

TRANSIT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Transit Administration

Subject Area: VI Public Transit

Responsible Senior Program Officer: Gwen Chisholm-Smith

Research Results Digest 89

International Transit Studies Program
Report on the Spring 2008 Mission

PUBLIC TRANSPORTATION'S ROLE IN ADDRESSING GLOBAL CLIMATE CHANGE

This TCRP digest summarizes the mission performed May 9–23, 2008, under TCRP Project J-03, "International Transit Studies Program." This digest includes transportation information on the organizations and facilities visited. It was prepared by the Eno Transportation Foundation and is based on reports filed by the mission participants.

INTERNATIONAL TRANSIT STUDIES PROGRAM

The International Transit Studies Program (ITSP) is a part of the Transit Cooperative Research Program (TCRP), authorized by the Intermodal Surface Transportation Efficiency Act of 1991 and reauthorized, in 2005, by the Safe, Accountable, Flexible, Efficient Transportation Equity Act. TCRP is managed by the Transportation Research Board (TRB) of the National Academies, and is funded annually by a grant from the Federal Transit Administration (FTA). ITSP was managed by the Eno Transportation Foundation under contract to the National Academies.

ITSP assists in the professional development of transit managers, planners, and others charged with public transportation responsibilities. ITSP carries out its mandate by offering transportation professionals practical insight into global public transportation operations. The program affords the opportunity for them to visit and study exemplary transit operations outside the United States.

Two ITSP study missions are conducted each year, usually in the spring and fall, and are composed of up to 14 participants, including a senior official designated as the group spokesperson. Transit organizations across the nation are contacted directly and asked to nominate candidates for participation in the program. Nominees are screened by committee, and the TCRP Project (J-03) Oversight Panel endorses all selections. Members are appointed to the study team based on their depth of knowledge and experience in transit operations, as well as for their demonstrated advancement potential to executive levels of the public transportation industry. Travel expenses for ITSP participants are underwritten by TCRP Project (J-03) funding.

Each mission abroad focuses on a theme that encompasses a topic of concern in public transportation. Cities are selected according to their ability to demonstrate leading-edge strategies and approaches to public transportation issues and challenges, as reflected in the study mission's overarching theme.

CONTENTS

International Transit Studies Program, 1
About This Digest, 2
Public Transportation's Role in Addressing Global Climate Change, 2
Dublin, Ireland, 3
Munich, Germany, 6
Freiburg, Germany, 9
Milan, Italy, 10
Bilbao, Spain, 13
Reducing Greenhouse Gases, 17
Comparisons with U.S. Cities, 18
Observations, 18
Conclusions, 19
Appendix A—Study Mission Team Members, 21
Appendix B—Study Mission Host Agencies, 21
Appendix C—List of Abbreviations, 22

The members of each study team are fully briefed prior to departure. The intensive, professionally challenging, two-week mission has three objectives: to afford team members the opportunity to expand their network of domestic and international public transportation peers, to provide a forum for discussion of global initiatives and lessons learned in public transportation, and to facilitate idea-sharing and the possible import of strategies for application to America's transportation communities.

For additional information about the International Transit Studies Program, please contact Gwen Chisholm-Smith at TCRP (202-334-3246; gsmith@nas.edu) or Kathryn Harrington-Hughes at 410-770-9192 (kathryn@harrington-hughes.com).

ABOUT THIS DIGEST

The following digest is an overview of the mission that investigated public transportation's role in addressing global climate change in several cities in Ireland, Germany, Italy, and Spain. It is based on individual reports provided by the mission 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, American Public Transportation Association (APTA), FTA, or Eno Transportation Foundation.

PUBLIC TRANSPORTATION'S ROLE IN ADDRESSING GLOBAL CLIMATE CHANGE

Energy-related activities in the United States account for most (75%) of the greenhouse gas (GHG) emissions generated by human activity, and about half of the emissions come from transportation. The U.S. government is seeking to slow the growth of GHG emissions from all sources.

The objective of this mission was to meet with transit leaders in five European cities that have been pioneers in the use of environmentally sensitive practices in transit operations and in new project development and who have worked to integrate transit into community land use planning. The mission team met with nongovernmental and governmental organizations that play a role in encouraging and regulating environmentally sensitive transport and land use practices. Topics addressed included emissions; the connection between land use and transportation/

transit, with particular emphasis on transit-oriented development; "green" facilities; and transit's possible role in a carbon reduction regime.

The cities visited on this study mission were Dublin, Ireland; Munich and Freiburg, Germany; Milan, Italy; and Bilbao, Spain.

Climate Change

Urban activities are the leading cause of climate change, and transportation is by far the largest energy user. While the transportation sector is the leading contributor to GHG in urban regions, it should be noted that vehicles do not operate on their own. Individual travel behavior and our decisions on when and how much to drive are subject to the built environment and the transportation options available to us. Land use and transportation funding policies heavily influence our travel behavior and travel choices. Studies show, and the European cities visited prove, that a more compact, mixed-use neighborhood with adequate pedestrian and bicycle facilities linked to transit services is more likely to be a city with fewer car trips and a greater amount of trips by walking, bicycling, and transit. If, however, funding policies favor road capacity expansion and single-use development with plentiful parking over compact mixed-use developments and public transportation (walking, bicycling, transit), then higher levels of single-occupancy vehicle use are inevitable.

The relationship between land use and transportation is undeniably linked, and it will take bold leadership to ensure that funding policies support that linkage and provide adequate transportation choices to the public. Such leadership was evident in the policies and practices of the cities visited by the study team. Comprehensive, sustainable mobility strategies demand a broad set of coordinated policies that are beyond transit agencies' traditional responsibilities. In the five cities visited on this study mission, those policies and the associated leadership were undertaken by city leaders, rather than the transit agencies that were responsible for implementing many of those policies.

At the core of the cities' sustainable mobility policies were two broad categories—energy conservation and demand management; within the energy conservation category are two subcategories—energy efficiency and sustainable energy—and within the demand management category there are three main subcategories—road pricing, smart growth, and park-

ing. These policy areas are controlled by federal, state, and local governments; transit agencies have little or no influence in these areas. In Europe, centralized federal governments play an integral role in the allocation of resources and in the development of policy, including planning and economic policies, in contrast to the U.S. model of decentralized federalist funding and planning, where policymaking is left to the states and local cities.

Suburban/exurban growth was overwhelming the five cities, similar to experiences in the United States in the early 1980s and the 1990s. The cities were diligently working to mitigate the environmental effects of this growth pattern, referred to as the “doughnut effect.” The doughnut effect results from people moving to the outer suburbs in search of more affordable housing or a more pastoral environment; this growth outpaces growth in the city center and causes peak-period increases in vehicular traffic to and from the central business district. The result is higher vehicle miles of travel, more congestion, and increased pollution levels in urban areas. Bringing transit service into the outer ring of a city, by extending train, tram, and/or bus lines or creating new services, can be an effective means of reducing vehicular traffic and thus reducing congestion and pollutant levels.

Transit agencies can further address climate change issues by using less energy, using renewable energy, and incorporating other sustainability measures, such as stormwater management, rainwater collection, and recycling of materials, into their operations and capital improvement projects.

The cities of Dublin, Munich, Freiburg, Milan, and Bilbao are all looking at ways of improving mass transit by increasing service and/or upgrading existing systems. Improving mass transit services within a city and its suburbs will not only benefit existing residents, but will also make the city more attractive and pleasant for households and businesses.

DUBLIN, IRELAND

The first stop on the study mission was Dublin, Ireland. Dublin is the hub of Ireland’s transportation network, with an active international airport, seaport, and rail center. The greater Dublin area is served by an extensive transportation system of roads, rail, buses, and subways. Fifteen related agencies—some state owned, some privately owned, and some semi-publicly owned—manage Dublin’s transportation

system. To improve coordination and increase system efficiencies, the agencies plan to create a more centralized management structure by 2009.

The Dublin region has a population of 1.2 million in an area of 922 sq km, giving it a population density of 1,218 per sq km.

The country has a population of 4.2 million, and about 45% of the population is between 15 and 45 years old. People of Irish origin are increasingly returning home to Ireland, helping to fuel a significant growth in population. The Dublin economy is the foundation for the “Celtic Tiger” reputation, and the city serves as Ireland’s gateway to the global marketplace.

“Transport 21” is Ireland’s 10-year capital investment framework for developing the transportation system in the 2006–2015 period. The framework covers national roads, public transport, and regional airports. The Irish Government has agreed to a total investment of €34 billion over the 10-year period. In particular, it provides funding to do the following:

- Bring about a radical improvement in the level and quality of rail services,
- Transform the public transport system in the greater Dublin area,
- Develop the public transport system in the provincial cities,
- Improve regional and rural public transport services, and
- Deliver a sustainable transport system that balances social, economic, and environmental considerations.

The Dublin Transportation Office (DTO) is a governmental agency providing transport and land use advice to organizations serving the greater Dublin area. It coordinates transport activities with land use agencies and monitors the performance of land use agencies in achieving regional transport objectives. In 2001, 4 years prior to “Transport 21,” DTO published *A Platform for Change: An Integrated Transportation Strategy for the Greater Dublin Area 2000 to 2016*. Among other things, the document calls for a living city and region at a human scale, accessible to all and providing a good quality of life for its citizens, and for reducing the need for car commuting by improving the reliability, availability, and quality of public transport. DTO is emphasizing the connection between land use and transportation, without which a reduction in auto dependence is not possible. DTO

also received traffic management grant funds to implement quality bus corridors (QBCs), which provide shorter journey and more consistent service through the use of dedicated lanes and traffic signal priority.

The Dublin City Development Plan is updated every 7 years. The plan published in 2005 responds to the needs of the greater Dublin area and conforms to the *National Spatial Strategy for Ireland: 2002–2020* and the *Regional Planning Guidelines for the Greater Dublin Area (2004–2016)*. The plan focuses on further development of the city’s core on protecting the city center as the “heart and pulse” of the Dublin region.

Under the Kyoto Protocol, the industrialized countries of the world (excluding the United States) have agreed to reduce their aggregate GHG emissions by at least 5% below 1990 levels in the 2008–2012 period. Ireland’s contribution to this objective is to limit average national GHG emissions over the 5 years to no more than 13% above 1990 levels.

The Irish Department of the Environment, Heritage, and Local Government published a report in 2000 titled *National Climate Change Strategy: 2007–2012*. The strategies within this report provide a framework for the radical actions that are necessary to meet Ireland’s climate change commitment. Key initiatives include switching to low and zero carbon fuels, improving fuel efficiency, exercising demand management, and encouraging a modal shift.

The main GHG in Ireland is carbon dioxide (CO₂), mainly arising from the burning of fossil fuel in transport operations, heating, and electricity generation. Emissions from the transport sector are forecast to have a 180% increase by 2010.

DTO’s *A Platform for Change* sets a goal of 63% market share for public transport in the peak-hour commute by 2020. The organization has committed to the following goals:

- A considerable shift to public transport, cycling, and walking;
- A significant reduction in congestion; and
- A reduction in transport emissions.

DTO is focusing on the following areas in achieving their vision:

- Land use and transport integration,
- Integration of public transport (light rail, commuter rail, and buses),
- Greater emphasis on higher density, and
- Increased fuel tax.

Dublin Bus (Bus Atha Cliath) is the main public transport provider for the greater Dublin area and carries 70% of all peak-period public transport users into Dublin. On average, the bus network carries a half million customers a day and provides 150 million passenger trips each year on its 1,100 buses serving 214 routes. Dublin Bus has 10 QBCs, which are defined by the following six key characteristics:

- Speed,
- Reliability,
- Route design,
- Modern buses,
- Attractive shelters, and
- Customer focused services.

Service on a QBC corridor has high frequency and visibility. QBCs are implemented in conjunction with local authorities. Active management of this service is key to its success.

Luas—the light rail transit system in Dublin—is operated by Veolia Transport Ireland. Veolia Transport (formerly Connex) manages bus, tram, rail, trolley bus, tax, and ferry services in 27 countries. There are two Luas lines—the Red Line and the Green Line. The Red Line is 14 km in length and has 23 stops from Connolly to Tallaght. The Green Line is 9 km in length and has 13 stops from St. Stephen’s Green to Sandyford. Together, the two lines carry 90,000 passengers on an average day; in 2007, the tram system carried 29 million passengers. Currently, the Red and Green lines are not connected; it is a 15-min walk to transfer between the two lines. New Luas lines, as well as a connector between the Red and Green lines, are planned for completion by 2014 as part of the “Transport 21” plan.

The trams are 40 m long on the Green Line and 30 m long on the Red line. The Red Line trams are, however, being extended by 10 m. The trams carry 90,000 passengers on an average day. Ridership has steadily increased from 22 million passenger trips in 2005 to 29 million trips in 2007.

The roles and responsibilities for implementation of the Luas system differ from the typical U.S. model in which a transit authority plans, develops, implements, and operates the system. In Dublin, the Railway Procurement Agency (RPA) is responsible for planning and developing the Luas system. Each line is built as a public-private partnership (PPP), which allows RPA to put the building and operation of individual lines out for bid. The operations contract is performance based. To keep the bidding process

competitive, RPA does not disclose the projected project cost to bidders.

DART (Dublin Area Rapid Transport) is an electrified rail line operated by Irish Rail. It connects the city center with the suburbs along the coast.

Coordination and collaboration between all 15 transportation agencies in Dublin continue to present a challenge to optimal operation. However, Dublin's transportation agencies are united in their commitment to reduce redundancy and improve efficiencies. Transportation funding of current and planned projects is an ongoing challenge. Current funding sources are not adequate to sustain Dublin's predicted growth, and tax revenues are being scrutinized to determine what changes are needed to fund necessary improvements. The city's transportation agencies are using comparisons with systems in other regions to create benchmarks useful in improving plans and services. Despite some fiscal challenges, however, the prevailing attitude is that environmental concerns cannot wait to be addressed and must be an integral part of successful system planning.

There is a strong mindset that creating sustainable environmental practices is integral to controlling costs and providing a good quality of life. This is evident in the Dublin Chamber of Commerce's interest in transport policy. The Chamber's vision is to develop Dublin into the best city for business and a great place to live. Good stewardship of the environment is considered good economics. An Taisce (the National Trust for Ireland), the country's most influential environmental organization, contends that a high-quality environment is key to a successful and sustainable economy and a high quality of life.

There are also strong environmental initiatives coming from governmental sources. CO₂ goals are being established by the government to emphasize the need for conservation; however, whether those goals are realistically attainable remains to be seen. Ireland's Department of Transportation issued a report in 2008 (*2020 Vision: Sustainable Travel and Transport*) that details the commitment that must be made on the part of their citizens and the nation as a whole to successfully realize the goal of transportation sustainability. The leadership for these initiatives is clear and comprehensive, involving all levels of enterprise. The government recognizes the need for more "mobility management." As stated in the 2020 report:

Mobility management has been widely used to improve the transport options available to users,

provide incentives to choose more efficient travel patterns, and/or reduce the need for physical travel. It includes soft support measures such as flexible working and workplace travel plans, car sharing and car clubs, travel vouchers, personalized travel planning and travel blending, and school travel plans.

Ireland's residents also have responsibility in creating a sustainable lifestyle. The government defines sustainable travel as encouraging people to make informed choices about the way they travel and realizing the consequences of those choices on their health and the environment. Commuters make up 40% of the greater Dublin population and typically spend between 60 and 89 min getting to work, with many living more than 100 mi from the city. The amount of commute time and a lack of connections between some routes have posed an impediment to increasing transit ridership. Because so many people live outside of the city where they work, land use planning is a vital factor in forming better practices for the future. How land is developed and used and what access is available to public transportation should be given careful consideration in planning a more sustainable future.

Dublin's residents are encouraged to use alternate forms of transportation that have less impact on the environment and also improve their health and wellbeing. Alternatives such as walking and biking are being fostered through planned improvements for better bike/walk paths, dedicated cycle lanes, reducing traffic volumes and speeds, and improving road surfaces. Limited parking spaces and higher parking costs, coupled with the high price of owning and operating an automobile, are making public transportation increasingly more attractive.

Parking policies also play a key role in encouraging people to shift to mass transit. Parking is limited and expensive, and parking regulations are strictly enforced.

The quality bus corridors, with their 12-hour bus-only lanes, signal priority, and appropriate, coordinated feed routes, have experienced a 20% increase in ridership.

Operators with performance-based contracts have a significant incentive to deliver services on time and with a high level of customer service. Operational efficiency is also key, due to the structure of the PPP.

Sustainability and climate change strategies seem to be an integral part of doing business in Dublin.

Dublin's public transportation system faces many challenges to accommodate the city's high rate of growth and improve some of the current barriers that prevent all of the various agencies from operating seamlessly. However there is a high level of awareness and momentum about what needs to be done. Strategic planning, infrastructure and service improvements, land use planning, and transport measures, along with consultant analysis, are being addressed to create a stronger transportation system. Many less visible initiatives are also being made to contribute to making the system's operation more environmentally friendly. One small example is the employment of "regenerative braking" on the Luas trams as a means of using energy more efficiently. There is a strong focus on on-time performance and reliability of service, which ultimately translates into more people using the service and reducing the number of cars on the roads.

MUNICH, GERMANY

The study team traveled from Dublin to Munich, Germany, for the first of two stops in that country. Germany is approximately the size of the state of Montana, but with a population of 82 million, it has 90 times as many people. The country is highly urbanized, with about 87% of the population living in urban areas.

Munich, the capital city of the state of Bavaria, is located on the River Isar, north of the Bavarian Alps. Munich is the third largest city in Germany behind Berlin and Hamburg. The population of Munich is 1.4 million, and the greater Munich area, which covers an area of 410 sq km, is home to 2.6 million residents, 880,000 jobs, and 680,000 automobiles.

For its population, Munich has one of the most comprehensive transport systems in the world, incorporating the U-Bahn (underground railway), the S-Bahn (suburban trains), trams, and buses.

The Munich transport company (Munich Verkehrsgesellschaft, or MVG), is a subsidiary of Munich Stadwerke GmbH (SWM), the utility agency for the city of Munich. MVG operates Munich's underground, trams, and most of its buses. More than 550 underground cars, 96 trams, and over 250 buses belong to the MVG fleet. Combined, these services provide six U-Bahn lines totaling 93 km in length, 10 street trams (light rail) lines of 71 km in length, and 67 bus lines covering 458 km. Ridership for the combined system exceeds 1 mil-

lion passengers per day, with a total annual ridership of 482 million. Unlike many public transport systems in Europe that are privatized, MVG is owned by the city.

In Munich, you are never more than a few minutes away from MVG because its network of lines puts every household within 400 m of an underground, bus, or tram stop. While auto ownership is high (one car for every two residents), 40% of Munich residents own no car. Car sharing is used extensively by Munich households with no car. In the 3 months prior to the study mission, 93% of Munich residents used public transport.

Modal split is another success in Munich, with 32% using public transport and an astounding 80% of peak period travel within the city center area carried on public transport. Bicycle usage is a popular mode (12%), as is walking (15%).

One of the strategies used in Munich to attract new residents to public transport is a "mobility management for new residents" campaign. All new residents are contacted and provided timely information and consultation on transportation options in the region. Early results of the campaign have shown a 7% increase in public transport use, which can be applied directly to calculated CO₂ emission reductions and kilometers traveled by auto. The success of this pilot project is now being expanded to all new residents.

MVG is currently involved in several environmental initiatives that are primarily infrastructure based, including new tram lines, signal prioritization to improve bus and tram travel times, and increased levels of service. Excluding infrastructure that receives national and state funding, Munich must cover 100% of the operating costs for its local system. MVG has a license to operate the service but has no contract or guaranteed revenue stream besides fares. The agency has thus been working for several years on improving its efficiency of operations. New vehicles purchased for the U-Bahn from Siemens use half the energy of previous models. Restructuring the agency has increased output by 20% while reducing staff by 30%. The bus network has been restructured, with wages, shop processes, vehicle turnover, and management efficiencies all addressed. Bus schedules that were centralized prior to 1996 were taken over by MVG, which allowed the output to be adjusted for maximum efficiency. MVG plans to tie a percentage of all workers' wages throughout the agency, including first-line operations staff, to

performance of the system. The net result of these efforts has been to reduce an operating deficit to an operating surplus of €60 million, which is paid back to the owner.

The agency uses solar energy for some of its facilities, has grass trackbeds for some of its tram lines to reduce noise, and cools many of its underground stations with groundwater.

MVG has made sustainability an important part of their core culture and annual goals. In fact environmental goals have been expanded for senior management since 2005. MVG encourages staff to generate ideas for energy savings and environmental protection. In the Munich area, transport only accounts for 8% of CO₂ emissions, compared with 20% countrywide. The other emissions sources in the Munich area are industry (22%) and energy/heating (70%). MVG riders are saving 160,000 metric tons of CO₂ per year, when compared with single-occupancy vehicles. The agency is focused on three major areas of sustainability—economic, ecological, and social, all seen as equally important to the vitality of the region. Diesel particulate filters are in use on the bus fleet, and biofuels make up 10% to 20% of the energy used, although this does not reduce CO₂ emissions. Hybrid bus technology is being tested and may be expanded in the future.

SWM and MVG view issues of sustainability and climate protection as multifaceted, requiring attention from all parts of the company.

The mission team met with Green City e.V., a Munich nongovernmental organization that has been working to improve Munich's quality of life through ecological urban planning since 1990. An engaged team of 18 staffers, more than 30 highly active volunteers, and hundreds of other activists organize, coordinate, and support numerous wide-reaching projects. Green City has ambitious goals, including a 50% reduction in kilometers driven by single-occupancy vehicles (compared with a 1990 baseline) and at least a 50% reduction in Munich's GHG emissions (compared with a 1987 baseline).

Green City's areas of focus include sustainable mobility (reducing auto use), improved urban design (creating quality public spaces), and climate protection (reducing CO₂ emissions). Quality of urban life is a Green City vision illustrated by several major initiatives. Green City is a strong advocate for developing a full multimodal transport system, including creating a better appreciation for walking and cycling, and they collaborate with MVG on a number of pro-

grams each year. Their actions include political activity via campaigns, public relations, and networking and project work via events, education, and knowledge transfer. Examples of Green City activities include the following:

- “Street Life Festival”—Green City's concept of a European Mobility Week, an event held two weekends per year and that drew 300,000 persons last year. The event takes place on streets closed to automobile traffic and provides a platform for more than 250 organizations to present their programs.
- “Moving Trees”—A project that has resulted in 140 urban trees being planted by and cared for by sponsors.
- “Senior Cycling”—A project designed to familiarize residents aged 55 plus with the use of bicycles for mobility. The project includes free training and support from staff and occupational therapists, as well as the use of special “Easy-Rider” bikes specially designed for seniors. The program offers opportunities for social interaction and exercise for the senior population residing in the urban area.
- “Zero Degrees Plus”—A campaign designed to get as many Munich residents as possible to move toward climate protection and sustainability practices as they live their lives. The campaign engages companies to create options for customers to promote sustainability, and it builds political pressure and public awareness for the topic over the long-term, as well as portrays climate protection actions as relevant, modern, and practical. The theme is, “We're stopping global warming.”
- “Speech Bubbles”—A campaign designed to convey positive messages about what individuals and the city can do to combat global warming. Cartoonish, attention-getting speech bubbles were posted at MVG stations, with “take me” and “thank you for using public transport” on them, along with a message about global warming.

The Green City representatives also spoke of the energy industry in the region. They noted that currently 11% to 12% of the energy generated is “eco-power.” The goal they would like to see reached is to increase the clean energy to 30% to 35% over the next 10 years. Nuclear power accounts for 20% of the energy in the Bavarian region; however, 75% of

the citizens are opposed to further nuclear expansion, viewing it as a limited resource with high risk. Solar generation accounts for only 1% of the power generated in Bavaria, and they do not see significant growth until some of the questions related to cost and technology are answered. On the carbon trading front, while there has been a market established, governmental policy has limited the value of such certificates.

Next, the mission team met with the team from DB Bahn, the passenger division of Deutsche Bahn AG, the German national railway. The first stop before our meetings and presentations was to tour the main railway station in Munich, the “Hauptbahnhof” (central station) in the city center. Munich’s central station houses four levels of transportation lines, with 36 platform faces on the main level. Each day, the station is served by 750 regional and international trains, 1,100 S-Bahn trains, and numerous light rail transit and bus lines. Every day, 2 million passengers pass through this station.

DB Bahn is currently owned by the German government; however, it is about to issue publicly traded stock for their system less the infrastructure, which will be retained by the government. The railway lines are open access as required under the EU laws; DB Bahn must allow other trains to have access via trackage rights agreements and fees. There are five companies or divisions within DB Bahn—network infrastructure, stations (including business and shopping hubs), freight operations (including trains and trucks), IntercityExpress (ICE) and international trains, and regional trains. Regional trains are the largest division within DB Bahn, accounting for 70% of all trains operated.

Every regional train is funded by the government. There is no government funding for freight operations, ICE, or intercity trains. The 17 German states decide the number of regional trains to operate. In the Bavarian region alone €700 million in government funding is provided for regional trains. Throughout the country, €8 billion is spent on regional trains. DB Bahn competes to provide regional train services and currently still operates 80% to 90% of all trains; however, as more contracts are tendered, DB Bahn expects that their share of the market will be reduced as other operators assume control of various lines.

This trend towards tendering services is part of a 10-year program to restructure the rail service in Germany. During this period, ridership has increased 35%, service levels have increased 33% with the

same infrastructure, and train mileage is up 28%. At the same time, costs are only up 15% due to various efficiency initiatives, including a complete restructuring of senior management, reducing overhead expense.

The S-Bahn metro service carries 800,000 daily riders on 1,100 trains that operate 20 million km of revenue service per year. There are 10 lines with service frequencies of 10 min in peak periods and 20 min in off-peak periods. In the main underground station, 30 trains per hour pass through on two tracks, which creates a congestion issue that could be solved by adding another tunnel and 10 km of tracks. The project would cost €1.5 billion and is currently awaiting financing.

The mission team had the opportunity to ride an ICE train from Munich to Freiburg and from Freiburg to Basel, Switzerland. The ICE system consists of high-speed trains predominantly running in Germany and neighboring countries. It is the highest service category offered by DB Fernverkehr and is the flagship of Deutsche Bahn.

The “ICE” name is also used for the vehicles used on the system, which were specifically developed for the system starting in the early 1980s. There are currently three different versions of the ICE vehicles in use, named ICE 1 (deployed in 1991), ICE 2 (1996), and ICE 3 (1999). The ICE 3, including its variant models, is made both by Bombardier and by Siemens. To overcome restrictions imposed on the ICE 1 and ICE 2, the ICE 3 was built to a smaller loading gauge to permit its use throughout Europe. Unlike their predecessors, the ICE 3 units are built not as locomotive-pulled trains, although they are still aerodynamically optimized, but as electric multiple units with underfloor motors throughout. This also reduced the load per axle and enabled the ICE 3 to comply with the pertinent UIC (International Union of Railways) standards.

Like the ICE 2, the ICE 3 was developed as a half-length train (compared with an ICE 1), and individual units are able to run on different lines and then be coupled to run together.

The ICE trains can also be seen in countries neighboring Germany. There are, for example, ICE 1 lines to Zürich, Switzerland, and Vienna, Austria. ICE 3 trains also run to Liege and Brussels, Belgium, and at lower speeds to Amsterdam in the Netherlands. On June 10, 2007, a new line between Paris and Frankfurt/Stuttgart was opened, jointly operated by Deutsche Bahn and SNCF, the French national

railway. While the ICE runs the Paris-to-Frankfurt branch, SNCF's TGV runs from Paris to Munich (via Stuttgart), with mixed crews on both trains. On December 9, 2007, the ICE TD was introduced on the service from Berlin via Hamburg to Arhus and Copenhagen, Denmark.

The newest high-speed line in Germany, the Nuremberg-Ingolstadt line, opened in May 2006 and is the most recent addition to the ICE network. It is one of only two lines in Germany (the other being the Cologne to Frankfurt line) that is equipped for a line speed of 300 km/h.

The mission team experienced the comfort, speed, and reliability of the ICE 3 firsthand on the trip from Munich and Freiburg. The trains were comfortable, with ample luggage storage, cell phone repeaters, internet access, and accessible restrooms. On the Munich to Stuttgart leg of the trip, the train frequently exceeded 250 km/h. The success of this system at reducing dependence on regional airline carriers and doing so at higher energy efficiencies and lower emissions levels illustrates the potential of high-speed trains in congested travel corridors in the United States.

FREIBURG, GERMANY

Freiburg, a well-preserved historic town in the southwest of Germany, has long been recognized as "the green city" of Germany. Transportation improvements are but a small part of its environmental efforts. It has pursued solar energy for homes and government offices, recruited solar-related businesses, pioneered transit-oriented development, and embraced an energy policy that moves away from nuclear power and toward wind and solar power and that supports cogeneration of heat and electric supply. Two of Freiburg's communities—Vauban and Reiselhof—are experiments in sustainable living, with easy transit access, high density housing, solar electricity, cogeneration plants, and green roofs.

The goals of the city's environmental policy are to reduce carbon dioxide by 2010 and halve the share of nuclear power in use. This is to be done through the following three approaches:

- Energy savings, which include thermal insulation, low-energy constructions, and power saving;
- Renewable energy, including solar, wind, hydro-power and geothermics; and

- New technologies, such as thermal power stations, cogeneration, and long- and short-distance heating.

Transportation is also a key part of Freiburg's environmental strategy. In 1989, the city leadership adopted "Freiburg Mobility," which is depicted as resting on five pillars: extending the public transport network, promoting bicycle traffic, restraining traffic, channeling single-occupancy vehicles, and managing parking spaces. For a town of 215,000, Freiburg has extensive public transportation coverage: buses, a tram system, S-bahn commuter trains, and regional trains. Its transportation policy is designed to encourage people to shift from their cars to more efficient, less polluting, alternative modes. Policies to promote this shift include the following:

- Most of the downtown was converted to a pedestrian-only zone in 1973.
- New routes, frequencies, and vehicles were added to the tram system so that 65% of the city's population currently lives within walking distance of a tram line.
- S-bahn trains were added in an attempt to reduce car travel into the city from adjoining communities.
- Since 1970, 500 km (310 mi) of bike lanes and paths have been created.
- Traffic calming has been instituted in residential zones.

The policies have clearly been successful for Freiburg, where the automotive modal share in the city has dropped from 39% to 30% in the 20 years from 1982 to 2002. At the same time, however, people traveling to Freiburg from the adjoining communities have increased their reliance on the automobile (38% in 1961 to 65% in 1994).

Freiburger Verkehrs AG (VAG), a city-owned company that operates the bus system and tram lines, has been steadily expanding its system and ridership since the 1980s, after struggling through a period of low ridership and disinvestment during the 1960s. While annual ridership was relatively flat at about 28 million passengers a year through 1984, annual ridership systemwide is currently just over 70 million passengers a year.

VAG currently has 30 km (18.6 mi) of tram lines on four routes, with 58 vehicles, and 270 km (167 mi) of bus lines with 62 buses. The buses are operated by 12 private bus companies. System ridership is

70 million passengers a year—85% on the trams and 15% on the buses. The buses run every 15 min, and the trams run every 7.5 min (every 4 min during peak hours), making schedules almost unnecessary. Riders can walk to the nearest tram station and count on a train arriving after only a short wait. Ticket vending machines are available at all the stations, making it easy to board once you have purchased your ticket. Several of the ticket vending machines downtown actually had VAG personnel on hand to explain how to use the machines and answer new riders' questions.

This expansion of local transportation has allowed the share of Freiburg residents using public transport to increase from 11% to 18% of all travel. Officials report that of the 25,000 students at the University of Freiburg, just 10% travel by car.

In addition to touting its coverage and frequency and laying claim to being competitive with the car in travel time, VAG's marketing efforts and promotional fare media are also a piece of the transportation picture in Freiburg. VAG aggressively markets its ease-of-use as well as its contribution to making Freiburg "green." And it has an innovative "RegioKarte" pass that is responsible for increasing ridership by about 5 million passengers per year. The monthly RegioKarte pass costs €34 (\$53) and allows travel by any of the transport services in three counties, including the regional trains. It allows family members to travel on one pass on the weekends, and it is transferable.

Freiburg has also focused on increasing bicycle and pedestrian mobility. The presence of bicycles is overwhelming, and the modal share for commuters on bikes has grown from 15% in 1982 to 28% in 2002. The VeloCafe is a prominent feature at the town's Hauptbahnhof (central station). It is a distinctive round building that allows up to 1,000 bicycles to be stored indoors and features lockers for bicyclists to store their personal items and shops that rent, repair, and buy bicycles. On-site stores sell bicycle-related equipment, and hundreds of bicycles fill the double-tiered rows of bike racks.

Freiburg calls itself the "Solar City" of Europe. It won the German Solar Prize in 2004 and has over 500 solar projects in homes, businesses, and public institutions. It offers financial support for people who wish to install solar panels, and all customers are offered the option of buying energy generated in the region.

The ITSP study group toured Vauban, a transit-oriented development (TOD), arriving by tram and then visiting homes, office buildings, and restaurants that are powered by solar panels. The most famous of these, a home called Heliotrope, was designed and occupied by the architect Rolf Disch; it has a revolving solar panel on top, and the cylindrically shaped house itself also revolves to seek the sun. The Vauban community produces its own heat through cogeneration in a plant fueled by wood chips, and many residences generate so much electricity through solar panels that they are able to sell energy back to the electric company. Most of these homes are attached townhouses averaging 1,000 sq ft in two or three stories, surrounded by shared green space and play areas.

Vauban's transit system and environmental lifestyle is enforced through a series of traffic policies. They are as follows:

- No private parking spaces at homes. All cars are parked in a nearby community parking lot.
- Speed in residential areas is limited to 5 km/h or just over 3 mph, which is considered walking speed.
- Two tram lines serve the community, and car-free households are given preference for homes near the tram lines.
- The community is designed so that shopping, schools, and restaurants are within walking distance of all homes.
- Five cars and one van are available for residents' use through a car-sharing business.
- People who subscribe to car sharing receive a 1-yr pass good for free public transport and for 50% off tickets for the regional trains.

The community of Vauban has just 16 cars per 100 residents; in comparison, Freiburg, as a whole, has 35 cars per 100 residents.

MILAN, ITALY

The mission team traveled by train from Freiburg, Germany, to Basel, Switzerland, and then transferred to another train for the trip to Milan, Italy. Milan is one of the largest cities in Italy, located in the plains of Lombardy. The municipality has a population of 1.3 million in a relatively small area—about one-eighth the size of Rome. The metropolitan area has a population of 7.4 million (3.8 million of which is in the Province of Milan).

Milan is renowned as one of the world capitals of design and fashion. The city hosted the World Expo in 1906 and will host the World Expo in 2015.

The city's narrow streets are highly congested, and parking space is limited. The sidewalks and streets do not appear to be as bicycle friendly, nor as pedestrian friendly, as what was observed in Germany. Little or no real-time information existed for parking availability or public transit on the street level. Milan evidences the same automobile culture that exists in most areas of the United States and has corresponding issues associated with traffic, congestion, and air quality.

The first organization that the team met with in Milan was Legambiente, a nongovernmental organization that is the principal environmental group in Italy. The first speaker was the director of car-sharing services, a program started in September 2001. Car-sharing is considered an essential strategy for spurring reductions in car ownership and use. The Italian culture is autocentric, with the second or third highest per capita car ownership in the world. The initial car share program grew from 20 to 600 members, which required the formation of a company in 2004 to manage the larger and more complex organization. The car-sharing concept has grown beyond the greater Milan area, with nine local cities creating their own car share programs, and a national organization that is coordinating all car sharing systems. Some financing from the states is given to the car-sharing firms; however, most is in the form of shared technical services. Smart cards are used to reserve cars and allow members to access and operate the vehicles. Members in the Milan car-sharing company can also reserve cars in other cities. By 2008, membership in Milan had grown to 1,900 members, and the Milan fleet consisted of 70 cars. Membership consists of 70% individuals and 30% businesses. There are now actually two separate car-sharing agencies that are independently operated in Milan, which has caused some overlap and policy issues.

One of the unique limitations for the Milan program is that car-sharing vehicles can't be parked on the street, in adherence with Milan's strict parking regulations. Thus all car-sharing vehicles must be parked in garages or in business lots, which adds costs. To solve this problem, the company is negotiating an agreement with the city that would allow car-sharing vehicles to park in "blue" designated parking areas on the street for free, which typically

requires a payment of €1.50 per hour, which would be paid by the car-sharing company. Currently, all vehicles must be reserved on a round-trip basis—i.e., the car must be returned to the pick-up location. The company offers a number of vehicle types, including cars, vans, and hybrids.

The principal reasons that people join the car-sharing program are economics and convenience. If a person typically drives less than 7,500 km/y, then car sharing is cost effective. While early members named the environment as their main reason for joining, as the system has grown, more members cite personal benefits. It is estimated that one car in the car share program replaces 10 cars that would otherwise be owned and operated in Milan. The car-sharing website includes a calculator for estimating the savings if an individual sells a car and uses car sharing for a portion of trips. The government is also sponsoring a program in which it pays bonuses to individuals who destroy old cars, and the bonus can be applied toward the purchase of a new, cleaner technology car or toward car-share membership.

Legambiente sees the next step in the evolution of this program to be the development of a "central mobility management" system, a resource to access for a variety of services, such as car share, bike rental, or trip planning.

The Legambiente team then spoke more about their environmental goals, which became a focus some 20 years after the Chernobyl disaster. Their motto is to "think globally and act locally." One of their highest priority campaigns is "Clean up the World," a program that advocates actions to clean up the rubbish and other community eyesores that mar a community. Another campaign related to global warming is called "Stop the Fever," an education and advocacy program to raise the awareness of CO₂ emissions and encourage city lifestyles and changes in behavior. The NGO is encouraging the city of Milan to get directly involved in this campaign and is requiring the city, as they do all participants, to do something tangible such as target actual GHG reductions or prioritize the purchases of renewable sources. Individuals can sign up for the campaign, essentially making a personal contract to change their behavior to reduce their carbon footprint. On June 7 the campaign was initiated with a declaration of "low emissions living day," encouraging local government, businesses, and individuals to get involved.

On other environmental fronts they are working nationally to apply diesel particulate filters (DPFs) to buses. There is no law mandating the use of DPFs, so Legambiente is promoting their use and showcasing the benefits. There are virtually no bicycle lanes in Milan; neither is there a formal bicycle policy. The city wants to try a bicycle-sharing program, where users could pick up and return bicycles at locations throughout the city, but most of the public believes that riding a bicycle in the city is dangerous due to the narrow and congested road conditions.

Legambiente spoke about the Kyoto Protocol. Although Italy signed the agreements, Legambiente staff believe that the country has not acted in accord with the agreement. They noted the very real and severe challenges the city and region face with regard to improving air quality and reducing the carbon footprint. They noted that 30% of the time that a car is in motion in the city of Milan it is looking for a parking space. This exacerbates traffic congestion; the average speed on a city street is 5 to 8 km/h. Asked what they would do if they were in charge of city government and public transport, the staff said they would advocate for more public transit to provide more trip combinations, encourage the use of bicycles as a mode of travel, improve the frequency and connections of the public transport system, address the air pollution problem (which is particularly bad in the winter months), and tackle parking issues within the city.

The mission team next met with the managing director and staff from Azienda Transporti Milanesi S.p.A. (ATM), the public transport agency for Milan. Established in 1932, it is 100% owned by the Milan city council. In 2001 it was converted to a public limited company. Today it has 10 business units with 9,000 employees. The company is responsible for construction of the new Metro Line 5, car parking management, insurance claim management, car sharing, network/infrastructure maintenance, public transport services, and management of the Copenhagen (Denmark) metro system and the Como (Italy) cable railway. ATM operates all public transit in Milan and the greater Milan area and actively bids on tenders issued by other areas for the delivery of services. Line 5, which is planned to have revenue service start prior to the World Expo in 2015, will be the first completely automated driverless line in the subway system.

ATM operates a vast network that covers 1,568 km, uses over 2,900 vehicles, and travels 142 million km/y. Ridership is over 600 million pas-

sengers per year. The surface system consists of 1,453 buses, 519 light rail trams, 156 trolley buses, and 81 small radio buses (door-to-door scheduled evening service). The underground Metro system runs on 74.6 km of track and has 88 stations and 729 railcars; 13.6 km are under construction, and 30 km more are in the development phase. Ridership on the Metro system alone tops 1 million passengers per day.

Like most operators the team met with on this trip, the current goals of ATM are centered on technology and efficiency. Their stated goals in the 2008–2010 period include maintaining financial stability, doubling their investment rate into the network, improving service quality, making technological innovation a corporate culture, and creating new alliances for growth in new markets.

Although prohibited from raising fares, ATM is trying to improve services. Fare evasion is a low 1% to 2% in the underground Metro and 10% to 15% on the surface systems. ATM's security force of 300 is licensed to carry weapons.

Because ATM does not control the surface streets, it has limited control over what it can do to improve travel speeds and reduce congestion, which affects on-time performance. While ATM is involved in bicycle programs, the existing bicycle network is very limited, totaling 40 km of bike lanes; it will be difficult to expand the network given the roadway and sidewalk configuration in most of the city area.

ATM has been working on reducing emissions from its own fleet, recognizing its contribution to the urban emissions of the region. All rail and tram lines are electrified. Newer-technology, higher-cost rail cars are being purchased that include regenerative braking and energy storage mechanisms such as on-board capacitors. The first of 30 new-generation vehicles will be delivered within the next year.

The city's Mobility and Environment Agency (Agenzia Milanese Mobilita) has established a plan to improve air quality and reduce GHG emissions in the region. The plan has the following seven components:

- Increase public transport ridership;
- Improve parking outside the center of the city so people can use public transport to get into the city center;
- Construct bicycle lanes and establish a bicycle-sharing system;
- Support car sharing and expand and promote the program;

- Improve pedestrian areas and requalify areas that are eligible for pedestrian improvements;
- Install dynamic message boards for parking lots to indicate to drivers where parking is available and thus reduce emissions from circling cars; and
- Continue operation of the EcoPass pollution charge.

Early in 2008 Milan implemented a pollution charging scheme, known as “Ecopass,” that is aimed at restricting access to the central business district by charging vehicles according to how much they pollute. The Ecopass program has three key goals:

- Improve air quality by reducing particulate matter emissions by 30% in the CBD;
- Relieve traffic congestion by reducing the number of cars entering the city center by 10%, thus allowing buses to travel more efficiently and provide more reliable service; and
- Improve public transport services by investing the money collected by the Ecopass system into transit and transportation improvements.

Only vehicles meeting the cleanest Euro 4 (emission standard) can enter the Ecopass zone without paying a charge; all other vehicles pay on a sliding scale that is based on emissions; a less-polluting vehicle will be charged less than a higher-polluting vehicle. As a vehicle enters the city, an image of the vehicle and its license tag is captured by on-street cameras; each image is matched to a database of registered vehicles, and the appropriate charge is assessed. To date, the Ecopass has resulted in a 15% reduction in the number of vehicles entering the city center. Fees collected from the Ecopass program are invested in sustainable transport in the city.

Implementation of the Ecopass pollution charge clearly has assisted in reducing traffic congestion and air pollution, including GHG, in the city center. It also encourages individuals to purchase more fuel-efficient cars that generate less pollution. The political leadership and vision of the recently elected mayor has allowed this program to be implemented so successfully.

BILBAO, SPAIN

Bilbao, the capital of the Basque country, is a port city 11 mi inland near the Bay of Biscay in Northern Spain. It is not just any mid-sized city in

Spain; it is a city that has, over the past dozen or so years, almost completely reinvented itself.

Bilbao suffered extreme economic distress from the 1940s through the 1970s, when the city’s two major economic engines (shipbuilding and the steel industry) began to collapse. In the late 1970s, the Bilbao government and the Basque government saw an opportunity to change the urban landscape and recapture and revitalize the economically depressed waterfront and port areas that had been the heart of the steel and shipbuilding industries. The Bilbao government focused on, among other large scale urban plans, cleaning the Nervión River, revitalizing its waterfront, repositioning railway infrastructure, and building a more pedestrian-friendly environment on its surface, as well as a major investment in transit.

Today, Bilbao (with a land mass slightly larger than Omaha, Nebraska, and a population slightly smaller) has a thriving city center, with a mix of high-end and affordable housing, retail and commercial space, public and open space, and a high-quality rapid transit subway system rivaling most major American or other Western European cities. Bilbao Ria 2000, which played the important role of community development agency, ensured that the development was accompanied by a significant investment in public transit—subway, tram, and buses, as well as new bridges to connect the riverbanks. The story of Bilbao’s success is one of strategically connecting transit infrastructure improvements with redevelopment, which resulted in the revitalization of the riverfront.

Bilbao is also home to the famous Guggenheim Museum, which is a major tourist attraction. The city also boasts dramatic Metro stations designed by Sir Norman Foster; the stations are now attracting new development.

In 2002, the Basque Country government came out with a report titled “*Assistance Plan for Sustainable Transport 2002–2012*.” The report acknowledges that cities were constructed for private automobiles and that the primary way of addressing traffic congestion had been to build more roads. The report discusses the goal of sustainable development. It recognizes that the solution of building roads is a short-term fix, and it calls for more investment in public transport for a sustainable transportation system.

The *Basque Plan to Combat Climate Change 2008–2012* states that private households collectively contribute more toward CO₂ than any other

single industry in the region. The contributing factors for the private households are use of automobiles, domestic combustion, use of electricity (by coal-fired plants), and waste.

Climate change strategies are well coordinated with the regional government. Strategies recommended include energy conservation, increasing mobility by more use of public transit, and new developments around transit stations.

Bilbao and its transit system are taking steps in accord with European best practices for sustainability. Specifics included upgrading maintenance practices to prevent runoff into the adjacent river, implementing recycling programs, and evaluating the feasibility of using eco-fuels for their nonrevenue fleet. The organization is also investigating the purchase of green power to operate their tram system; however, they expressed some skepticism of the credibility of green claims by the utility provider. As with many other transit agencies, they do calculate carbon reductions for their passengers, and they use that information in their marketing efforts. Additionally, EuskoTren, the regional rail provider, has taken significant action to reduce its carbon footprint. This agency has achieved ISO 14001 compliance and has the corresponding systems in place to track environmental compliance and GHG emissions. As with the other countries visited, transportation constitutes a smaller percentage of CO₂ emissions than commonly found in the United States.

At the heart of Bilbao's redevelopment effort is an award-winning metro system dubbed Metro Bilbao. This two-line subway system, which was initially viewed with skepticism, has been a huge success. Ridership currently stands at an impressive 86 million trips per year, with forecasts showing it rising to more than 120 million trips by 2012. In a city with only 400,000 residents (approximately 1 million in the metropolitan area), these are impressive figures. Equally striking is the design of the system, with unique and visually attractive entrances, gleaming stainless steel stations, and clean and appealing trainsets.

Key to the success of the system are the alignment of the routes, serving key destinations throughout the city, and the superior levels of service. The system offers service every 2.5 min in the peak period on the main segment and every 5 min on the branches, and service is fine-tuned throughout the year to match demand, with up to 70 different service schedules. Metro Bilbao is truly the kind of service that attracts

the broadest spectrum of riders with its excellent design and high quality of service.

Metro Bilbao is a young company, having started in 1995. The previous suburban rail lines that fed into the city center area carried 22 million passengers per year. The Metro system was built for a 100 million annual capacity, with ridership last year topping 86 million. The current system is 28 km in length. Plans to add more lines and extend the line to 32 km are under way, and the 2012 ridership estimates are that 120 million per year will use the system. Ridership is extremely high for a city with a population of less than 400,000 in the city and less than 1 million in the greater Bilbao area.

The system was a complex engineering feat, as the subway tunnels have to reach adequate depths to allow the system to cross the river that bisects the city multiple times.

The system was built with financing from multiple sources, including the Basque government, the regional government, and the European Union. Revenue recovery on the system is 92%, with the remaining 8% subsidy coming from the Basque government. The Metro Bilbao team doesn't handle the construction activities for system expansion. The Basque government formed a separate design/construction firm named IMEBISA to handle all construction-related activities, and when completed, the project was turned over to Metro Bilbao to operate.

The system has 70 stations with 92 elevators, 103 escalators, 155 ticket vending machines, and 378 entrance/exit fare gates. Service is provided with 37 trainsets, 32 sets being required for peak-period service. System expansion will increase the number of trainsets to 46 total, with 40 used in the peak period. Each four-car train costs €8 million and are electric multiple units, which include redundant power converters in each drive axle. Average speed of the system is 35.6 km/h, with a maximum speed of 80 km/h. The system has won numerous prizes for original design and appearance, as well as cleanliness.

These ridership numbers are supported by an extremely lean operating company with only 640 employees. They support the entire range of services needed for the system, including operations, engineering, power, signal and communications and security. The system operates 6 am to 12 am, and there is a strong desire to expand service hours to 5am to 1am. This makes the required maintenance performed by a staff of 100 employees challenging due to limited track and system access. The operations

support 70 different schedule variations that are used for days, evenings, weekends, holidays, special events, as well as seasonal changes.

The robust ridership of this service is driven by frequency of service. Unlike most U.S. systems that complete construction and then struggle to identify adequate funding to operate high frequencies, the Bilbao Metro was opened and operates on 2.5-min headways in the peak in the center of the city and 5 min in the outlying areas. Off-peak service is almost as good, with 3-min headways in the city center and 6 min in the outlying areas. Fares are extremely reasonable and there is a diverse offering of fares, including day passes, weekly passes, and monthly passes. To address the need for youth mobility and to attract youth riders to the system, they offer an annual pass for anyone under the age of 26—truly an example of “if you build it on the right route and operate it frequently and charge a fair price” you can pull ridership to your mode of service.

Access to the stations is primarily by walking. There are only two park-and-ride facilities in the Metro Bilbao system, with modest capacities of 250 and 150 vehicles. The daily parking fee is 65 cents. Plans for future line expansions, particularly in the outlying areas, call for additional parking at the stations to improve access and choice.

The system uses a fixed-block control system with a capability of 90-sec headways; however, Metro Bilbao is looking at movable block to improve system reliability. All trains are capable of full automatic driverless operation, but an operator is stationed on each train for safety and security purposes. Metro Bilbao buys AC power, €6 million per year, and converts power to DC train operations. Metro Bilbao isn't focused on the sources of power or initiatives to buy from renewable sources. They are working on new train power systems that have the potential to capture energy from braking and they hope to regain 50% of the power loss.

Despite the lack of focus on cleaner energy sources for its trains, the company wanted to show its customers that the agency is interested in sustainability and environmental practice. They have done this through numerous other initiatives. The original maintenance facility location was inherited and was highly contaminated by the previous owners, with all waste oil and water flowing into the river. A 2-year plan was adopted and the entire facility was upgraded to modern standards. Bilbao Metro signed the UITP Sustainability Charter in 2000.

In 2003 they purchased equipment that allowed 80% of water used for undercarriage washing to be recycled. This investment was fully recovered in 3 years. Staff has been encouraged to bring forth environmental ideas to apply to the agency, and four prizes have been awarded to date to employees. A clever new campaign, to deal with the litter generated by free newspapers discarded by riders, was launched to encourage customers to take the papers with them when they leave the train. Video displays in the stations are used to show ads for this campaign, which are done in a funny, lighthearted way. A client behavior campaign video was also on display in the stations, which addressed undesired behaviors such as skating, running, and placing feet on seats.

Eco-fuels are being used for the system's support vehicle fleet. While they are speaking to energy suppliers about cleaner sources, in Spain it is much more costly, at least 9% premium in cost, which makes it difficult to justify.

They are measuring/calculating the tons of CO₂ that are being saved by the riders of the Metro system, and this will be used in a marketing campaign called “Metro-BIO is a way of Life.”

Metro Bilbao is planning to target the pre-18-year-old market to expose them to quality public transit service and influence future travel decisions. They noted that a recent rider survey found that 33% of Metro Bilbao riders had two cars at home, evidence that public transit can be an alternative to single-occupancy auto use in the region.

There are two bus systems operating in Bilbao—the provincial buses, which are yellow in color, and the local Bilbao Bus system, which is red in color. The bus systems are funded and controlled by the local town and provincial governments. Metro Bilbao doesn't coordinate specifically with these systems as their customer surveys show that only 3% of the public transport riders in the Bilbao area use more than one mode of transit for their daily trip. Riders prefer the Metro system to the other modes; however, the government is still deciding on which mode will be used for future system expansions (Metro, tram, commuter rail, and bus).

The team met with Bilbao Ria 2000, which was founded in 1992 by the Bilbao and Barakaldo municipalities, the Greater Bilbao metropolitan area, and the Basque and Spanish governments. The corporation's aim was to regenerate the city planning of Bilbao and its surroundings, which were heavily punished by intense industrial contamination and decay. It is a

publicly owned, limited company, whose ownership is split between the Central and Basque governments. The company is governed by a high-level board with executive powers. The staff is small, with much of the planning and development work contracted out. The redevelopment projects are funded by following a strategy of land consolidation, transfer of development rights to sites, land preparation including cleanup and infrastructure, and sale of sites for final development. To date, €600 million has been invested in this effort, with an annual investment target of €60 million to €70 million.

Bilbao Ria 2000 was established to regenerate sites within the Bilbao area, coordinating and undertaking developments that integrated urban design, transport infrastructure, the environment, and social culture.

The opportunity before the Bilbao Ria team was vast, large “brownfield” sites on flat land surrounding the river throughout the community. With a small group of direct employees and less than €2 million in seed funding, the process began. The transformation process included four key strategies to “climb out from the hole”—urban and environmental regeneration, external accessibility and internal mobility, technology and human resources, and cultural centrality. Seizing on these they began the process of transformation. Two of the biggest projects that they needed to complete were to clean up the river and build the new Metro transit system. They also wanted to address the following issues:

- New public spaces, using the land acquired from relocating heavy industries and the port.
- New high-quality housing to attract residents back to the city to work and live.
- New airport to address the external accessibility.
- The new Metro and the new light rail line were to become the thread to link all local municipalities and provide internal mobility.
- Footbridges over the river, linking the communities separated by the river and creating usable open space along the river for public access and enjoyment.
- Developing an “icon” to drive the expansion of cultural enrichment. They found such an icon in the building of the Guggenheim Bilbao Museum.

The Guggenheim development is an example of a project that has literally paid for itself with an

increase in the gross domestic product in the region. This also spawned additional investments in the cultural arts, including a new music and congress center, a fine arts museum, and several prominent displays of public art. The new bridges built over the river are themselves stunning design masterpieces that draw tourists and residents to admire as they stroll along newly created public recreation space that parallels the riverfront.

Bilbao Ria is trying to apply development standards that would create two-thirds less carbon output compared with typical developments.

Bilbao is also served by EuskoTren (which consists of a regional rail system and a 5-km tram system serving the Guggenheim and riverfront), Renfe (regional rail), FEVE (regional rail operating on a different, narrow gauge track), Bilbao Bus (funded by the municipality), and Yellow Bus (funded by the provincial government).

EuskoTren is a publicly owned company formed in 1982 by the Basque government. They have 850 employees and are responsible for a variety of transport services, including commuter rail, the Bilbao light rail tram system, regional bus lines, freight movement, rolling stock maintenance, and other logistics and transport-related activities.

A new light rail surface tram system (EuskoTram) was built and opened in December 2002. It is 5 km in length, with 12 stops running through the center of the city of Bilbao. Eight trains operate on the line, and annual ridership is up to 3 million.

EuskoTren operates regional trains in the Basque area, including the line from Bilbao to the south of France. The line is 181 km in length, with 150 km in single track and the remaining 31 in double track. The line is a 1-m gauge and is electrified. This line carries 18 million passengers per year. By 2011 they hope to have 40% of the line double tracked. The 1-m gauge makes for some interface challenges since there are three different rail gauge standards operating in Europe—1-m narrow gauge, Spanish national standard 1.6 m, and European standard 1.4 m. This requires forced transfers of passengers at key junction points.

They are working with the national and Basque governments and the EU to develop a high-speed rail corridor between Madrid, Bilbao, and France; initial segments of the line are already under construction. The travel time reductions will be significant.

EuskoTren also operates a 67-vehicle regional bus line, a funicular railway, the Basque railway

museum and steam train, and a freight movement division.

On the environmental front, EuskoTren established an Environmental Department in 1999 and started to work on sustainable practices, including energy, maintenance practices, and compliance with 14,001 standards. They established closed-circuit steam clean systems, recycled water systems for their train wash systems, and separated waste disposal and recycling.

In 2006, GHG emissions in the Basque Country increased 21.9% compared to baseline, which exceeded the targets set in the Kyoto Protocol, which calls for limiting increases to 15%. The Basque government had set a goal of only a 14% increase, so that goal was missed. Energy, at 34%, and transport, at 22%, are the largest contributors. The energy impact has come about as the Basque region has made policy decisions to become more self-sufficient in energy by generating more and importing less energy.

EuskoTren's GHG emissions increased 2.8% in 2007 compared with 2005. However when accounting for increases in ridership and cargo tonnage moved in the period, emissions have decreased. They are using biofuels for 4.3% of the bus fleet and have been following a fleet turnover plan to reduce total bus emissions. They see an opportunity to reduce total GHG emissions if they can work collaboratively to reduce vehicle traffic/km traveled and improve the public transport system, including expansion of their light rail tram line.

As the operator of the existing tram, by Spanish law adopted in 2004, EuskoTren cannot serve as both the builder and operator of a public transport line. To address this, EuskoTren separated these functions into separate companies. They are currently working on an extension of the existing line from Bilbao to Rekalda, which will add 1,400 m and three new stops, as well as a new tram line in Vitoria. For the long term, they envision the tram network as providing a ring around the city of Bilbao, which will connect with local bus lines and Metro Bilbao underground subway stations. These plans, together with the expansion of regional and high-speed rail and the promotion of using rail transport options, are seen as the way to improve GHG emissions.

In addition to the system/network developments, EuskoTren is also pursuing internal strategies to reduce their carbon footprint as they deliver transport services. These include purchasing lighter-weight aluminum cars, adding regenerative braking, adding

energy consumption recording devices on cars, developing more efficient operating patterns, increasing the use of biofuels in support fleets, and using solar power for shops and offices.

By their calculations, EuskoTren has prevented 25.8 metric tons of CO₂ emissions through the delivery of their services, with a corresponding savings to passengers of €38 million and €750,000 for freight customers.

REDUCING GREENHOUSE GASES

GHG emissions and global warming were very much of interest to the agencies we visited, but were not always a high priority or part of agency-specific goals or programs. Munich had a target of 50% reduction in bus fleet emissions by 2030, and Freiburg's target was a 40% reduction by 2030.

Some cities are looking for new or emerging technology. Milan, for example, is evaluating three hybrid-electric buses over the next 2 years. Moreover, transit providers plan to buy the latest engine technology when they replace buses.

In almost all instances, bus transport is typically the smallest increment of their overall transport offering. Their efforts to provide electrified public transportation need to be recognized as they work to reduce their overall reliance on the diesel bus. Major investments are being made to expand light rail, tram, and commuter rail services. Nearly all rail lines were electrified, allowing cleaner propulsion technology, faster operations, and greater energy efficiency.

In the larger scheme, each city and country is more concerned about how they generate electricity to support public transport, as well as provide energy for industrial, commercial, and residential usage. Clean energy production (wind power, hydropower, and cogeneration) is being expanded, while natural gas and oil energy production are being reduced. Italy was the only country actively looking at nuclear energy.

In Munich, transport is responsible for only 8% of total GHG emissions and industry is responsible for 22%, while home fireplaces account for 70%. Because fireplaces are unregulated emissions, Munich is focusing efforts on improving home insulation and encouraging people to shift from wood burning fireplaces for home heating.

Freiburg regards residential GHG emissions as more of an opportunity for environmental improvement than automotive emissions. Their data showed

93% of the residential energy consumed is from homes older than 25 years. The German government has recognized this and offers subsidies for home renovations, as well as roof, wall, and window upgrades. They offer a further bonus if solar panels are added to the project.

The German government's data also suggests that for every €1 million invested in home upgrade subsidies, €10 million is generated in private-sector spending.

COMPARISONS WITH U.S. CITIES

The cities visited on the study mission were older, historical cities. Though the cities have seen major changes and expansion over the past quarter of a century, each has a basic urban setting that was established well in excess of 200 years ago. It is interesting to note that for the most part, each of these cities' basic grids and land network were established at the time that European settlers were arriving in what is now the United States, and while major changes in those cities have certainly occurred, these cities' overall layouts remain strikingly similar.

The economic history of these five cities over the past 50 years is very different from almost all U.S. cities. The post World War II era brought massive economic opportunities to most Americans. This economic growth occurred at the same time as the expansion of the U.S. Interstate Highway system and the initiation of the GI Bill. Programs such as these contributed to the expansion of housing demand and the growth of the American suburbs. This move to the suburbs resulted in a change in American lifestyles and behaviors and created a culture far more oriented towards low-density residential areas and an expanded presence of the automobile in middle class lives.

The European cities, while experiencing growth, did not experience this same fundamental change. These cities, as well as the rest of most of Europe, continued to have their populations living and working in the high-density urban cores.

The challenge that U.S. regions face, in their attempts to develop higher-density and stronger urbanized areas, is reducing or ameliorating the demand for and enchantment with the single-family, multi-acre development and the corresponding lifestyle that came about in the post-war area and continues to expand through the current day. The challenge for U.S. policymakers and for its governments, when trying to address climate change and sprawl, is to make changes

to land use policies while at the same time being realistic about the different American perspective. Policymakers and government agencies must make these changes, recognizing, however, that to some these low-density suburbs and the accompanying reliance on the automobile are measures of success.

European counterparts, due to the way that their economies developed during the post-war era, do not face this same challenge, or at least, not on the same scale as most U.S. cities.

OBSERVATIONS

A review of the five key strategies the five cities found for effective, sustainable public transport is provided.

Articulate the Role of Transit

Each city successfully established the role of public transportation in sustainability policy through the adoption of a strong policy statement at the outset. This "policy statement" could take one of many forms, and could come from the national government, from the city government, or from a collaboration between government and nongovernmental organizations. In each case, however, the policy statement accomplished the following:

- Established national goals for sustainability and GHG emissions reductions;
- Articulated the role of public transportation in meeting the goals;
- Quantified benefits associated with implementing the goals;
- Included objectives that could be achieved in the short, medium, and long term;
- Provided a framework for measuring progress; and
- Addressed funding and recognized that increasing the role of public transportation required that bus and rail services be improved and extended.

Believe in Change

Transportation policy in the United States is frequently dominated by the view that Americans "love" their cars and will not support policies that make them more expensive or less convenient to drive, and that the country's investment in highways and the resulting low-density land use patterns are impossible to overcome. Yet in the face of the same trends, national

and local governments in the European cities visited have been able to shift both policies and modal share in a relatively short amount of time based on the belief that better policy outcomes are possible.

Build Political Support for Investments

To build the public transportation services necessary to significantly increase transit mode share, the European cities studied as part of this mission had to first build political support for their systems. The agency managers had to make the case that they could be efficient; provide clean, safe, and reliable service; and make a tangible contribution to the quality of life of the region they were serving.

Reform Agencies to Improve Performance

Compared with the United States, European transit agencies seem to enjoy a high degree of corporate autonomy. Many agencies are organized as “companies” owned by one or more local government agencies, but appear to operate under what would be considered in the United States a private-sector model, with highly accountable executive management and a limited need for publicly funded operating subsidies. Yet in each case the organization evolved in response to calls for improved service and a larger role in reducing GHG emissions as part of a national strategy.

Deliver Excellent Transit Service

Transit can only make a substantial contribution to GHG emissions reductions and sustainability if it is utilized and if its mode share increases over time. Notwithstanding recent ridership increases attributed to the rising cost of gasoline, most U.S. transit agencies struggle to increase their ridership and mode share. The European case study cities demonstrated substantial success in this area.

CONCLUSIONS

The strongest messages taken from the mission were the need to think more and think differently about land use and density in relation to transit and the need for strong political and citizen leadership to spearhead changes.

Each of the cities visited provided examples of transit systems that were integrated into local land use patterns far more extensively than is the case in most American cities. The cities were far less auto-centric

than most American cities of comparable (and even smaller) size.

The five cities visited presented their plans for expanding or improving transit services and were able to tie each plan to overall goals of reducing pollution and specifically reducing GHG emissions. The agencies we met with did not seem, however, to have specific goals for transit and climate change strategies, but instead discussed their plans to extend transit service as part of an overall economic development strategy, with the environmental and climate change benefits a welcome further benefit.

This is not to imply that the projects do not have substantial climate change benefits or that they were not designed for those purposes. Instead, it appeared to be more of a function of the fact that the mission team met primarily with service providers, not planning agencies. In each of the cities, there seemed to be a strong separation between organizations that planned projects and organizations that actually provided the service. In fact, in all five cities, the transit providers were private agencies whose sole function was to run the systems, while separate government agencies planned and built the systems. There may have been more of a focus on how decisions are made to develop transit plans and projects so as to maximize the environmental benefits of transit if more meetings had been held with transit and urban planners.

The Role of Political Leadership

In each of the cities visited, the city and/or regional government had some clear and definitive ideas as to how it wanted to implement a certain policy and/or transit infrastructure improvement. Strong political leadership played a key role in whether or not the project was successfully implemented, as it was the political leaders who clearly articulated why the project was needed and what the city stood to gain from the project.

A striking example was the case for the Milan pollution charge (EcoPass) program. In May 2006, Milan elected a new mayor who ran on a platform that included a commitment to implement the downtown pollution charge system as a means of addressing Milan’s long-term and infamous air pollution problems. The mayor, upon inauguration, focused intently on the project and had the city’s transportation and environmental agencies work toward implementing the EcoPass program.

The program required the utilization of the existing street camera network (currently in use for traffic

controls), as well as the addition of many more cameras so as to blanket the area. In addition, the city needed to develop a system by which the license plate numbers captured by the photographic images could be cross-referenced with the national database of automobile registrations. This information then allowed the system to calculate the charge for each vehicle, based on make and model: the more polluting the vehicle, the higher the charge.

The project was a massive undertaking for the city and one that would result in a major change in driver behavior. The technological, public relations, information, and political programs required for the project were considerable. Yet the city had the program up and running in only 18 months. The project was operational by January 2008, and in the first 5 months had resulted in measurable benefits.

It was apparent that a project of this magnitude succeeded in large part because of the mayor's political leadership and her willingness to utilize political capital to achieve the project. A program like this in the United States would go through many years of review, debate, analysis, and litigation; it is difficult to imagine such a bold program being implemented in a similar timeframe.

Another example was the overall redevelopment plans in Bilbao and specifically the transit components. The city leaders saw an opportunity for changing the city in the late 1970s and developed bold plans. These plans not only included visions of how the city would look, but also included strong funding programs (e.g., leasing and selling of development and air rights for private development) to see that these ideas came to fruition.

These projects, as well as similar situations in Munich and Dublin, required a strong political vision and a commitment to see that the public understood the value of the project to the region. For American cities to implement the type of projects that will be necessary to address the challenges of climate change, the need for the same type of political leadership and political will cannot be understated.

Transit as a Pivotal Role in the Urban Layout

Compared with most American cities, transit appeared to play a much greater role in the day-to-day functions of each of the five cities, and land use seemed to be much more geared towards transit. Development appeared to be a much higher density and more focused towards transit. While all of the cities visited appeared to have traffic congestion

problems, the problems appeared to be very different from congestion in most American cities.

These European cities all strove towards developing more sustainable land use patterns and all tried to address congestion. They did not however, seem to have the same degree of urgent needs that American cities had. Transit appeared to have been a priority. The cities are well served by transit infrastructure, and this appears to have been the case for many years. It was interesting to speculate as to whether these efficient and accessible transit systems allowed these cities to sidestep the urban sprawl problem that is so common in the United States.

With the threat of climate change becoming more real every day, strong bold action needs to be taken. Transit agencies and cities have an opportunity to maximize the role of transit in a climate change strategy. New land use policies and transit services that support those policies, along with transportation-related energy programs, represent some of the major steps that transit agencies can take to address climate change.

The European transit models provide excellent guidance on how things can be done. American transit agencies need to find their own way to make transit part of a climate change strategy that is aggressive, yet consistent with American ideas and cultural habits, as well as the American legal and regulatory framework.

In the public transportation arena, addressing global warming means taking on broader responsibilities and operating collaboratively with other organizations. It means forming new partnerships, sharing trials and tribulations, and breeding success. It means developing careful purchasing practices, such as the ones advocated by ICLEI that encourage procurement based on life-cycle cost rather than the more simplistic, short-term view of lowest price. One system will be dependent on others. Strong linkages between systems will be critical to success regardless of prior structures.

Sprawl was far more of a concern in Europe than might have been expected, since it is generally thought that Europeans live in densely packed villages that are easy to serve with transit. This is not so. Virtually every transit company discussed the need to compete with the automobile, and, with the exception of the German cities, they reported large increases in car ownership. In the classic prescription for sprawl, automobile ownership was allowing people to move farther from the center city and thus were harder to serve with public transport.

The sprawl phenomenon varied from the United States in an important way: none of the center cities seemed to be experiencing the “donut effect” common in U.S. cities as the suburbs begin to out-populate the inner cities. Instead, because the center cities remain popular, they have an even greater crisis of congestion as people drive from the outer suburbs to the center city for work. This was especially acute in Ireland, where the “emerald” countryside is appealing to homeowners who are willing to commute one to two hours into Dublin and then pay astronomical rates for parking. Even though the cars are smaller and the fuel mileage is better, they are even farther along the curve of having excessive use of energy consumed by cars and traffic gridlock.

Interestingly, the recent rise in fuel prices seems not to have a major impact for European car drivers. Fuel prices run about \$11 a gallon there, so perhaps the percentage increases are that much smaller and therefore are not creating ripples. Clearly, however, congestion is motivating the general public to embrace government measures to reduce the use of the automobile and is shifting some trips to alternative modes, such as public transport.

European cities have also embraced transit-oriented development as one approach for increasing public transport ridership, although it was not generally referred to in those terms. Germany, in particular, was inclined to support mixed-use communities that are designed to make a transit-based lifestyle possible. As a rule, however, the center cities in these communities already meet the livability and transit requirements of transit-oriented development; public transport, pedestrian walkways, and bicycle paths have been part of the urban fabric for decades.

APPENDIX A—STUDY MISSION TEAM MEMBERS

Fred Hansen, Team Leader, General Manager, Tri-County Metropolitan Transportation District of Oregon, Portland, OR

Thomas Abdallah, Chief Environmental Engineer, MTA New York City Transit, Capital Program Management, New York, NY

Manjiri Akalkotkar, Manager of Strategic Planning, VIA Metropolitan Transit, San Antonio, TX

James Boon, Vehicle Maintenance Manager, King County Metro, Seattle, WA

Andrew Brennan, Director of Environmental Affairs, Massachusetts Bay Transportation Authority, Boston, MA

Michael Ford, Assistant General Manager/COO, San Joaquin Regional Transit District, Stockton, CA

Charles Harvey, Chief Operating Officer, San Mateo County Transit District, San Carlos, CA

Todd Hemingson, Vice President Strategic Planning and Development, Capital Metro, Austin, TX

Henry Kay, Deputy Administrator for Planning and Engineering, Maryland Transit Administration, Baltimore, MD

Jeanette Martin, General Manager, Chicago Transit Authority, Chicago, IL

Timothy Papandreou, Transportation Planning Manager, Los Angeles County Metropolitan Transportation Authority, Los Angeles, CA

Anna Price, Planning Specialist, Maine Department of Transportation, Augusta, ME

Susan E. Schruth, Associate Administrator for Program Management, Federal Transit Administration, U.S. Department of Transportation, Washington, DC

Nina Lee Walfoort, Director of Marketing and Planning, Transit Authority of River City, Louisville, KY

Kathryn Harrington-Hughes, Mission Coordinator Manager, International Transit Studies Program, Easton, MD

APPENDIX B—STUDY MISSION HOST AGENCIES

Dublin

Dublin Chamber of Commerce

Dublin Bus

Dublin Area Rapid Transit (DART)

Railway Procurement Agency

Dublin Transportation Office

Luas

An Taisce

Munich

Munich Verkehrsgesellschaft (MVG)

Green City e.V.

DB Regio Oberbayern

Freiburg

Freiburger Verkehrs AG (VAG)

City Council

Bureau of Transport Planning

Department of Environment

ICLEI (Local Governments for Sustainability)

Innovation Academy

Milan

Legambiente
Comune di Milano
Agenzia Milanese Mobilita (Mobility and
Environment Agency)
Azienda Transporti Milanese S.p.A. (ATM)

Bilbao

Metro Bilbao
EuskoTren
Bilbao Ria 2000

APPENDIX C—LIST OF ABBREVIATIONS

CO ₂	carbon dioxide
DPF	diesel particulate filters
DTO	Dublin Transportation Office
GHG	greenhouse gases
ICLEI	Local Governments for Sustainability
PPP	public-private partnership
QBC	quality bus corridor
RPA	Railway Procurement Agency (Ireland)
TOD	transit-oriented development
UITP	International Association of Public Transport

These digests are issued in order to increase awareness of research results emanating from projects in the Cooperative Research Programs (CRP). Persons wanting to pursue the project subject matter in greater depth should contact the CRP Staff, Transportation Research Board of the National Academies, 500 Fifth Street, NW, Washington, DC 20001.

COPYRIGHT PERMISSION

Authors herein are responsible for the authenticity of their materials and for obtaining written permissions from publishers or persons who own the copyright to any previously published or copyrighted material used herein.

Cooperative Research Programs (CRP) grants permission to reproduce material in this publication for classroom and not-for-profit purposes. Permission is given with the understanding that none of the material will be used to imply TRB, AASHTO, FAA, FHWA, FMCSA, FTA, or Transit Development Corporation endorsement of a particular product, method, or practice. It is expected that those reproducing the material in this document for educational and not-for-profit uses will give appropriate acknowledgment of the source of any reprinted or reproduced material. For other uses of the material, request permission from CRP.

THE NATIONAL ACADEMIES™

Advisers to the Nation on Science, Engineering, and Medicine

The nation turns to the National Academies—National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council—for independent, objective advice on issues that affect people's lives worldwide.

www.national-academies.org



Transportation Research Board

500 Fifth Street, NW
Washington, DC 20001