covered all costs for implementing Wiener Linien's vehicle locating system, based on its potential for generating cost savings and providing passengers better travel status information.

In Linz, Linz Linien is subsidized at a rate of 65%. Funding for new technologies, primarily new vehicles, comes from a variety of sources. These sources include the city and regional governments, as well as utilities like the electric power company that could profit from technology-related procurements. Recent Austrian public transit reforms require that transit subsidies be earmarked for a specific public benefit. To this extent, Linz Linien must persuade government officials of the value of investments in new technologies. The transit system is currently working to secure funding for 16 additional tramcars. It recently obtained a loan from the European Investment Bank to extend tramlines, build new tram stations, and purchase 11 new tram sets.

France

France is making internal adjustments to allow for some privatization of public transit services. Although the transit systems continue to rely on public subsidies for a significant portion of their funding, two of the three cities (Rouen and Orléans) have forged relationships with private companies to provide transit service to their citizens.

Paris's RATP is publicly funded by both the city and state governments through regional and county-collected taxes. The subsidy rate is 58%. The collection of fines and fare revenue make up the remainder of the system's overall budget. The RATP must share its fare revenue with other transportation providers, including France's national railroad.

The RATP transit capital budget is 4 billion euros in public debt. This debt is primarily due to the addition of the third tram line, which will complete the tram system circling Paris; the expansion of transit service to Charles de Gaulle airport; and continued modernization of the subway system that will include the use of operator-less vehicles. This high level of debt is considered significant because Paris has not expressed intentions of privatizing any portion of the transit system, a move that could help the city reduce its costs and retire the debt sooner.

In Rouen and Orléans, the public transit systems are operated by private contractors. Both companies have long-term contracts that are greater in length than the 5- to 8-year terms proposed in the EU charter. Connex is operating under a 30-year contract with Rouen; SEMTAO's contract with Orléans is for 9 years. The EU does recognize, however, that longer-term contracts may also be beneficial in lowering operating costs.

The contracts establish joint partnerships between the companies and the cities. The companies not only operate and maintain the transit systems, but also help to construct the infrastructure upon which they operate. The cities and surrounding municipalities provide a portion of system funding and also fund any infrastructure capital improvements. Rouen's TCAR transit system is subsidized at a rate of 60%. In Orléans, approximately one-third of the transit system's overall budget is covered by fare revenue. The remainder comes from the city in the form of a tax collected from employers at a rate of 1.75% of total payroll.

MAINTENANCE HIRING AND TRAINING

Germany

Transit systems in Germany are placing greater emphasis on recruiting and training a qualified maintenance staff as they come to rely more on new technologies for effective and efficient operations. Identifying individuals who may have the aptitude for maintenance and engineering work starts early. When children are 10 years old, the country's education system begins to administer tests that are used to select students for vocational training leading to skilled employment or further academic study in the university.

In Berlin, BVG manages its own vocational training school for nine professions: electronic technician for devices and systems, electronic technician for technical services, track worker, industrial sales representative, electronic technician for information technology (IT) systems, merchant for office communications, mechanic, industrial mechanic, and mechanic–electronic technician. Students attending the school are considered to be apprentices who work temporarily for BVG while they receive much needed experience. Those who work hard and excel have an opportunity to gain full-time employment with the agency on a permanent basis. Apprentices also have an opportunity to get further education and training at a university or technical school. While attending the university or technical school, students become BVG employees. BVG commits to hiring the students for 3 years after their studies are complete. Students must also commit to work for BVG at a minimum of 3 years. Eight young students are currently in the program.

BVG also provides a training program for young engineering graduates. Under an 18-month contract with BVG, engineers receive valuable education and training by working in various departments of the U-Bahn system. After they complete an orientation period, the engineers are assigned various tasks to ensure that they become equipped and qualified for the jobs with the agency. At the conclusion of the contract periods, BVG decides whether to hire the trainees permanently. There are currently three trainee engineers in this program.

BVG has programs in place to recruit experienced engineers in specialized fields. The agency recruits from leading companies around the world, including manufacturing companies such as Bombardier Transportation and Rolling Stock Industry. The expense of

Figure 11 The inside of a Berlin rail maintenance facility.

bringing experienced engineers to BVG and providing them additional training comes from the agency's operating budget.

Dresden's DVB prides itself on providing specialized training to all its employees. Many positions with the agency begin through DVB's apprenticeship program, which takes 3 years to complete. DVB also recruits from various vocational training centers around the world. Maintenance training is continuous, and there are opportunities for ongoing training with the private contractors who provide vehicles to the system. The maintenance training comprises the following six components:

- Basics of maintenance;
- Basics of modern vehicle technology (mechanical);
- Basics of modern vehicle technology (electrical);
- System presentation of the low-floor, articulated vehicle NGT 6 DD;
- Driving training; and
- Introduction into SAP.

In addition, DVB operates mentoring programs through which experienced employees train new personnel to ensure that the ability to repair older equipment is maintained and to support continuity in performing maintenance procedures.

Austria

With an educational system similar to that which exists in Germany, Austria also supports its transit systems' need for maintenance personnel through the early identification of individuals who may be better suited for skilled technical careers.

Unlike BVG in Berlin, Vienna's Wiener Linien apprentice program is much more informal. Wiener Linien recruits from the pool of skilled workers who have obtained basic technical educations from vocational high schools and trains them in specialized courses. These courses include training on the SAP maintenance tracking system, for example. Wiener Linien also sends employees to train with the private companies that provide vehicles and equipment to the transit system. This training is very expensive, however; therefore, only a few employees participate in this training at any one time.

Wiener Linien's primary maintenance facility is capable of building a complete vehicle, and vehicles used in the system span from those constructed in the 1960s (shorter vehicles) to newer 1990s models (longer vehicles). Therefore, the agency faces the challenge of developing and retaining a maintenance staff that possesses a broad knowledge of new and old technologies. Wiener Linien is working to solve this problem through the development of mentoring programs to ensure that the knowledge base for older technologies (e.g., relay technologies) is maintained.

Wiener Linien is also making a push to train employees in multiple job assignments. This cross-training provides a staff that is capable of performing more functions within the organization and may enable the agency to reduce hiring and cut personnel costs. Maintenance personnel are included in this agency-wide effort.

Linz Linien does not have an apprentice program. Linz's transit agency largely recruits maintenance personnel that already have the skills and experience necessary to perform the work. Training is conducted on an as-needed basis, typically by established training organizations or the vendors who provide parts and equipment to the system. Linz Linien does, however, provide one in-house workshop and an electrical vocational workshop.

France

As part of its overall program for recruiting and training maintenance personnel, Paris's RATP is recruiting more young people that are familiar with new technologies. The agency is offering alternative training programs within the school systems as well as apprenticeships and vocational training. Current

RATP technicians offer tutoring to teach young employees and to transfer their experience. The goal is to transfer, maintain, and grow as much knowledge as possible to maximize RATP's expertise.

New recruits are welcomed into RATP at several levels. At the RATP network level, they are given information about the RATP organization and its policies and learn the specifics of their jobs. At the division level, they participate in a conference that lasts several days. At the local level, they are interviewed during their third, sixth, and ninth months of their employment at which time the RATP uses specific tools to validate their development.

French law requires that all companies spend 4% of employee earnings on training. In recent years, the arrival of new technologies and equipment has caused RATP's training investments to increase, but the agency has a long-term goal of keeping training levels at 5% to 6%.

General and theory training classes range from 1 to 15 days for groups of four to six trainees. Training is offered to all employees in every maintenance unit. General training includes managing the message to employees on policies and the importance of quality and safety. Courses on theory alternate with practical drills on vehicles. Training courses are specific to the vehicle generation and maintenance level (i.e., troubleshooting, preventive maintenance, and heavy repair and overhaul). The principal goal is for the maintenance technician to be able to detect as many existing, and potential, problems as possible during preventive maintenance to avoid in-service breakdowns. Improvements to preventive maintenance have a direct impact on fleet capacity. For example, if the technician can identify a fault during the preventive maintenance cycle, s/he can quickly swap out the module. This is the ideal scenario from an efficiency perspective.

At RATP, every maintenance trainee becomes proficient with the basics in different technologies. Dedicated training rooms and classes are offered for electric, electric/mechanical, engineering, pneumatics, onboard IT, and other specialties. These specialty classes are 1 to 10 days long and include six to eight trainees. Upon completing the training, employees should be capable of dealing with the whole vehicle as well as their specialties.

Training opportunities with vendors may be included in procurement contracts for new vehicles and technologies. The manufacturers' documentation is often used to develop the training plans.

Each maintenance employee is evaluated to identify the need for additional training. RATP managers update each employee's level of competence after training. Managers are responsible for managing competencies and planning for the development of their technical pools. Training classes for experienced technicians are networking opportunities where technical issues are exchanged and knowledge is shared between operational units.

There has been a move within RATP to decentralize some of the training. The highest skilled technicians are considered experts in a specialty and now also serve as trainers in the field. These trainers receive 12 days of instruction on how to teach.

More training needs to be developed and delivered as new technologies and equipment arrives, but the workforce must also be capable of supporting the older technologies that are still in use within the system. Luckily, RATP's staggered approach to introducing new technologies line by line allows for a smooth transition and provision of the necessary training.

In Rouen, only about 5% of TCAR's newly hired mechanics are already experienced when hired. Typically, mechanics are hired with a maintenance diploma and then participate in a 2-year apprenticeship program on operator Connex's Veolia Environment campus. The apprentices also work with experienced technicians on the shop floor. Apprentices are hired on a short-term contract. If an apprentice proves to be a good employee, s/he will be offered a permanent position. However, there is no commitment on the part of the apprentice or TCAR during the training program. Tram maintenance staff must also be certified to drive the tram.

Training at TCAR includes vocational training and validation of training. TCAR has found technical recruitment to be difficult; therefore, training is offered to adapt existing staff to new technology when possible. When new equipment or technology is implemented, the manufacturer trains the maintenance staff. Connex devotes 4.2% of wages to training, for a total of 26,000 hours per year.

APPENDIX A—STUDY MISSION TEAM MEMBERS[1]

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[1]Titles and affiliations are at the time of the mission.

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APPENDIX B—STUDY MISSION HOST AGENCIES/COMPANIES

Berlin, Germany

Berliner Verkehrsbetriebe (BVG)

Potsdam, Germany

Verkehrsbetriebe Potsdam (ViP)

Dresden, Germany

Dresdner Verkehrsbetriebe AG (DVB)

Vienna, Austria

Wiener Linien

Linz, Austria

Linz AG Linien

Paris, France

Régie Autonome des Transports Parisiens (RATP, Paris Transport Co.)

Rouen, France

Transports en Commun de L'Agglomeration Rouennaise (TCAR/Connex)

Orléans, France

Société d'Economie Mixte des Transports en Commun de l'Agglomération Orléanaise (SEMTAO)

APPENDIX C—LIST OF ABBREVIATIONS

APTA	American Public Transportation Association
AVL	Automatic Vehicle Locator
BRT	Bus Rapid Transit
BVG	Berliner Verkehrsbetriebe
BVWP	Bundesverkehrswegeplan (Germany's National Transport Infrastructure Plan)
CCTV	Closed Circuit Television
DAISY	Dynamische Auskunfts- und Informationssystem
DVB	Dresdner Verkehrsbetriebe AG
EU	European Union
FTA	Federal Transit Administration
GPS	Global Positioning System
GVFG	Gemeindeverkehrsfinanzierungsgesetz (Germany's Municipal Transport Funding Law)
IT	Information Technology
ITSP	International Transit Studies Program
LED	Light Emitting Diode
LVWP	Landesentwicklungsplan (Germany's Regional Development Plan for Transport)
OBS	On Board System
PEM	Proton Exchange Membrane
RATP	Régie Autonome des Transports Parisiens

RER Réseau Express Régional (surface rail in Paris)
RF Radio Frequency
RFID Radio Frequency Identification
SEMTAO Société d'Economie Mixte des Transports en Commun de L'Agglomération Orléanaise
STAR Systemtechnik für den automatischen Regelbetrieb
TCAR Transports en Commun de L'Agglomeration Rouennaise
TCRP Transit Cooperative Research Program
TRB Transportation Research Board
ViP Verkehrsbetriebe Potsdam

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TRB
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