



TR News May-June 2012: Active Transportation: Implementing the Benefits

DETAILS

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TR NEWS

NUMBER 280

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ACTIVE TRANSPORTATION: IMPLEMENTING THE BENEFITS

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Michael J. Cynecki

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COVER: Bicycle lanes on Pennsylvania Avenue in the nation's capital. (Photo: Richard Layman)

TR NEWS

features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

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COMING NEXT ISSUE

State departments of transportation and metropolitan planning organizations are implementing policies to mitigate and adapt to climate change. Articles in the July–August issue of *TR News* present an array of initiatives—the rationales, strategies, progress, and goals—including key facts that transportation leaders and professionals should know about climate change and transportation; Washington State’s commute trip reduction program; Oregon’s solar highway program; Michigan’s preparations for adapting to extreme temperatures and precipitation events; establishing a biofuel infrastructure in Tennessee; a multistate, West Coast partnership to showcase sustainable transportation solutions on Interstate 5; ecodriving policies to reduce fuel consumption and greenhouse gas emissions; plus relevant findings from National Research Council studies and more.



PHOTO: VERMONT AGENCY OF TRANSPORTATION

In 2011 Tropical Storm Irene washed out more than 2,000 roadway segments, undermined more than 1,000 culverts, and damaged more than 300 bridges in Vermont, in a possible preview of the more intense and frequent storm events that scientists have associated with the changing climate. As it rebuilds the transportation network to be more flood-resilient, the Vermont Transportation Agency is exploring and implementing short- and long-term approaches to climate change adaptation.

INTRODUCTION

Making Way for Pedestrians and Bicycles

Realizing the Environmental, Health, and Economic Benefits



PHOTO: RICHARD LAMMAN

This special theme issue of *TR News* addresses topics in the planning, design, operations, and maintenance of pedestrian and bicycle facilities, including efforts to integrate the pedestrian and bicycle modes more fully into the transportation system. The development of the articles was a project of the Transportation Research Board's (TRB's) Pedestrians and Cycles Section, notably the Pedestrians Committee and the Bicycle Transportation Committee.

The initial proposal designated the theme as “Vulnerable Road Users,” but members of both committees roundly rejected that identification and proposed instead a focus on several key descriptors for the pedestrian and bicycle modes of transportation, such as healthy, sustainable, “green” or environmentally sound, active, economically beneficial, and encompassing all road users; other terms of focus included complete streets, smart growth, safe routes to school, and accessible transportation. The assembled articles expand on and affirm these goals.

The pedestrian and bicycle modes have been overlooked in many parts of the United States, while the goal of optimizing design and operations for motor vehicles has prevailed. In the past, many U.S. roadway facility designs neglected to provide adequate space or accommodation for pedestrians and bicycles; those that addressed these needs often offered only minimal accommodations. With rising fuel prices and increasing concerns about the environment and public health, walking and bicycling have become increasingly important modes of transportation.

Walking and bicycling are not exclusively recreational—they represent viable, beneficial, economical, and environment-friendly modes of transportation. Everyone is a pedestrian. Transit riders usually have to walk or bike to and from their transit stop. Even those who drive have to walk from a parking area to their final destination.

Much of the research on facility and traffic control design and on the operational characteristics of the bicycle and pedestrian modes has come from outside the United States. The new planning tools, technologies, and models, however, must be adapted to U.S. con-

texts. U.S. researchers have developed, evaluated, and gained approvals for exciting new traffic control devices for pedestrians and bicyclists, such as the pedestrian hybrid beacon, adopted into the 2009 *Manual on Uniform Traffic Control Devices*, and the rectangular rapid flash beacon, a more effective type of flasher that has gained interim approval from the Federal Highway Administration.

Research is under way to advance innovation for improving the safety and mobility of pedestrians and bicyclists. New technologies are emerging, such as advances in light electric bicycles, and new bicycle facility designs are addressing safety and mobility.

Articles in this issue describe new tools to measure mobility for the pedestrian and bicycle modes, applying real-time data from roadway environments. The need for more and better data to measure and evaluate these modes is ongoing, at a time when resources are shrinking. Articles also explore the relationships between community design and public health, as well as the economic issues related to these modes.

The need and potential for nonmotorized travel must be communicated to engineers who are trained and experienced in optimizing motor vehicle flow. Many state departments of transportation (DOTs) are encouraging engineers to question their long-time assumptions and are providing design project managers with checklists that include facilities and other provisions to accommodate bicycle and pedestrian modes. Some state DOTs require the involvement of bicyclists and pedestrians in project development.

Thanks are due to Shawn Turner, Chair of the Pedestrians Committee, and to Jennifer Dill, Chair of the Bicycle Transportation Committee, and to all the Committees' members and friends who volunteered countless hours to write or review the articles in this issue. Thanks also to Russell Houston of TRB and the other members of the *TR News* editorial board for their interest, guidance, and enthusiasm in producing this theme issue.

—Michael J. Cynecki, *Lee Engineering, LLC*
Chair, TRB Pedestrians and Cycles Section



PHOTO: DAN BURMEN

Policy makers are looking to research findings for ways to address the causes of the comparatively low rates of walking and bicycling in the United States for utilitarian purposes, such as getting to work or school and completing daily errands.

Walking and Bicycling in the United States

The Who, What, Where, and Why

J. RICHARD KUZMYAK AND JENNIFER DILL

Kuzmyak is Principal, Renaissance Planning Group, Arlington, Virginia. Dill is Associate Professor, School of Urban Studies and Planning, Portland State University, Portland, Oregon. For National Cooperative Highway Research Program Project 8-78, Estimating Bicycling and Pedestrian Demand for Planning and Project Development, Kuzmyak serves as principal investigator and Dill as panel chair.

Concerns about health and obesity have directed attention to the possible link between physical exercise levels and the built environment. In the United States, development in the past 60 years has turned away from the traditional compact, walkable city or town toward a more dispersed, automobile-centric pattern that makes travel by any means except private vehicle impractical and inconvenient.

People living or working in these automobile-oriented environments may still walk or bicycle, but generally for exercise or recreation and not for utilitarian purposes such as travel to work or school, shopping or running errands, visiting a friend or going to a restaurant, or accessing public transit. This raises the question of whether—and to what extent—people would choose to walk or bicycle for these routine travel purposes under the proper conditions.

According to the latest National Household Travel Survey (NHTS), fewer than 11 percent of daily trips

in the United States are made by walking and about 1 percent by bicycle. This is in marked contrast to the rest of the world. Although the high rates of non-motorized travel in many Asian and third world countries may be explained by the intensely populated cities and poor economic conditions, different reasons are needed to explain the major differences between the United States and other Western nations. In Switzerland, for example, 45 percent of trips are made by walking and 5 percent by bicycle; in Spain, Germany, and Sweden, the amounts are 23 percent and 9 percent; and in the United Kingdom, 24 percent and 3 percent (1).

What makes the United States so different? Does the design of modern U.S. cities and neighborhoods discourage walking and bicycling? Or is it the lack of facilities to assure safe and efficient travel by foot or bicycle, or the array of incentives for driving—such as low fuel prices, free parking, abundant and unpriced road capacity, and subsidized mortgages for housing at the urban fringe? Or does the Ameri-

can lifestyle inherently find driving more pleasurable and convenient? To plan sustainable—and healthful—human environments, and to determine the most cost-effective measures to encourage more walking and bicycling, more must be known about the various influences on bicycling and walking behavior.

Data and Planning Tools

In the past decade, interest in walking and bicycling has elevated so that travel surveys and transportation plans are addressing these modes. A major contributor to this interest is the link between exercise and public health. Transportation and community planners, however, also envision walking and bicycling as key elements in development patterns and transportation systems that offer more travel choices and that reduce vehicle demand, congestion pressure for new highways, and environmental impacts.

Conventional data sources and travel models, however, have constrained planners and decision makers from fully incorporating bicycle and pedestrian policies, programs, and outcomes into the planning process. The standard travel forecasting models used by metropolitan planning organizations (MPOs) fail to incorporate bicycling and walking as modes in the planning process, and the traffic analysis zone (TAZ) geography is too coarse to relate to the shorter distances associated with walking and bicycle travel or with the relevant characteristics of the built environment.

PHOTO: COLIN BOGART, LOS ANGELES COUNTY BICYCLE COALITION



New techniques incorporating geographic information system tools and parcel-level data are beginning to isolate and quantify the role of land use attributes such as density, mix of uses, multimodal accessibility, and urban design on travel behavior, particularly on walking and bicycling. Many MPOs are upgrading their models to work with smaller TAZs and to include measures of the built environment, with walking and bicycling as explicit travel modes. An emerging class of activity- and tour-based models enables analysis at the level of parcel points but may not be available nationally for many years.

A bicycle count in Glendale, California, under the Safe and Healthy Streets project provided city officials with information on walking and biking trends and laid the groundwork for improvements.

PHOTO: TED SWEENEY



In the Netherlands, 25 percent of errands and other daily trips are made by bicycle and 22 percent are made by walking.



PHOTO: STEVE PINKUS

Walking rates for many Europeans steadily increase until age 75; in the United States, walking rates remain stable until age 65 and then drop off.

The most comprehensive data on walking and bicycling are from the household travel surveys used in regional models. These surveys obtain full sociodemographic and travel diary information from a large sample of households, selected and weighted to represent the region.

In the past five years, surveys have improved at

capturing walk and bicycle trips, with better techniques and stratified sampling approaches that are likelier to include candidate households. Many of these surveys follow the pattern of the NHTS, conducted nine times since 1969 by the U.S. Department of Transportation (DOT). The NHTS documents trends in travel, although subtle changes in the survey approaches make direct comparisons of walk and bicycle activity levels difficult.

Many research studies have collected data on bicycle and pedestrian travel with a range of methods from user intercept surveys to national surveys to special panels. The National Bicycle and Pedestrian Documentation Project, initiated in 2002, has attempted to systematize data collection and create a national repository for planning use; the data, however, are principally from counts.

Although counts are the most common type of data for bicycle and pedestrian planning—particularly for facilities—their value for understanding bicycle and pedestrian travel behavior is limited. Counts record activity levels at a particular location but yield little or no information about who is making the trip, for what purpose, from what origin to what destination, or what alternative routes were available. Without this information, building realistic estimates of demand from count data alone is difficult.

The following sections highlight factors that research has shown to be important in bicycle and pedestrian travel behavior. This in turn suggests the types of data that are most needed for bicycle and pedestrian demand analysis.

Collecting Bicycle and Pedestrian Data

The lack of data on pedestrian and bicycle volumes hampers transportation agency efforts to plan more effective facilities and to improve safety for pedestrians and bicyclists. As noted in the article by Aultman-Hall et al. (page 8), transportation agencies have well-established procedures for collecting, summarizing, and disseminating motor vehicle traffic volumes, but these procedures do not generally include systemwide pedestrian and bicycle volume data. This limits the ability of transportation agencies to provide or improve pedestrian and bicycle facilities to meet needs; moreover, the lack of data impedes the development of improved methods for predicting pedestrian and bicycle crashes.

Under National Cooperative Highway Research Program Project 07-19, a research team led by Paul Ryus of Kittelson & Associates will assess current and innovative technologies and methods and will provide guidance for transportation practitioners on how best to collect pedestrian and bicycle volume data. The project began in April 2012 and is scheduled for completion in spring 2014.

The assessment will consider the feasibility, availability, quality, reliability, cost, and compatibility of volume data. The guidance will include methods to (a) mine and manage data sources efficiently; (b) acquire and use data from new and innovative technologies; and (c) summarize and disseminate pedestrian and bicycle volume data for site-specific, local, and systemwide needs assessments, project development, and safety management.

Walking and Bicycling Data

Demographics

According to the 2009 NHTS, the most frequent travelers by nonmotorized modes are children under 16 years of age who depend on others for motorized travel (Figure 1). Among walkers, the next most active age group consists of adults 25 to 34 years old. Walking rates remain stable until the age 65 group and then decline. In many European countries, by contrast, the walking rates steadily increase until age 75.

Among those more than 24 years old, domestic bicycling rates are low and relatively flat. Gender differences are most pronounced for bicycling—across all age groups, males are two to four times more likely to have made a bicycle trip than females.

Walking—but not bicycling—appears to be linked to income (Figure 2, page 7). People in the lowest income category made 16.9 percent of their trips on foot and another 4.8 percent on foot to access transit. The share declines to 8.9 percent for

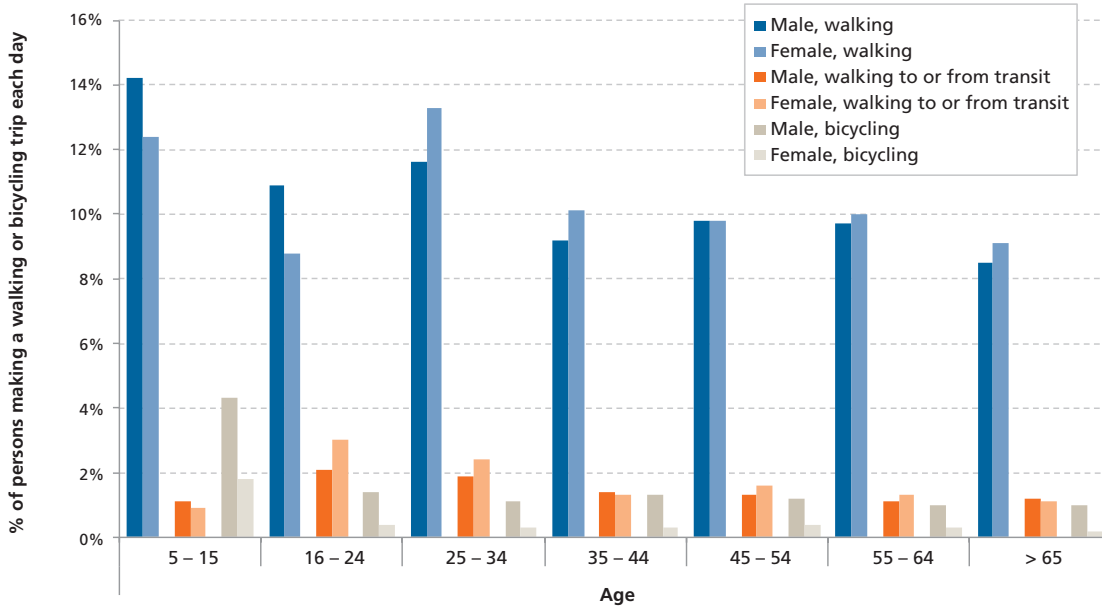


FIGURE 1 Percent of daily trips made by bicycling or walking, by age and gender. (Source: 2009 NHTS.)

people with annual incomes between \$40,000 and \$99,999 and rises to 10.1 percent for people with annual incomes of more than \$100,000.

Bicycling is more consistent across income classes, with the highest rate—1.3 percent—in the \$20,000 to \$40,000 range, 0.9 percent in the \$75,000 to \$99,000 range, and 1.1 percent for all other groups.

The relationship to education differs (Figure 3, below right)—the highest rates of walking and bicycling are among people without a high school diploma, with 16.7 percent of trips on foot, including access to transit, and 1.1 percent on bicycles; the

next highest rates are among people with graduate or professional degrees—13.9 percent on foot and 1.1 percent on bicycle. The lowest rates of both walking and bicycling are among people with only a high school diploma or GED and some college or an associate degree.

Automobile ownership and availability is perhaps the most telling demographic measure. Persons in households with fewer vehicles than licensed drivers averaged 12.3 percent of daily trips by walking and 1.6 percent by bicycling, in comparison with 7 percent and 0.8 percent when vehicles outnumbered drivers.

(continued on page 10)

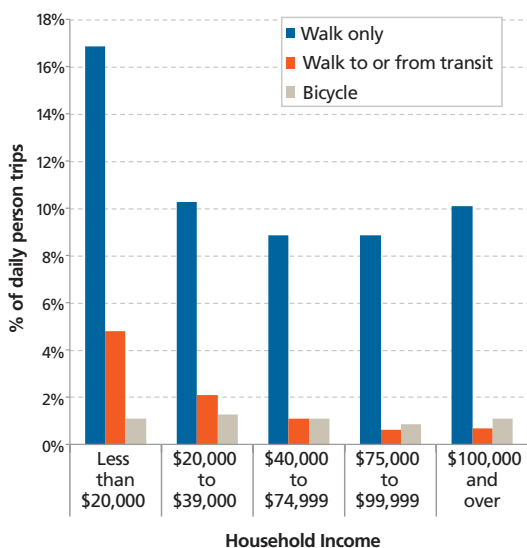


FIGURE 2 Percent of daily person trips, by income.

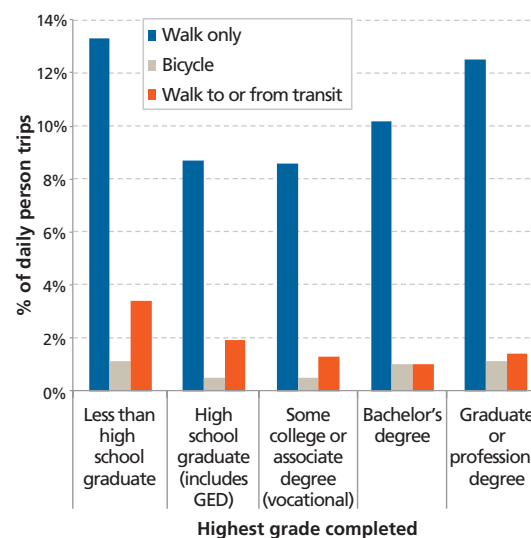


FIGURE 3 Percent of daily person trips, by education.



Innovative Data Collection for Pedestrians, Bicycles, and Other Non-Motor Vehicle Modes

LISA AULTMAN-HALL, JONATHAN DOWDS, AND BRIAN H. Y. LEE

The transportation community has long recognized the need for improving pedestrian and bicycle volume counts. The collection of nonmotorized travel data under a consistent, systematic methodology is a priority for improving research, planning, and policy making for pedestrian and bicycle travel. Volume data are needed for safety and risk assessments, new infrastructure evaluations, travel model inputs, and estimations of miles of travel.

One of the most significant concerns about the lack of data for nonmotorized transportation is that decisions based on judgment may lead to a less efficient use of limited funds. Data scarcity and poor data quality remain challenges for all modes, but with recent technological innovations and widespread advances, the scarcity of bicycle and pedestrian data could be disproportionate.

Although poorly quantified, pedestrian and bicycle activity increasingly is recognized as a vital component of the transportation system, spurring solutions to the data gap. These nonmotorized modes have specific infrastructure and safety requirements that must be met to maximize the utility they provide and to minimize associated safety risks. Successful infrastructure planning relies on accurate volume data by facility and location type, with adjustments for the time of day and year. These data are not widely available for pedestrians and bicyclists. The lack of data—and the resultant lack of informed decision making about facilities and other programs—is a significant reason these modes continue to have limited trip shares nationwide.

Volume collection processes should reflect the unique physical characteristics of pedestrian and bicycle travel. Adding to the complexity is the increasing recognition of the variety of nonmotorized modes in the transportation system, such as skate-



Photo: Ed Younison

Other nonmotorized forms of transportation—such as skateboards, scooters, and strollers—can complicate the task of collecting volume data.

boards, strollers, rollerblades, and scooters, which provide mobility with differing levels of benefits and risks and also require documentation. Some devices, although motorized, are legitimately considered within pedestrian planning, including wheelchairs of various designs and other assistive devices. Consideration of these modes is important because they are disproportionately used by the most vulnerable populations: seniors, youth, and the physically and mentally challenged.

Flawed Programs

Transportation agencies have well-established, systemwide programs for collecting, summarizing, and disseminating data on motor vehicle traffic volumes, but most do not require pedestrian and bicycle volume data, which may be collected on a project-by-project basis at a few isolated locations. The limited scope of the data collected precludes extrapolation systemwide to uncounted sites.

Volume count programs for nonmotorized travel typically have a small extent—for example, at major intersections or specific points of particular facilities and for limited periods during select times and days. The dissemination and use of the collected data are often constrained, and the count locations rarely are selected to allow statistically valid extrapolation, even for total miles of travel within the jurisdiction, because typically only the highest-volume locations are counted. Programs often are strictly urban, although the authors recently have collected data to measure the volumes of bicycles and pedestrians in rural areas in relation to neighborhood activities and tourism.

Technology to the Rescue?

Some of the most advanced pedestrian- and bicycle-counting technologies are available commercially, each with different capabilities and limitations. These tools include microwave and infrared sensors, active and passive; pneumatic and pressure-sensitive devices; inductive loops; piezoelectric counters; and video-image processing equipment. Several groups have compared the



Photo: Tony Camp, University of Vermont Transportation Research Center

Successful infrastructure planning requires data that accurately represent an area, whether urban or rural.

accuracy of these technologies and have found the same range of accuracy as that of the methods used for motorized transportation modes. Costs are becoming reasonable and are not the main barrier to widespread use.

The literature and recent experience suggest that commercial devices have trade-offs in terms of the accuracy, the setting, and the duration at which they are effective in distinguishing between pedestrians and bicyclists and other users. Many infrared devices, for example, do not distinguish between pedestrians and bicycles or other moving objects and can be recommended only for settings that have a physical separation between the count target and motor vehicle traffic. The devices therefore are not suitable for counts of mixed traffic. As another example, some pressure-sensitive devices may not be suitable for winter conditions if snow and ice reduce the sensitivity or if snow removal equipment can damage the device.

Some of the shortcomings of individual devices may be surmountable, however, by combining multiple devices or by deploying them in innovative ways. Siting infrared sensors at locations with a traffic loop that is insensitive to bicycles and taking the difference between the counts from each device, for example, may offer one approach for capturing bicycle volumes on a roadway.

In addition to commercial products, other emerging methods and technologies hold promise for counting pedestrians and bicyclists or for extracting count data from current data sources. These include

- ◆ Passive signal-processing from the mobile devices of pedestrians and bicyclists—that is, extracting the locations of pedestrians and bicyclists by tracking their mobile phones or other digital signals;
- ◆ Active route- and behavior-logging applications—such as tracking registered users through web-based social media applications; and
- ◆ Passive video-image processing—using image processing software to analyze video from existing cameras.

Video-image processing is appealing because video cameras are becoming ubiquitous for traffic monitoring and security. Nonetheless, the approach raises challenges, particularly the practitioner's level of control over the placement and direction of the cameras. If the camera is not installed to include pedestrian and bicycle activities, then the angle of view or the lighting can make it inaccurate for comprehensive, accurate count data.

Call to Action

An assessment of the factors affecting counting technology feasibility, availability, quality, reliability, cost, and compatibility reveals significant but surmountable technical barriers. Available technology can allow for systematic, methodologically consistent data collection for nonmotorized travel. Effective widespread counting programs for nonmotorized transportation are achievable with off-the-shelf technologies, within the specific needs and budgetary constraints of a variety of practitioners.



PHOTOS COURTESY JOAN HUDSON, TTI

A pedestrian and bicycle traffic counter is installed in Austin, Texas (above), and a newly placed counter is tested (below). The Texas Transportation Institute and the Capital Area Metropolitan Planning Organization handled the installations and conducted research on bike and walking paths throughout the city in 2011.



Because of the proliferation of new data collection technologies and the unique capabilities and challenges associated with these technologies, the need is urgent to develop uniform guidelines for nonmotorized travel data collection and data management and to create policies mandating the collection of these data, modeled on the data collection methods for other modes. Management and planning systems now are the main obstacles to action, and coordinated leadership is needed to overcome this barrier.

Acknowledgment

The authors acknowledge valuable discussions with James Sullivan, University of Vermont, and Wesley E. Marshall and Krista Nordback, University of Colorado, Denver.

The authors are with the Transportation Research Center at the University of Vermont, Burlington.

TABLE 1 Proportions, Distance, and Duration of U.S. Walking and Bicycling Trips by Purpose

Trip Purpose	Walk Only Total Trips: 40,962 million			Bicycle Total Trips: 4,082 million		
	Percent of Trips	Average Trip Length (miles)	Average Travel Time (minutes)	Percent of Trips	Average Trip Length (miles)	Average Travel Time (minutes)
To or from work	4.5	1.0	16.2	10.9	3.8	21.2
Work-related business ^a	1.7	1.1	14.0	1.8	3.3	21.7
School or church ^b	8.6	0.6	14.5	6.0	1.6	15.2
Shopping ^c	14.7	0.6	12.7	9.8	1.3	14.0
Other family or personal business ^d	21.5	0.5	11.2	8.2	1.4	15.5
Medical or dental	0.9	0.7	16.1	0.2	2.2	26.0
Vacation ^e	1.9	0.8	22.5	2.1	2.4	21.0
Visit friends or relatives ^f	8.7	0.6	11.7	13.0	1.0	13.9
Other social or recreational ^g	35.4	0.8	18.3	47.3	2.6	22.5
Other	1.4	1.2	13.1	0.1	2.3	16.0
Refused or not available	0.8	0.8	22.0	0.8	2.7	25.7
All purposes	100.0	0.7	14.9	100.0	2.3	19.4

SOURCE: 2009 NHTS.

^a Includes business meetings and other work-related activity.

^b Includes going to school, religious activity, school or religious activity, and library for school purposes.

^c Shopping, buying goods, and buying gas.

^d Includes day care, buying services, family or personal business, wedding or funeral, grooming, pet care or dog walk, civic meeting, transporting someone, meals, social event, getting a meal, and getting snacks.

^e Includes rest and relaxation or vacation.

^f Visit only.

^g Includes social or recreational; exercise (e.g., walking and jogging); playing sports; going out for entertainment; visiting a public place; eating a meal; social event; getting or eating a meal, coffee, or snacks.

(continued from page 7)

Frequency of Travel

Because bicycle or walk trips are made less frequently than might be registered in a one-day travel diary, the 2009 NHTS asks about the use of these modes in the past week. The data reveal that 87 percent of Americans had not made a bicycle trip during the past week, and 32 percent had made no walk trips.

Travel Distance

The NHTS showed that average distance for a walk trip was 0.7 miles, for a travel time of less than 15 minutes. The average for bicycling was 2.3 miles and approximately 19 minutes. Only 12 percent of all walk trips were 1 mile or longer, and only 13 percent were for 30 minutes or longer; 54 percent of all bicycle trips were 1 mile or more, with 26 percent more than 2 miles, but only 12 percent were longer than 30 minutes.

Travel Purpose

Walking and bicycling destinations differ from those by other modes (Table 1, above). Only a relatively small percentage of walking and bicycling trips are to or from work—4.5 percent and 10.9 percent, respectively—but 8.6 percent of walking trips and 6 percent of bicycling trips are to or from school, reflecting higher use among children.

The single largest purpose for both modes was for social or recreational travel, comprising 35.4 percent of walk trips and 47.3 percent of bicycle trips, suggesting a goal of exercise or relaxation without a particular destination. By contrast, two-thirds of bicycle travel in Europe is for utilitarian purposes (2). Travel to work was associated with the longest trips for walking, at 1.0 mile, and for bicycling, at 3.8 miles, in the United States; in contrast, trips for nonwork utilitarian travel—for example, shopping, family or personal business, and visiting friends or relatives—were shorter, at 0.5 to 0.6 mile for walking and 1 to 1.4 miles for bicycling.

Geographic Location

The highest rates of walking, 19.2 percent, are found in metropolitan areas with populations of 1 million or more that have rail transit. The rate falls to approximately 10 percent for areas of the same size without rail transit and to slightly more than 8 percent in smaller urban and nonmotorized areas.

Bicycling is not as sensitive to urban setting, registering 1.3 percent in areas with populations of 200,000 to 500,000 and averaging 1.1 percent in other areas. Among U.S. regions, the mid-Atlantic

The National Household Travel Survey revealed that walking in the United States is linked closely to metropolitan areas and the presence of transit.



PHOTO: LARRY LEVINE, WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

states have the highest rates of walking at 15.8 percent, with the Pacific and New England states at a midrange of 10.3 to 10.6 percent, and the lowest rates in the East and West South Central states at 6.0 to 6.3 percent.

Influence of Environment

Price can influence the choice of travel mode. Increases in the direct costs of driving—gasoline, tolls, and parking, for example—may make walking or bicycling more attractive for more travelers, despite the extra time required. Differences in the price of gasoline and parking may explain some of the differences between mode choices in Europe and the United States. Nevertheless, these costs do not differ much between U.S. cities, yet different rates prevail for walking and cycling to work among the largest cities (Figures 4 and 5, right).

The differences perhaps stem from characteristics of the physical environment—the natural and man-made. In the natural environment, hills and other features affect the directness of travel or the amount of effort required of the walker or cyclist, and weather and climate affect levels of comfort. The man-made, or built, environment, determines the location and proximity of origins and destinations and the characteristics of the environment between.

Travelers respond differently to these influences. Research under National Cooperative Highway Research Program (NCHRP) Project 8-78, Estimating Bicycling and Pedestrian Demand for Planning and Project Development, is investigating the relationships between the built environment and walking and bicycling (see sidebar, page 12).

Two basic research techniques can gauge the importance of particular environmental features in the decision to walk or bicycle to a particular location or via a particular route:

1. The stated-preference approach presents the subject with a range of choices, described in terms of key attributes, and asks for a ranking of the alternatives by personal preference. Statistical analysis of the data from a diverse sample can quantify the relative importance of each attribute.

2. Geographic Positioning System (GPS) devices can trace travel as it occurs, recording actual behavior instead of subjective information. Statistical techniques identify and quantify sensitivities to particular environmental characteristics that influence the travel choices.

In both cases, the sensitivities link to the characteristics of the traveler, which is important for planning.

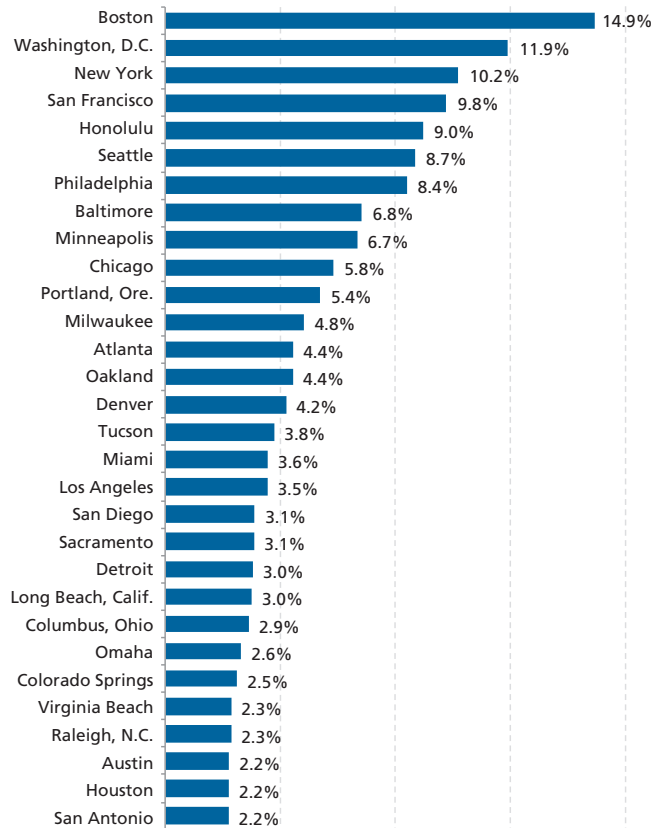


FIGURE 4 Top large cities for commuting by foot. (Source: American Community Survey, 2006–2010, 5-year average; top 30 cities among the largest 50 cities.)

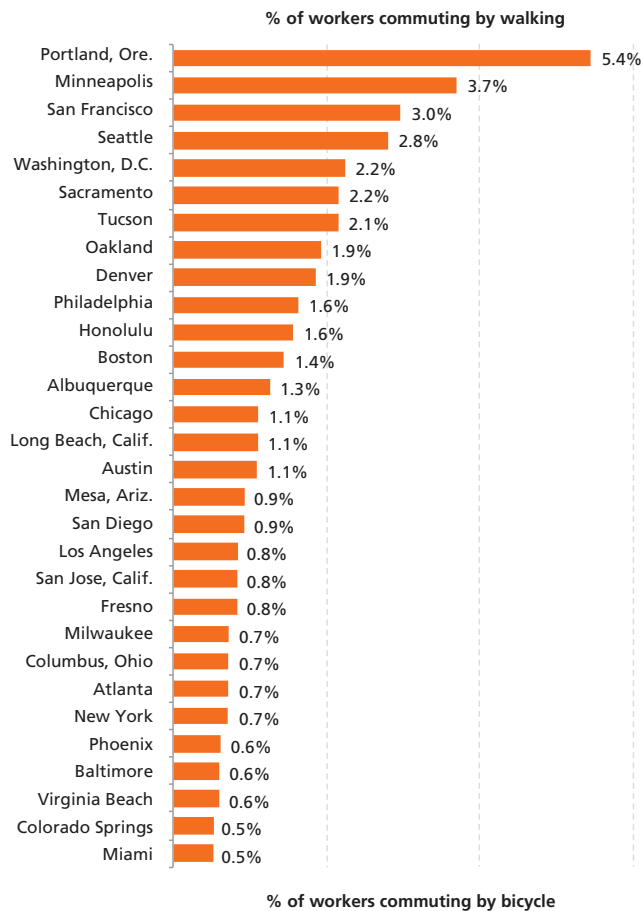


FIGURE 5 Top large cities for commuting by bicycle. (Source: American Community Survey, 2006–2010, 5-year average; top 30 cities among the largest 50 cities.)



The effects of seasonal weather on pedestrian and bicycle activity are difficult to distinguish from the effects of acute weather events such as heavy rainfall.

Natural Environment

Topography

Several studies have demonstrated that hills and steep grades have a negative impact on walking or bicycling. A stated preference approach determined that slope was extremely important in walk and bicycle route decisions in San Francisco but was almost twice as important for bicycling (3). GPS data from 166 cyclists in the Portland, Oregon, region indicated that the typical utilitarian cyclist would travel 27 percent farther to avoid each 1 percent of addi-

tional average upslope (4). The same study found that the effect of slope was much more significant for women than for men and for infrequent or inexperienced cyclists than for experienced bicyclists.

Climate and Weather

Walkers and cyclists are exposed to the elements; sensitivity to major changes in temperature and precipitation is expected. Distinguishing between climate effects that involve seasonal variations in atmospheric conditions—for example, hot summers, cold winters, or rainy seasons—and the shorter-cycle events of weather—like a snowfall, heavy rain, or uncommonly hot or cold days—is difficult. Although research has documented a decline in bicycle activity in areas with strong climate differences, the most pronounced variations in bicycle or walk activity are most closely tied to acute weather events.

Built Environment

Land Use

Walking and bicycling are easier and more relevant in compact, mixed-use settings, which register much higher rates for both modes, particularly for utilitarian purposes. Households in mixed-use areas own fewer vehicles, make more trips to nearby destinations, and are more likely to use transit for trips outside the community.

As a destination, a compact mixed-use setting is more likely to attract trips by nonautomobile modes. Cyclists tend to be less sensitive than pedestrians to immediate surroundings, particularly at the origin of a trip.

Facilities

Planners and engineers have focused on facilities for walking and bicycling. Pucher and Buehler (2) and others who have compared the U.S. bicycling and walking experience with that of Europe have emphasized the high-quality, coordinated travel networks for cyclists and pedestrians as a key influence on the high rates of walking and bicycling.

The effectiveness of European walk and bicycle networks is the result of a high level of connectivity; in conjunction with the compact mixed-use design of communities, this allows for direct, convenient paths. Also evident are public policies and attitudes that support walking and bicycling as modes of transportation—for example, traffic calming measures are widely applied and enforced in urban settings, allowing motorized and nonmotorized traffic to coexist. In addition, vehicle parking is much more limited and expensive in urban areas.

In the United States, if the objective is to create a safe and pleasant recreational environment for walking

Answering the Demand for Bicycling and Walking

NCHRP Project 8-78 is developing a guidebook on methods for Estimating Bicycling and Pedestrian Demand for Planning and Project Development. The project is responding to a long-recognized need for robust methods that can measure bicycle and walking activity accurately in relation to the contexts of land use, infrastructure, sociodemographics, and environment—including motor vehicle traffic, hills, and climate and weather—that are uniquely important to nonmotorized travel.

The project has completed an extensive review and synthesis of international research on this topic and has summarized what is known and what is uncertain, identifying important needs for clarification and for integration into reliable tools. An interim report, released in April 2011, documents this research.

The project team is progressing with primary research, using data from Seattle, Washington, and metropolitan Washington, D.C., to develop and test model formulations for a new, more comprehensive set of relationships to support analyses at the regional, subarea or corridor, and project levels. The work is scheduled for completion in September 2012. For additional information, visit <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2707>.

and bicycling—and perhaps for some long-distance commute travel—then a network of exclusive off-road trails may be the priority. If the objective is to integrate walking and bicycling into the community design and daily transportation, then the focus may fall on the shared use of roads and streets, emphasizing features that allow for safe shared use, such as sidewalks, bicycle lanes, and convenient signalized crossings. In both cases, the aspects of accessibility and connectivity are critical to network design.

Urban Design

Walking for utilitarian purposes probably is influenced most by urban design—having interesting and relevant destinations that can be accessed efficiently via minimum-distance paths and with minimal direct contact with vehicle traffic.

Planning bicycle networks, in contrast, is complicated and technical. Cyclists are much more likely

to share facilities and interact with motor vehicles. Building separate off-road facilities can be expensive, and the availability of land can produce paths that do not go where most travelers want to go. Much less expensive—and more conducive to everyday use of bicycles for a range of travel purposes—are shared-use facilities such as striped bicycle lanes or signed bicycle routes on low-volume, residential streets.

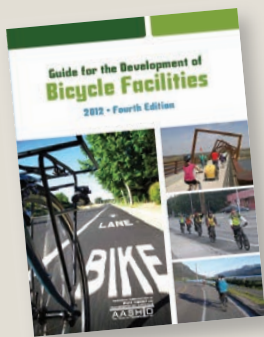
Improving Designs

Research has found that the factors most important to cyclists planning a route include separation from traffic, the steepness of grades, crossings or turns at arterial intersections, and surface type and quality; these factors vie in importance with the shortest path and minimum travel time to the destination; moreover, the effects vary with the type of traveler and the purpose of the trip. Stated preference surveys and GPS monitoring have allowed researchers to begin to

Bringing Bicycle and Pedestrian Guidelines Up to Speed

The American Association of State Highway and Transportation Officials (AASHTO) has released the *Guide for the Development of Bicycle Facilities, 4th Edition*, an update of the 1999 guide, incorporating results from a National Cooperative Highway Research Program (NCHRP) project.^a

A scoping study in 2005 by Sprinkle Consulting, Inc., conducted the initial research, interviews, and a literature review to determine the focus and content of the revisions to the bicycle facilities guide. Under the subsequent NCHRP project, a team led by Jennifer Toole of Toole Design Group, with additional input from the Midwest Research Institute, developed new recommended guidelines applying findings from research, as well as from practical experience in the design and construction of bikeways throughout the United States.



Another NCHRP project is starting up this summer to update the 2004 AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. Toole Design Group completed a scoping study in late 2010, identifying pedestrian issues and treatments that were not included or that were not covered in sufficient detail in the 2004 guide. Changes at the federal and

state levels—such as the imminent adoption of new accessibility standards and the adoption of the 2009 *Manual*

^a For more information about the revised AASHTO bicycle facilities guide or to place an order, go to https://bookstore.transportation.org/item_details.aspx?ID=1943.



PHOTO: NICK JACKSON, TOOLE DESIGN GROUP

For the revised AASHTO bicycle facilities guide, NCHRP reviewed design practices in cities and states nationwide, including approaches to signing and marking bike lanes. The City of Boston, Massachusetts, has installed more than 50 miles of new bike lanes in the past three years.

on *Uniform Traffic Control Devices*—have rendered the current guide obsolete.

In addition, pedestrian planning and design is advancing at a rapid rate in response to widespread concerns among government agencies and citizens that the transportation system does not adequately meet the needs of pedestrians. NCHRP Project 15-45, Proposed Update of the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities*, has been contracted to a team led by Theo Petritsch of Sprinkle Consulting; the project is slated for completion in 2014.^b

^b <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3175>.

Striped bike lanes and other shared-use facilities provide a cost-effective, efficient way to incorporate bicycle networks into urban design.



PHOTO: JEFF NICKERSON

quantify the relative importance of these attributes to particular populations, which will improve designs.

Experienced cyclists making a trip to work or school are more concerned about minimizing travel time, are less sensitive about proximity to traffic, and are more comfortable with on-road bicycle lanes. Less experienced cyclists and those making nonessential trips, however, may be more concerned about ambience, comfort, and ease of travel than with time or distance and are more likely to favor separate facilities to reduce interactions with motor vehicles. Because this group of less experienced cyclists represents the market with the greatest potential for utilitarian cycling, solutions are needed to make bicycling as safe, convenient, and attractive as it is in most European cities.

A combination of good urban design, traffic calming, and efficient, connected networks of bicycle-only and joint-use local streets is needed. Cities such as Portland, Oregon; Minneapolis, Minnesota; New York; and Washington, D.C., are investing in facility designs borrowed from European counterparts, such as cycle tracks, traffic-calmed bicycle boulevards, and bike boxes; each of these cities has recorded increases in bicycling rates.

Attitudes and Perceptions

Many other influences on the choice to walk or bicycle are rooted in attitudes and perceptions that are difficult to gauge. Safety concerns and self-selection are prominent among these.



PHOTO: DAN BUREN

Traffic calming measures in European neighborhoods, like these speed bumps in Cologne, Germany, allow for the coexistence of motorized and nonmotorized vehicles.

Safety

Safety concerns are twofold: travel safety during exposure to traffic and personal safety from crime or when passing through uncomfortable surroundings. Facilities planning and traffic management can address concerns about traffic safety, but personal safety is a different matter.

Public health researchers at the Centers for Disease Control and Prevention found strong relationships between physical inactivity and perception of neighborhood safety, with older adults and racial and ethnic minorities demonstrating the greatest sensitivity (5). This finding, confirmed in many other studies, stresses the importance of street lighting, landscape maintenance, and crime control in overcoming resistance to walking or bicycling.

Self-Selection

Perhaps most befuddling to planners of new urban places and bicycle and pedestrian environments is the role of self-selection. Some researchers have asked if the difference in travel behavior in different settings is attributable to the physical characteristics of the setting or to the tendencies and preferences of the people who live there. In other words, people who want to walk or bicycle self-select to live in neighborhoods that are more bikeable and walkable. Therefore building places that are friendly to walking or bicycling will only attract people who are favorably disposed to walk or bicycle.

This conundrum of nature versus nurture has been the subject of many studies. A review of 11 studies found that two concluded that self-selection was present, five found self-selection and the built environment equally important, and four found the effects of built environment most important (6). A definitive answer may never emerge; nevertheless, the demand for housing in walkable areas continues to be a strong market trend (7).

Future Research

Even with the new NHTS data, much remains to understand about bicycle and pedestrian travel. This is partly the result of how travel surveys are conducted. When an activity is rare—such as bicycling—a random sample of households and single-day trip diary methods will not capture a sufficient amount of information to address the behavioral questions important for planning.

The physical environment more emphatically influences the decision to walk or bicycle than the decision to drive or take transit. Therefore, detailed route information is important in understanding individual decisions. Travel surveys rarely collect these data, although GPS tracking is a promising technique.

Many cities are conducting regular counts of bicycles and pedestrians. But these efforts often rely on manual counts that require staff expenditures or many volunteers, and the results are not comparable to counts of motor vehicle traffic. Advances in technology are likely to solve this problem but will require investments in counting equipment and software. Nevertheless, activity counts do not provide insight into the types of trips being made, the characteristics of the travelers, and the reasons for their choice of mode, destination, or path.

Even if quality data on travel behavior were available, accurate and comprehensive information is lacking about the physical environment, including the presence of bicycle and pedestrian infrastructure. This limits understanding of the interrelationships. Several recent studies have shown that attitudes and other psychological factors also play a significant role in travel decisions, particularly for walking and bicycling. Data on these factors are also rare and are not collected in a consistent way to allow comparisons.

Finally, much of the data is generated from people who already walk or bicycle. If the objective is to increase the use of these modes for transportation, more needs to be known about the people who do not walk or bicycle or who do so only for recreation. These people are likely to differ from current cyclists and pedestrians, and encouraging them to change modes will likely require a different approach.

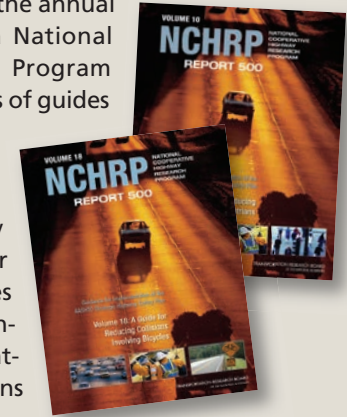
Although the gaps in knowledge about walking and bicycling are great, the prospects for filling these gaps are equally great. The number of papers reviewed by the TRB Pedestrians Committee and the Bicycle Transportation Committee has been increasing steadily. NCHRP has several related projects under way and nearing completion. TRB's Research in Progress database lists 67 projects with "pedestrian" in the title and 52 with "bicycle," "bicycling," or "bicyclist," sponsored by U.S. DOT, state DOTs, University Transportation Centers, and other agencies.

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Implementing Safety Measures for Pedestrians and Bicyclists

To advance the goal of reducing the annual number of highway deaths, a National Cooperative Highway Research Program (NCHRP) project has produced a series of guides for state and local agencies. Each title corresponds to one of 23 emphasis areas outlined in the American Association of State Highway and Transportation Officials plan for highway safety. Published as volumes of NCHRP Report 500, the implementation guides cover topics from seat-belt use to unsignalized intersections to pedestrians and bicycles.



Volume 10 of NCHRP Report 500, *A Guide for Reducing Collisions Involving Pedestrians*,^a offers research findings and proactive strategies to address pedestrian safety. Types of pedestrian crashes, victims, and precipitating events are examined, as well as a list of measures categorized by implementation timeframe and relative cost. Measures include minimizing pedestrian exposure to vehicular traffic, improving sight distance and visibility between motor vehicles and pedestrians, reducing vehicle speeds, and improving pedestrian and motorist safety awareness.

Characteristics of bicycle crashes and strategies for bicycle safety are explored in Volume 18, *A Guide for Reducing Collisions Involving Bicycles*.^b Safety objectives presented include reducing bicycle crashes at intersections, along roadways, and at midblock crossings; lowering vehicle speeds; raising safety awareness and encouraging safer behavior; increasing the use of bicycle safety equipment; and reducing the effect of potential hazards.

For more information on the NCHRP Report 500 series, see www.trb.org/Main/Public/Blurbs/152868.aspx.

^a http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v10.pdf.

^b http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v18.pdf.

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Traveler Response to Pedestrian and Bicycle Facilities and Programs

RICHARD H. PRATT

For three-and-a-half decades, *Traveler Response to Transportation System Changes*, now in its third edition, has provided transportation professionals with comprehensive, accessible, interpretive documentation of results and experience from across the United States and elsewhere in the application of changes and policy actions affecting motorized transportation. The third edition, issued as separate chapters under the banner of Transit Cooperative Research Program (TCRP) Report 95, recently released findings for nonmotorized transportation as well.

TCRP Report 95, Chapter 16, *Pedestrian and Bicycle Facilities*, also covers not only the effects of infrastructure but also outcomes of walking and bicycling programs and of promotional and information campaigns. Encouraging active transportation with its built-in physical activity is of interest not only to transportation planners and modelers seeking to curb congestion and enhance mobility but also to public health professionals seeking to promote healthy lifestyles.

Nuggets from Chapter 16

The 500-plus pages of Chapter 16 draw on sources from Aarts to Zwerts and cover walking and cycling outcomes through careful explorations of circumstances and assessments. The following selected points offer a sampling of the responses to changes in walking and bicycling facilities and programs:

- ◆ The presence of stores nearby, preferably with attractive sidewalks at the front door, is a strong encouragement for adult utilitarian walking—that is, walking for transportation. The extent of the sidewalk system is not as strong a factor in adult choice of modes but is significant; sidewalks are demonstrably related to health indicators such as lower rates of obesity. Child pedestrian counts increase in response to the addition of sidewalks and of signals at intersections; on California school routes, for example, average counts of child pedestrians increased by 46 percent in response to sidewalk improvements and by 24 percent in response to signal installation.



Research shows that child pedestrian counts increase when sidewalks and intersection signals are added to roadways.



Improvements in bicycle facilities led to a fivefold increase in bicycle volume on downtown Willamette River bridges in Portland, Oregon.

- ◆ Studies continue to show that adult bicyclists prefer bike lanes to undifferentiated streets with moderate to heavy traffic. Cyclists will go farther out of their way to use bicycle boulevards—that is, low-volume streets with traffic calming provisions. Most user groups prefer paved off-road paths, as long as the routings are reasonably direct. Physically separated bike lanes in the form of cycle tracks appear to attract more users than conventional bike lanes, but supporting research is limited.

- ◆ Improvements in system interconnection can stimulate active transportation. In Austin, Texas, when 3.5-ft sidewalks on a bridge were superseded by an exclusive pedestrian and bicycle river crossing, walk and bike volumes increased fivefold, reaching 4,000 to 5,000 users per day. Endpoint facilities are important to bicyclists, whether the cyclist is headed to work, shopping, personal business, or a transit stop. In Edmonton, Alberta, Canada, participants in a stated-preference survey valued secure bicycle parking as much as 27 minutes of saved cycling time.

- ◆ Multifaceted, systemwide programs have produced notable results. Brisbane, Australia, introduced shared-use paths in three corridors, plus local connectors and a major pedestrian-bicycle bridge. With housing growth in the downtown, walk-commute shares to the central area increased threefold in 20 years, to a share of more than 17 percent, and bike shares increased sixfold. In Portland, Oregon, 17 years of coordinated improvements in bicycle lanes, multiuse trails, bicycle boulevards, and bridges, plus individualized marketing programs,

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have yielded a fivefold increase in bicycle volume on key Willamette River downtown bridges—an outcome that parallels the mode shifts in Brisbane.

◆ Mass marketing of active transportation appears to have little staying power, but individualized marketing with information packets and one-on-one trip planning assistance produces better results. Most full-scale individualized marketing applications in the United States and Australia have engendered gains of 1 to 4 percentage points in walk mode share and gains of 1 to 2 percentage points in bicycle mode share and in transit mode share in the target areas. In the context of U.S. demonstrations, these gains translate into increases of 20 to 25 percent for walking, bicycling, and transit riding.

Resource Applications

Chapter 16 offers resources for planning and public health practitioners. The Overview and Summary delineates data and analytical pitfalls that must be understood to make reliable use of pedestrian and bicycle travel demand information. A section on Underlying Traveler Response Factors helps in understanding observed phenomena and their implications. For example, male and female comfort with bicycling is nearly identical on quiet streets, but female comfort levels decline more precipitously as route characteristics shift from off-road paths to bicycle lanes to busy undifferentiated streets.

The Related Information and Impacts section covers supplementary topics in active transportation. A discussion about the extent of walking and bicycling notes that 16 percent of U.S. walk trips occur in going to or from bus and urban rail stops. Counts indicate that usage of paths and bike lanes may take 7 or 8 years to mature. A subsection on Public Health Issues and Relationships adds information about exercise and health.

References and a section of additional resources guide readers to more detail and to associated topics. Seven case studies add depth; one consists of several ministudies undertaken to fill gaps in the literature.

Administrators, engineers, and planners sometimes focus on the programmatic and construction aspects of walkways and bicycle facilities and give inadequate attention to the travel and recreation desires of the intended users. *Pedestrian and Bicycle Facilities* provides user response information that allows professionals to give informed consideration to the facility and system characteristics and promotional activities that have achieved wider impacts and more effective outcomes.

Approaches to Consider

Chapter 16 is not a design or operations manual for pedestrian or bicycle facilities and does not set forth best practices or recommended policies. The information on impacts, however, suggests that the following approaches deserve special consideration:

TCRP Report 95, *Traveler Response to Transportation System Changes*, Chapter 16: *Pedestrian and Bicycle Facilities*, is available from the TRB online bookstore, www.trb.org/bookstore; to view the book online, go to www.trb.org/Main/Blurbs/167122.aspx.



Photo: Richard H. Pratt

Shared-use, off-road paths and trails that are well-connected to the network and popular destinations attract active transportation participants and exercisers of all ages and backgrounds; (above:) Capital Crescent Trail, near Bethesda, Maryland.

- ◆ Retrofitting sidewalk improvements in commercial areas, on school approaches, around transit stops, and along busy streets.
- ◆ Providing interconnections, large and small, to create system continuity and to link up with places people want to go.
- ◆ Concentrating walk and bike facilities and mixed-use development around transit nodes and activity centers.
- ◆ Attuning program and facility decisions to the preferences and needs of individual groups, ranging from disabled transit riders to risk-averse bicyclists. For example, attracting a broader clientele to bike riding and improving service for female and child cyclists calls for more emphasis on well-placed, off-road facilities, bicycle boulevards, other quiet street through-routings, and—if these are not workable—cycle tracks and buffered bike lanes.
- ◆ Using intensive individualized marketing techniques to promote the adoption of active transportation options for travel and exercise.

Acknowledgments

The U.S. Department of Transportation published the first and second editions of *Traveler Response to Transportation System Changes* in 1977 and 1981. The third edition has been issued in separate chapter-volumes as TCRP Report 95, starting in 2003, under the sponsorship of the Federal Transit Administration (FTA). Additional sponsorship for Chapter 16 came from the National Center for Environmental Health, Centers for Disease Control and Prevention.

Richard H. Pratt, John E. (Jay) Evans, Herbert S. Levinson, Shawn M. Turner, Chawn Yaw (C. Y.) Jeng, and Daniel Nabors authored Chapter 16. Richard H. Pratt, Consultant, Inc., serves as the research agency for the project,* in association with ten subconsultants. The subconsultants for Chapter 16 include the consultancies of Jay Evans and Herb Levinson, along with Gallop Corporation, Texas Transportation Institute, Parsons Brinckerhoff, Inc., and VHB. A TCRP panel has provided oversight throughout the project.

* TCRP Project B-12A, <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1034>.



Photo: Laura Sandt, PBC Image Library

Leveraging the Health Benefits of Active Transportation

Creating an Actionable Agenda for Transportation Professionals

LAURA SANDT, NANCY PULLEN-SEUFERT, SETH LAJEUNESSE, AND DAN GELINNE

The authors are researchers at the University of North Carolina Highway Safety Research Center, Chapel Hill.

(Above:) Cyclist waits at bike box at corner of Broadway and Fifth Avenue in New York City. Bicycling offers a way for adults and children to achieve moderate or vigorous physical activity and meet recommended health guidelines.

Walking and bicycling for health is not a new concept. These activities cannot be relegated to tracks, gyms, and malls, however—they need to be viable options for transportation in communities.

The evidence of the health benefits from walking and bicycling is mounting, and many initiatives showcase how public health and transportation professionals have been working together to create communities that are more pedestrian, bicycle, and transit friendly. These initiatives hold the potential for improving quality of life—through improved health and travel convenience.

Transportation planning, funding, and engineering can benefit from expanding the agenda to include health. A review of the research reveals ways to incorporate health considerations into transportation planning and design.

Benefits of Walking and Bicycling

Walking and other forms of physical activity once were integral parts of American life. Today the average commute to work, generally to desk jobs, takes 25 minutes per day across all travel modes—this does not include the return trip home. One of the trade-offs has been more time sitting and less time moving.

According to the Physical Activity Guidelines for Americans, adults need at least 150 minutes of moderate activity or 75 minutes of vigorous activity per week to experience the substantial health benefits of physical activity. Currently, less than 10 percent of Americans reach the recommended amount. Brisk walking and leisurely bicycling are both considered types of moderate activity, and integrating these activities into daily life holds promise for meeting physical activity needs.

Actively commuting to work is one way of attaining the recommended amount of physical activity (1). Almost one-third of transit users, for example, accumulate recommended amounts of physical activity by walking to and from transit stops.

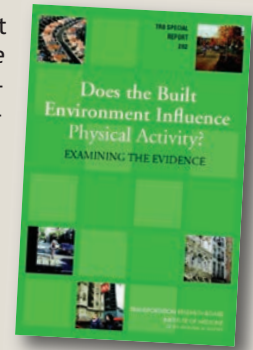
A large body of evidence has established the many individual, social, and economic health-related benefits of engaging in more physical activity and less sedentary activity. A lack of physical activity has been implicated in a long list of negative health outcomes, including premature death and chronic illnesses.

The health-enhancing role that walking and bicycling could play extends beyond the recommended moderate or vigorous physical activity. A leisurely walk to work on a route that requires stopping at many intersections can impart health benefits. Sedentary behavior—whether in a car, in an office chair, or on the couch—is associated with premature death and chronic disease. The amount of time spent seated has been isolated as a health risk in its own right, separate from a lack of physical activity (2). Exchanging time seated in a car for time spent moving about, therefore, offers health benefits regardless of how quickly a person is moving.

Physical activity—including walking and bicycling—also improves mental health. Many health-care providers recommend that patients with minor depression take regular walks, and patients with more severe depression are often encouraged to walk or to engage in other physical activity as part of their treatment regimen.

The health problems avoided by maintaining an active lifestyle not only affect quality of life but also have financial consequences. Drawing on findings from three studies, a recent estimate placed the

MAKING CONNECTIONS—TRB Special Report 282, *Does the Built Environment Influence Physical Activity? Examining the Evidence*, released in 2005, reviews the broad trends affecting the relationships among physical activity, health, transportation, and land use; summarizes what is known about these relationships, including the strength and magnitude of any causal connections; examines implications for policy; and recommends priorities for future research. Links to the full text of the book, a summary, and background papers can be found at www.trb.org/Publications/Blurbs/155343.aspx; to purchase a copy of the book, visit the TRB Bookstore at <http://books.trbbookstore.org/>.



annual healthcare costs of physical inactivity at \$544 per person in 2008 dollars (3).

In addition, the physical activity of walking and biking in the community can lead to social benefits. People are more likely to linger in outdoor environments that support walking and cycling and to mingle with members of the community; this encourages residents to become engaged in community issues and to enhance their quality of life. Streets with less car traffic, adequate lighting, and good visibility block opportunities for crime, instill a sense of personal security, and facilitate active travel (4).

Addressing Barriers

Achieving the health benefits of walking and bicycling requires addressing barriers and risks. After controlling for distance traveled, rates of injury among pedestrians and cyclists are higher than for



PHOTO: LUBBY THOMAS, PBIC IMAGE LIBRARY

Many roadways have high vehicle speeds and volumes and few facilities to support pedestrian or bicyclist activity, raising safety concerns.

To help encourage active transportation, policymakers must address the safety risks of bicycling and walking.



PHOTO: AAA FOUNDATION FOR TRAFFIC SAFETY

those traveling by motor vehicle (5). Commonly reported barriers to walking and cycling are the lack of safe facilities and concerns about crime and inclement weather, according to the National Survey of Pedestrian and Bicycle Attitudes and Behaviors. In addition, elevated exposure to ultraviolet light and air pollution, a risk for pedestrians and bicyclists, is gaining attention from the public and policymakers.

But prescribing more walking and bicycling without removing the barriers and risks is ineffective in promoting active transportation. Multifaceted, pop-

ulation-level approaches that address social and environmental barriers to bicycling and walking are needed to reap the health benefits of active transportation.

Environments and Facilities

The structure and quality of built environments may encourage people to use active travel modes and may affect the amount of physical activity. Regions with high levels of accessibility—large numbers of destinations reachable within a short travel time—tend to have significantly fewer vehicle miles traveled by automobile and greater proportions of walking and transit trips (6). Similarly, neighborhoods with a greater diversity of land uses, higher residential and employment densities, and high levels of connectivity—shorter distances between origins and destinations—correlate with higher levels of active transportation (6).

Research indicates that people in denser urban areas and in small-town communities tend to walk, bike, and use transit more (7). After self-selection biases and attitudinal preferences are accounted for, compact, mixed-use developments maintain a positive relationship with walking, cycling, and transit use (8). Although evidence suggests that the environment can facilitate physical activity regardless of lifestyle preferences, more research is needed to quantify the amount of physical activity attributable to characteristics of the built environment apart from social and individual influences.

In addition to elements and characteristics of the built environment—such as land use, connectivity,

Dense, diverse environments incorporating pedestrian amenities can stimulate active transportation.



PHOTO: DAN BURTON/PHIC IMAGE LIBRARY

and density—policies and roadway features can discourage single-person car use and effectively promote active transportation. For example, communities that reduce car parking availability—through pricing or by limiting the spaces—have lower levels of car use and higher levels of active transportation (9). Wayfinding signage and pedestrian and bicyclist-oriented crossing signals also facilitate walking and bicycling (10).

Bicycling amenities such as cycle tracks and bike boxes separate bicyclists from car traffic and reduce potential conflicts. Facilities that support walking and transit include such features as increased sidewalk widths, continuity, and connectivity. Lower traffic speeds, visible aids at pedestrian crossings, and the provision of amenities such as benches and trash bins also are associated with enhanced pedestrian activity (11).

Making the Transit Connection

Built environments can support walking and bicycling to transit facilities, offering opportunities to satisfy recommendations for daily physical activity.

PHOTO: LAURA SANDT



Pedestrian- and bicycle-oriented signs help promote active transportation; special signage assists visitors in a historic district of Charlotte, North Carolina.

Healthy Transportation Success Stories

In Nashville, Tennessee, the metropolitan planning organization (MPO) is making major strides to incorporate active transportation and support for transit into its long-range plans and policies. The investment strategy emphasizes healthy, sustainable, multimodal projects. The MPO is planning routine collections of data on travel and physical activity and is drafting criteria for health impact assessments (HIAs) as part of its review of land development projects. The MPO participates in a multidisciplinary statewide Obesity Task Force and in ongoing

collaborations for policy change.^a

In Shasta County, California, local transportation and community planners teamed with the Shasta County Public Health Department to create a Public Health Development Checklist, which provides healthy design alternatives for proposed development types, along with the rationale for each. The checklist is now part of the development review process and is used to frame comments and feedback to developers about considerations for the built environment.^b

Officials in Decatur, Georgia, used the HIA process to evaluate a new transportation plan, Decatur Gets Around, in terms of potential health impacts, including physical activity, safety and injury, social capital, mental health, and equity and access. The assessment found that the plan would have positive impacts on long-term community health and made recommendations for using the plan to promote health within the community.^c

The Local Public Health and Built Environment Network in Humboldt County, California, provides training, technical assistance, and funding to help local agencies integrate public health concerns into community design through workshops and walking audits.^d



PHOTO: REAVINNO, FUGER

The Sundial Bridge is a pedestrian bridge in Shasta County, California. County guidelines advocate infrastructure elements that encourage walking, bicycling, and other forms of active transportation.

^a www.apha.org/NR/rdonlyres/B08309C5-EA0D-4C6E-836C-1C3208E1E535/0/APHAW1Jan2011Meehan.pdf.

^b www.co.shasta.ca.us/HHSA/CommunityPartners/Checklist.sflb.ashx.

^c www.decaturga.com/Modules/ShowDocument.aspx?documentid=1211.

^d www.caactivecommunities.org/our-projects/local-public-health-and-the-built-environment/.



Measuring Walking and Cycling for Transportation

Expert Panel Examines Practice, Challenges, and Gaps

The Centers for Disease Control and Prevention (CDC) hosted an Active Transportation Expert Panel meeting, February 27–28, 2012, in Atlanta, Georgia, to advance cooperation among organizations that measure active transportation—that is, walking and bicycling for transportation purposes. The program objectives were to

- ◆ Document the state of active transportation measurement, particularly at the national level;
- ◆ Develop joint efforts to promote and enhance the monitoring and surveillance of active transportation; and
- ◆ Recommend key action items for near-term and longer-term collaboration involving public health, labor, and transportation.

Experts in the measurement of active transportation from academia, state and local governments, and federal government agencies attended the meeting and provided perspectives from the fields of transportation, planning, environmental science, engineering, and public health. In addition, representatives from a national partnership of private foundations described how data are applied to inform policy and advocacy efforts that support environments conducive to active living.

The meeting was structured as four main sessions. Presentations at the first session, on current measurement approaches, described national-level surveys that collect data on walking and bicycling for transportation purposes, including the National Household Travel Survey, the American Community Survey and other U.S. Census surveys, the American Time Use Survey, the National Health Interview Survey, and the National Health and Nutrition Examination Survey. The panel identified similarities and major differences in the measures, the data systems, and the data collection procedures; assessed the comprehensiveness of each approach; and identified common measurement challenges and gaps.

The second session focused on the application of available



Participants in the CDC Active Transportation Expert Panel meeting in Atlanta, February 2012.

data. Presenters described how data are used from the public health, transportation, research, and policy or advocacy perspectives. The panel identified how organizations are using—or not using—available data and discussed opportunities to optimize data resources across the systems. Suggestions were made for improving the characterization of time and trips spent in active transportation to inform research, as well as policy and advocacy efforts.

The third session examined emerging technologies and methods for monitoring active transportation. The advantages of incorporating these methods into large- and small-scale studies were discussed.

Collaboration was the focus of the final session. The panelists outlined a research agenda for collaborative efforts and developed recommendations for near-term and longer-term actions to promote active transportation data collection and monitoring. Participants consid-

ered how to build a strong network to ensure that data are collected efficiently and systematically to meet the maximum number of needs.

The planning committee^a is coordinating the development of several products. A summary review of the meeting is in preparation, along with a comparison of measures of walking and bicycling for transportation purposes across data systems at the national, state, and local levels. In addition, the committee will foster continued collaboration in support of active transportation measurement.

For more information, contact Dianna D. Carroll, U.S. Public Health Service Officer, Physical Activity and Health Branch, Division of Nutrition, Physical Activity, and Obesity, Centers for Disease Control and Prevention, Atlanta, Georgia, feu9@cdc.gov; 770-488-6339.

^a Members of the Active Transportation Expert Panel Planning Committee are Dianna Carroll, Janet Fulton, and Tom Schmid, CDC; David Berrigan, National Cancer Institute; Kevin Krizek, University of Colorado; and Gabe Rousseau, Federal Highway Administration.

Even after controlling for socioeconomic variables, for individual differences in the enjoyment of physical activity, and for the walkability of a neighborhood, significant associations remain between transit use and moderate physical activity. This finding suggests that accessing transit via walking or bicycling is largely responsible for higher rates of physical activity, more than a positive attitude about being active (12).

These transit-derived physical activity gains have been documented across diverse cultures and geographies. Active transportation and transit support each other reciprocally. By simultaneously improving transit access and operations, planners, engineers, transit officials, and public health practitioners can leverage the health benefits from transit use.

Partnering for Active Transportation

New federal initiatives are emphasizing connections between the fields of public health and transportation to address health concerns through the support of bicycling and walking improvements. For example, through its Communities Putting Prevention to Work program, the Centers for Disease Control and Prevention has provided \$257.1 million to communities addressing obesity issues through policy and environmental changes and other health programs.

In 2009, the U.S. Department of Housing and Urban Development, the U.S. Department of Transportation, and the U.S. Environmental Protection Agency formed the interagency Partnership for Sustainable Communities. The effort has developed several livability principles, including a goal to provide



PHOTO: RICHARD MASONER, CYCLECIOUS

Adults can achieve daily recommended guidelines for physical activity by commuting to work via methods that incorporate exercise, such as bicycling or walking to and from transit.

more transportation choices—such as walking, bicycling, and transit—to decrease transportation costs, improve air quality, and promote public health.

Building from the example and the funding offered by federal programs, many state and local transportation departments are connecting with public health departments to address health and transportation issues. These collaborative efforts involve a variety of activities, including training, resource and tool development, and designing and evaluating

Key Resources on Health and Transportation

- ◆ In 2011, the Transportation Research Board formed a Subcommittee on Health and Transportation to share research to improve the understanding of the health impacts of transportation decisions: www.trbhealth.org.

- ◆ The Sustainable Communities Partnership website provides resources and funding opportunities to enable communities to invest in healthy, safe, and walkable neighborhoods: www.sustainablecommunities.gov/.

- ◆ The Federal Highway Administration's Pedestrian and Bicycle Information Center has assembled research, case studies, and training materials on

active transportation and health: www.walkinginfo.org/promote/.

- ◆ The American Public Health Association's Transportation and Health website contains useful, research-based tools for practitioners: www.apha.org/transportation.

- ◆ The World Health Organization has developed the interactive Health Economic Assessment Tool to estimate the value of the reductions in mortality that result from walking and bicycling; this tool can be helpful in conducting analyses and in planning for new infrastructure: www.heatwalkingcycling.org/.



PHOTO: JESSICA DOWNING, AMERICAN PUBLIC HEALTH ASSOCIATION

The presence of transit facilities is associated with higher levels of walking.



PHOTO: LAURA SANDT, PBLIC IMAGE LIBRARY

transportation plans and projects through the completion of health impact assessments. The sidebars on pages 21 and 23 offer examples of state and local initiatives plus links to useful resources.

Collaborative Endeavors

Research on the benefits of active transportation has proliferated in recent years, clearly establishing the health benefits of physical activity and active transportation. The potential of active transportation to increase physical activity for all is widely recognized, but more research is needed to understand the complex relationship between features of the built environment and their influence on travel choice and safety.

Even when conditions for walking and bicycling are ideal, using active transportation modes will not be possible for everyone in every circumstance. Improving conditions for walking and bicycling, therefore, is only one part of a comprehensive approach to increase physical activity. Improving pedestrian and bicycle infrastructure, access, and connectivity is a unique contribution that transportation professionals can make to combat the health effects of sedentary lifestyles.

As concerns continue to rise about individual health and its social and economic implications, public health professionals will call on the transportation community to collaborate in creating safe and

healthy transportation solutions. Interagency coordination will be needed to collect data systematically in support of health and transportation research, planning, and monitoring. In addition, collaboration is needed for research to refine and institutionalize the processes for evaluating health benefits and incorporating health issues into planning and decision making.

With new tools and resources available and continued leadership from federal and local agencies, transportation professionals can strengthen interagency communication, integrate health considerations into planning and engineering efforts, and realize the promise of active transportation systems.

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Advancing the Discourse on Health and Transportation

ELOISA TIGRE RAYNAULT AND ED CHRISTOPHER

Transportation decisions affect health across all populations in profound ways, positively and negatively. In recent years, the number of papers on health-related research submitted for peer review to Transportation Research Board (TRB) standing committees has increased. To encourage and stimulate the growing interest and activity in this topic area, TRB formed a Health and Transportation Subcommittee to serve as a venue for researchers at the intersection of health and transportation.

Previously researchers and decision makers involved in this area had to search across several TRB committees to identify the latest health-related research and to improve understanding of the health impacts of transportation policies and projects. The Environmental Justice in Transportation, the Transportation and Sustainability, the Traveler Behavior and Values, and the Urban Data and Information Systems Committees sponsor the subcommittee, which was inaugurated at the TRB Joint Summer Meeting in Boston, Massachusetts, in July 2011.

The mission of the Health and Transportation Subcommittee is to identify, advance, and publish research and information to improve the understanding and evaluation of the health impacts of federal, state, regional, and local transportation policies, procedures, and actions. The subcommittee offers interested parties an opportunity to pool insights and expertise on the connections between health and transportation.

The subcommittee's scope includes an array of topics designed to cover diverse impacts and issues related to health, with attention to vulnerable populations. Subcommittee deliberations will address active transportation—such as walking and biking; safety; the impacts of freight transportation and aviation on health, air quality, and noise; and the use of health impact assessments and other metrics to advance and incorporate the consideration of health in transportation decision making.



Photo: Jessica Downing, American Public Health Association

The subcommittee plans to review and publish research, sponsor calls for papers, develop research proposals, and contribute to the rapidly expanding base of knowledge. Participants from a variety of disciplines—engineers, public health professionals, planners, epidemiologists, economists, advocates, elected officials, academics, and more—are working together to advance the subcommittee's mission and scope. For more information and to participate in subcommittee activities or to join the list of friends, visit the subcommittee's website, www.trbhealth.org.

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PHOTO: ERIC RODRIGUEZ, KEAM/ISTOCK

Business Cycles

Catering to the Bicycling Market

KELLY J. CLIFTON, SARA MORRISSEY, AND CHLOE RITTER

Clifton is Associate Professor of Civil and Environmental Engineering, and Morrissey and Ritter are graduate students, Nohad A. Toulan School of Urban Studies and Planning, Portland State University, Portland, Oregon.

Cycling is on the rise across the United States, and its popularity has grown beyond the usual leaders—Portland, Oregon; Seattle, Washington; Davis, California; Minneapolis, Minnesota; and Boulder, Colorado. Other cities making significant investments in bike infrastructure in recent years include New York City; Chicago, Illinois; and Washington, D.C.—all three have realized substantial growth in the numbers of people taking to the streets on two wheels.

New York City has added more than 200 miles to its bicycle network, for example, and the number of bicycle commuters has more than doubled since 2007 (1). Many other cities, large and small, are eyeing these successes and recognizing the potential of cycling as a viable mode of transportation for their communities.

Although improvements that support bicycling can offer benefits such as reduced congestion, improved air quality, and healthier communities, many question the economic impacts, specifically for the business community. Some evidence supports the assertion that bicycling is good for business, but many business owners express concern that cyclists



PHOTO: GREG RASMAN, FLICKR

A bike parking area at a Fred Meyer grocery store in Portland, Oregon. Portland has long been a national leader in urban bicycling, serving as a model for other cities as the popularity of bicycling grows.

(Above:) A University of Minnesota study is examining consumer-oriented business activity near bike-share stations.

are not a lucrative market compared with customers who arrive by automobile. They argue that efforts to cater to cyclists—such as increasing bicycle parking and adding bike lanes—can hamper access for automobiles and that an economic return from new facilities is not guaranteed.

Empirical evidence to settle these claims is lacking, but anecdotal evidence points to an increasing awareness of the benefits that bicyclists bring to local businesses—for example, some businesses have made concerted efforts to cater to bicyclists, including the addition of features that support cycling, as well as programs or services for cyclist customers. A few emerging studies are working to understand the returns on these investments for businesses and for the community at large.

Returns on Investments

Several studies have aimed at understanding the influence of bicycle tourism and the cycling industry—such as bicycle manufacturers, retail and repair shops, and clothing merchandisers—on local and regional economies. Fewer studies have focused on the cyclist as a consumer and on the potential economic benefits to specific types of businesses.

Industry, Retail, and Tourism

Research into the benefits of recreational bicycling and bicycle tourism has tracked expenditures directly related to bicycle equipment or to travel-related food and lodging. A study of the Outer Banks in North Carolina estimates that tourists who come to the area specifically for bicycling generate approximately \$60 million a year for the local economy, nine times the cost of constructing the bicycle facilities in the area (2). More than half of the visitors on the Greenbrier River Trail in West Virginia spend more than \$100 per visit and most come from out of state (3). According to a recent study, the revenue generated by recreational cyclists and by bicycle tourism in Wisconsin amounts to nearly \$1 billion annually (4). Colorado similarly estimates the impact of cycling by out-of-state tourists and active residents at \$1 billion (5).

Some analyses have examined the bicycle manufacturing, retailing, and service sectors of the economy. Wisconsin claims nearly 20 percent of the bike manufacturing in the United States; the industry contributes \$556 million annually to the state economy (6). In 2008, bicycle-related industries in Portland accounted for \$90 million in direct economic activity, with 60 percent coming from the retail, repair, and rental sectors (7). Since 2006, these industries have grown by 50 percent and provide 850 to 1,150 jobs in Portland.



PHOTO: BIKE AND ROLL WASHINGTON D.C.

Several other studies have focused on the perceptions of business owners about efforts to discourage driving or to improve nonautomobile access to commercial districts. In some cases, business owners reported that restrictions to vehicular traffic to improve facilities for cyclists or pedestrians had a positive impact on their businesses. For example, business owners on a street in San Francisco, California, noted that the installation of bike lanes increased the number of customers arriving by bike and had improved sales or had no impact on sales (8). Businesses located near bicycle parking corrals in Portland estimated that one-quarter or more of their customers arrived by bicycle (9).

A bicycle rental station in Washington, D.C. Research has uncovered economic benefits of bicycle tourism and recreational biking for localities.



PHOTO: JESSICA DOWNING, APHA

Some studies show a positive impact when bicycle facilities, such as bike lanes, are added near retail businesses.

Research into grocery shopping patterns showed that bicyclists spend less than automobile drivers, especially when they travel long distances to reach the store; however, bicyclists, pedestrians, and transit users shop more frequently.



Spending Patterns

Few U.S. studies have documented the interrelationships between mode, expenditures, and frequency of trips. In Seattle, researchers studied the mode choice of customers for trips to the grocery store (10). The results showed that stores in higher-density neighborhoods had a higher likelihood of shoppers using an alternative mode of transportation or transit. A survey in a commercial corridor in San Luis Obispo, California, revealed that consumers arriving by bike spent similar amounts yet visited more frequently than those who arrived by car (11). Internationally, studies from Münster, Germany (12), and from Utrecht (13) and Amsterdam (14) in The Netherlands have found that cyclists spent less per visit to a business but visited the business more frequently, which results in higher spending patterns over time.

U.S. researchers are beginning to explore this topic, working to measure the value of the cyclist as a customer for local establishments. At the University of Minnesota, a local economic activity study is conducting surveys and interviews of businesses near Minneapolis bike-share stations to collect information about changes in sales and in customer activity; bike-share system users are asked about their expenditures at local businesses. The data collected will be used to associate bike-share use patterns with consumer-oriented business activity.

Portland State University researchers recently collected survey information about customers and their transportation to various establishments, including high-turnover restaurants, convenience stores, and drinking establishments across the greater metropolitan area (see sidebar, page 29, for details and preliminary

results). The study aims to provide answers about the links between the mode of travel to these destinations, the amount spent, and the frequency of trips, while controlling for income, urban form, the transportation environment of the establishment, the number of persons in the household, and other factors.

Supermarket Data

As part of this effort, the researchers analyzed survey data collected independently by a supermarket chain on customer travel choices to 10 stores across the Portland metropolitan region (15). The limited data included information about the store's location, the residential locations of customers, the time of day and the day of the week, the mode of travel to the store, and expenditures on that day.

The findings revealed that customers who traveled by automobile to the grocery store spent more per trip compared with those who arrived by bike, walking, or transit. Cyclists spent approximately \$13 less per visit than automobile patrons. Results also highlighted the importance of bicycle infrastructure, urban form, the distance from home to the store, and the day of week in the choice to bike.

In addition, cyclists who traveled farther spent approximately \$5 less per mile of travel. No information was collected on the frequency of trips; therefore, the expenditures of customers across modes cannot be evaluated over longer time periods. The same grocery chain, however, collected data more recently that included the frequency of trips, and the preliminary results suggest that customers who walked, biked, and rode transit shopped more frequently.

Exploring the Relationship Between Consumer Behavior and Mode Choice

KELLY J. CLIFTON, SARA MORRISSEY, AND CHLOE RITTER

Researchers at Portland State University are studying the relationship between mode choices and customer expenditures. Funded primarily by the Oregon Transportation Research and Education Consortium, the study aims to provide a quantitative analysis of the connections between consumer spending and travel behavior.

During the summer of 2011, patrons of restaurants, bars, and convenience stores in different urban settings throughout greater Portland were asked to complete short surveys as they exited the establishments. Survey results suggest that patrons who arrive by automobile do not necessarily convey greater monetary benefits to businesses than bicyclists, transit users, or pedestrians. This finding is contrary to what business owners often believe. Nevertheless, motorists comprise the largest share of customers across establishment types and urban contexts.

Results from all establishment types show that customers who arrive by automobile spend more on average per trip than others (see Table 1). Taking the frequency of visits into account, however, reveals a different result—cyclists are greater spenders on average. The monthly differences are not statistically significant, however, and suggest that business owners may not realize gains by appealing to customers solely on their mode choices.

When consumer expenditures by mode of travel are examined in the context of the establishment's location, statistically significant differences emerge. The contexts include central business district (CBD); urban core—the central city outside of the CBD; neighborhood centers—commercial centers within neighborhoods; and low-density suburban business districts. Establishments in the urban core receive the highest average expenditures per visit across all modes at \$14.55, followed by establishments in neighborhood centers at \$11.55, in the CBD at \$11.07, and in suburban contexts at \$10.08 (see Figure 1). Patrons who arrive by automobile spend more per visit in all urban contexts, but the expenditures vary across contexts for consumers who travel by other modes.



Portland State University researchers survey customers about their travel behavior outside local establishments.

The study includes different types of establishments—high-turnover restaurants selling pizza and Mexican food, convenience stores, and bars. The average expenditures vary significantly across these different establishment types, as shown in Table 1. Convenience stores have the lowest average expenditures per visit at \$7.36 but the highest average expenditures per month, at \$80.40, because of the frequency of

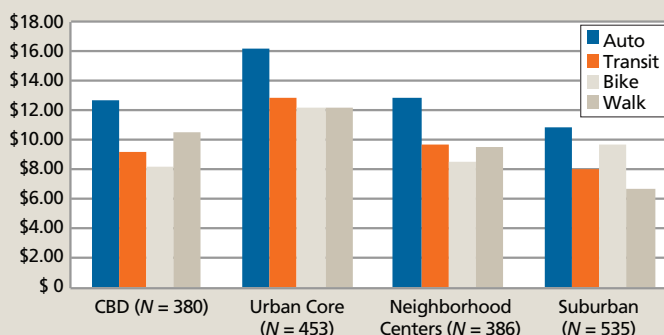


FIGURE 1 Average consumer expenditures per visit, by type of district.

visits. Customers who arrive by automobile spend the most per visit across all of the establishments, but cyclists spend the most per month.

These results suggest that marketing to cyclists is likely to generate a positive expenditure return for businesses in the right context. Profit margins and net gains must be evaluated on the basis of operating costs, which vary by location and space requirements. More evidence is needed to provide more conclusive direction for economic development. This ongoing study will examine the findings more closely, controlling for establishment characteristics, customer demographics, and the built environment near the business in disaggregate models of expenditures.

TABLE 1 Average Customer Expenditures by Mode of Travel and Type of Establishment

Mode	Establishment	Trips per Month	\$ per Trip	\$ per Month	N
Auto	Bar	1.6	25.55	40.21	88
	Convenience	9.9	7.98	79.37	543
	Restaurant	2.2	18.74	41.16	409
	Total	4.5	13.70	61.03	1,040
Bike	Bar	4.9	14.08	68.56	42
	Convenience	14.5	7.30	105.66	63
	Restaurant	3.5	12.08	42.52	48
	Total	7.1	10.66	75.66	153
Transit	Bar	1.8	19.54	35.35	13
	Convenience	10.9	6.91	75.62	53
	Restaurant	3.5	11.52	40.68	36
	Total	5.7	10.15	58.16	102
Walk	Bar	3.1	22.17	68.42	53
	Convenience	12.6	6.13	77.34	254
	Restaurant	2.6	16.74	43.77	131
	Total	5.9	11.25	66.22	438
Total	Bar	2.5	21.78	53.59	196
	Convenience	10.9	7.36	80.40	913
	Restaurant	2.4	17.39	41.78	624
	Total	5.0	12.60	63.46	1,733

NOTE: N = number of respondents.



PHOTO: BEACH650, FLICKR

One or two car parking spaces can be converted to bike corrals for 20 to 40 bicycles. In Portland, bike corrals are a growing feature of the urban landscape.

Bicycle-Supported Development

Transit-oriented development (TOD) has become an accepted term in the transportation vernacular, but bicycle-supported development is a lesser known term. Similar to TOD, bicycle-supported developments are areas with attributes and features conducive to bicycling—such as density of development and mix of uses, abundant and convenient bicycle parking, and proximity to cycling facilities.

Business establishments in these developments have a culture that accepts the bicycle mode, sometimes offering specials for those who arrive by bike, plus amenities such as lockers, showers, and other services that are less obvious from the street. Portland is actively pursuing this development concept, but the individual elements of bike-supported development are catching on nationwide, even when support from the business community is mixed.

Some local businesses embrace bicycling and are recognizing the potential new market share of these

consumers. Not all efforts to accommodate this market, however, are met with enthusiasm, and some have encountered organized opposition. For example, Memphis, Tennessee, is adding dedicated bicycle lanes to Madison Avenue as part of a facility redesign and repaving project funded by federal stimulus dollars, but many local merchants have opposed the changes, fearing a loss in their customer base.

Bike Corrals

Bicycle infrastructure can be controversial, particularly when on-street parking for motorists is removed to make way for bicycle lanes or parking. Typically, one or two automobile parking spaces can be converted to on-street parking for 20 to 40 bicycles; these clusters of bicycle racks are termed bike corrals. Businesses sometimes fear that the loss of automobile parking will have a negative effect, making their establishment less accessible to customers who drive and leading to a loss in their customer base that will not be replaced by cyclists. Evidence suggests that these concerns may be unfounded.

Pioneered in Portland, bike corrals have become so popular with local businesses that the city cannot keep up with the requests. More than 75 bike corrals currently have been installed at the request of adjacent business owners who see cyclists as an important customer base. Bars and restaurants have capitalized on this new infrastructure, which provides a buffer from moving traffic, by adding outdoor seating for sidewalk cafes. Because demand is so high, the city must place future corrals strategically and may institute a fee for installation.

This movement is catching on in other parts of the country, with corrals recently installed in such cities as Chicago; Milwaukee, Wisconsin; Los Angeles, California; Cincinnati, Ohio; Baltimore, Maryland; and Salt Lake City, Utah, as well as in Toronto, Ontario, Canada. In the past year, Austin, Texas, has installed seven bike corrals adjacent to bars, live music venues, and coffee shops. The businesses had been trying to accommodate their cycling customer base but the available bicycle parking was insufficient to meet the demand. Somerville, Massachusetts, has added two corrals and plans to install several more.

Built-In Accommodations

In New York City, housing and office buildings are offering more bicycle parking and storage, complementing the new bicycle lanes and parking areas that the city has built in the past several years. Dedicated bicycle rooms in private buildings are on the rise, with amenities ranging from secure indoor bicycle racks to locker rooms. Real estate listings for office spaces and apartments advertise these features.

A bike storage area in a Seattle condominium building. More private buildings in urban areas are incorporating bicycle storage and bike parking.



PHOTO: BRAD HOWELL

In 2009, the city endorsed this trend through the Bicycle Access to Office Buildings Law, which guarantees that employees who have bicycle storage or parking facilities inside their workplace cannot be refused building access by security or management. Hostels and hotels in New York increasingly are offering loaner bicycles or repair tools to encourage guests to travel by bicycle.

In response to the strong bicycling culture in Portland, developers have started taking advantage of the marketing possibilities along heavily-traveled bicycle corridors. Bike-supported developments are cropping up in commercial and residential projects, offering amenities and services that appeal to cyclists. For example, a successful urban renewal project along North Williams Avenue, a popular bicycle commuting corridor, has attracted a cluster of new businesses catering to cyclists: restaurants, bars, coffee shops, a guest house, a bicycle-oriented apartment building, and a bike repair and frame-building shop.

This level of bicycle-supported development has not yet become popular beyond Portland. Nonetheless, if cities continue to support bicycling through infrastructure investments, the private sector appears poised to respond to advantage.

Bike-Sharing Programs

Bicycle-supported development and the TOD model may come together with the rise of bicycle-sharing programs in cities across the United States. Systems are in place in Minneapolis; Denver, Colorado; New York City; Boston, Massachusetts; Miami Beach, Florida; and Washington, D.C. The placement of bike-share stations at rail stops aims at the traveler's "last mile," extending access from transit to destinations.

In Washington, D.C., the program is popular with tourists and residents alike. Bike-sharing stations are strategically placed near Metrorail stops and concentrations of employment, housing, and entertainment. As TODs mature around rail stations, bicycle-supported development may become an important link in their success.

Smaller bike-share programs operate on institutional and workplace campuses, capitalizing on the short trip lengths and connections to retail, shopping, and other local destinations. San Luis Obispo's bike-share program is designed to facilitate the use of bicycles for workplace trips. The program has provided 15 participating employers with bicycles, helmets, and locks and has conducted safety workshops. Higher education also has embraced the approach, with nearly 90 programs serving students, staff, and faculty at colleges and universities across the country (16).

PHOTO: JENNIFER WEEKS



Capital Bikeshare in Washington, D.C., is a popular bike-sharing program, with stations placed near transit stops and concentrations of employment. The slogan boasts, "150 locations, endless temptations!"

Programs and Special Events

Commercial districts around the country are also experimenting with programs, special events, and services aimed at attracting cyclists or encouraging customers to travel by bicycle. The City of Long Beach, California, has established four bike-friendly business districts under a pilot project funded by the Los Angeles Department of Public Health in 2010 as a part of a larger program to combat obesity, improve nutrition, and increase physical activity. Efforts include providing bicycles for area employees to run errands and conduct business in the area, providing discounts for bicycle patrons on Saturdays, conducting courses on bicycle safety, and offering maintenance and valet parking for bikes during special events, such as street fairs and art festivals. The hope is that the districts will continue the programs after the pilot project ends in 2012.

Bike Valet Parking

Bike valet parking is becoming a popular strategy to encourage bicycling to special events. Tucson, Arizona, has offered the service at its semiannual Fourth Avenue Spring and Winter Street Fairs. In Washington, D.C., bicycle valet service was available for the Presidential inauguration in 2009 and for the annual National Cherry Blossom Festival. The San Francisco Bicycle Coalition provides free bike valet service for San Francisco Giants home games and other major public events; city law requires monitored bicycle parking at all events with an anticipated attendance of 2,000 or more.

These bike valet programs are intended to encour-



PHOTO: CARL SUNDBLUM

Cyclists comprise a growing share of the consumer market, creating opportunities for research on the effects of bicycle infrastructure on commercial environments.

age attendees to consider bicycling and to reward those who do with free and convenient service. The strategy has focused on special events, however, and has yet to be embraced for everyday shopping and dining trips, although the University of Arizona and the Oregon Health and Sciences University recently began offering free valet parking to cyclists on campus. Business corridors and commercial districts may find the approach worthwhile if bicycle demand increases.

Marketing Efforts

Many businesses are working together to market their goods and services to cyclists. In Vancouver, British Columbia, Canada, Business for Bikes promotes the bike-friendly establishments of its more than 100 members, who receive information on how to market to cyclists and attract new customers who cycle. A recent publication, *Bicycling Brings Business: A Guide for Attracting Bicyclists to New York's Canal Communities (17)*, provides information to businesses along the Erie Canal about accommodating cyclists. Clearly, recognition is growing that cyclists constitute a current or potential consumer market and that certain kinds of infrastructure and services may attract cyclists or encourage business patrons to shift modes.

Tracking the Evolution

With the growth in bicycling investments throughout the United States, the need for more rigorous and detailed evidence on the economic impacts of cycling is pressing. The opportunities are abundant to conduct longitudinal studies that track the evolution of commercial environments before and after the introduction of bicycle infrastructure and services. The profitability and benefits to the private sector should be given more scrutiny, as many advocate for increased public investment in bicycling.

Clearly, the topic is a prime area for more research. More information is needed to document the planning and political processes that make these projects successful, the balance of investments between public and private entities as bicycle-supported developments mature, and the changes—if any—in customer characteristics that occur with mode shifts.

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Regulating Emerging Light Electric Vehicles to Enhance Urban Transportation System Sustainability

GEOFFREY ROSE AND CHRIS CHERRY

The range of innovative, electrically powered, personal mobility devices is expanding with advances in technology and product design (see photo, right). Many of these vehicles are variants of bicycles. Some are self-propelled; others provide propulsion assistance. These innovative personal mobility options can have a valuable role in enhancing the sustainability of urban transportation systems. Integration into a system, however, requires consideration of the risks and opportunities the devices provide in terms of safety, system efficiency, mobility enhancement, energy consumption, and environmental impacts.

Regulatory frameworks, therefore, are key, but the regulations governing these vehicles vary from nation to nation and, in the United States, from state to state. Because of their characteristics and performance, many personal mobility devices are not subject to the Federal Motor Vehicle Safety Standards or similar regulations. Whether a device's characteristics or performance permits classification as a bicycle or as a moped—that is, a low-powered motorcycle—is important. Classification as a moped usually entails more stringent requirements in terms of the rider's age, as well as licensing, registration, and mandatory personal protective equipment—such as wearing a helmet.

The vehicles shown in the three photos below illustrate some of the regulatory boundaries. The vehicle in Photo *a* is not considered an electric bicycle in most jurisdictions around the world, except the United States, because of the 750-Watt power of its motor. Most jurisdictions consider the vehicle in Photo *b* an electric bicycle, because it has perfunctory pedals; the vehicle in Photo *c* is not classified as an electric bicycle, because it lacks operable pedals. The maximum speed and weight of the vehicles, which affect the kinetic energy in a crash, vary greatly but are not factors in the classifications.

Prescriptive standards can spur innovative approaches to skirt the regulations but can do little to improve safety. For example, a vehicle like the one shown in Photo *b* might be fitted with pedals to classify it as a bicycle, but few riders would



IMAGE SOURCE: C. CHERRY

Examples of light electric vehicles.

be able to propel it themselves, because of the vehicle's weight and the spacing of the pedals. Regulations therefore should be carefully designed to ensure that the community can benefit from innovative solutions to transportation challenges.

To enhance understanding of these vehicles, four TRB technical standing committees—Pedestrians, Bicycles, Motorcycles and Mopeds, and Traffic Law Enforcement—have established a joint subcommittee on Emerging Technologies and Vehicles for Personal Transportation. The subcommittee will focus on personal mobility devices that are not normally subject to the U.S. Federal Motor Vehicle Safety Standards or similar regulations, on the underlying technologies, and on the supporting systems. The subcommittee will examine the use, demographics, and operational characteristics of the devices, and how they may be safely incorporated in the transportation infrastructure. For additional background and details on literature about these vehicles, visit the joint subcommittee's website, www.trb-emergingtech.com.

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PHOTO: G. ROSE



PHOTO: G. ROSE



PHOTO: WWW.YIKEBIKE.COM

Design variants of light electric vehicles.



On this road in Santa Barbara, California, motor vehicle lanes were replaced by a bidirectional bike path, separated from car traffic.



PHOTO: RALPH FERRE

Walking and Cycling in Western Europe and the United States

Trends, Policies, and Lessons

RALPH BUEHLER AND JOHN PUCHER

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Walking and cycling are the most sustainable means of daily travel. They cause virtually no noise or air pollution and consume far fewer nonrenewable resources than any motorized mode of transport. The energy that walking and cycling require is provided directly by the traveler, and the use of that energy offers valuable cardiovascular exercise.

Walking and cycling require only a fraction of the space needed for operating and parking cars. Moreover, walking and cycling are economical—they cost far less than the private car or public transport, in terms of direct outlays by users and of invest-

ments in public infrastructure. Walking and cycling are affordable by virtually everyone and therefore are the most equitable of all transport modes.

Following is a brief overview of cycling and walking trends and policies in the United States and Western Europe, with a focus on the United Kingdom, Denmark, Germany, and the Netherlands, the countries for which the most comparable and detailed data are available (1–9).

Variations and Trends

The share of daily trips by walking and cycling varies greatly from country to country (see Figure

1, right). At the low end, approximately one-tenth of daily trips are by foot or bike in car-oriented countries such as Australia, Canada, and the United States. At the high end, more than half of all daily trips in the Netherlands are by walking or cycling. Most European countries have levels in between, with active travel accounting for 25 percent to 35 percent of daily trips.

Differences in national travel surveys limit the comparability of walking and cycling statistics. Nevertheless, the European countries included in Figure 1 clearly have active transport rates at least twice as high as those of North America and Australia.

Active travel generally has declined in the United States and Western Europe in the past four decades. The most dramatic change has been in trips by walking. The modal share of walking fell by roughly one-half in France and the United Kingdom, by one-third in Germany, and by one-fourth in Denmark (see Figure 2, below). Only in the Netherlands did the share of walking trips remain stable. The bike share of trips fell by one-half in the United Kingdom, by one-third in France, and by one-tenth in the Netherlands but increased slightly in Germany and Denmark.

In the five European countries in Figure 2, the combined modal shares of walking and cycling in

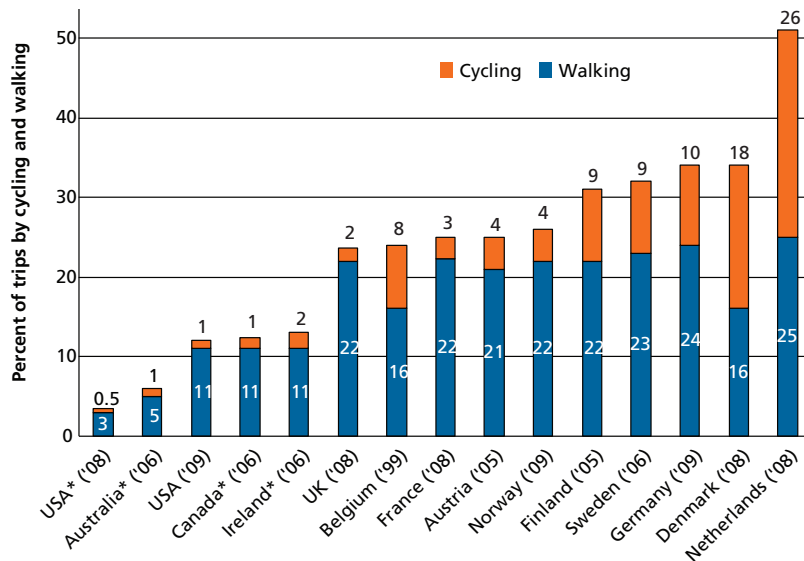


FIGURE 1 Cycling and walking share of daily trips in Europe, North America, and Australia, 1999–2009.

Note: The latest available travel surveys were used for each country; the year of the survey is noted in parentheses after each country's name. The modal shares reflect travel for all trip purposes except for those countries marked with an asterisk, which only report journeys to work derived from their censuses. Dissimilarities in data collection methods, timing, and variable definitions limit the comparability of the modal shares shown. [Sources: Danish Ministry of Transport (MOT), British Department for Transport (DfT), German MOT, Statistics Netherlands, U.S. Census Bureau, U.S. Department of Transportation (DOT), and Norwegian Institute of Economic Research.]

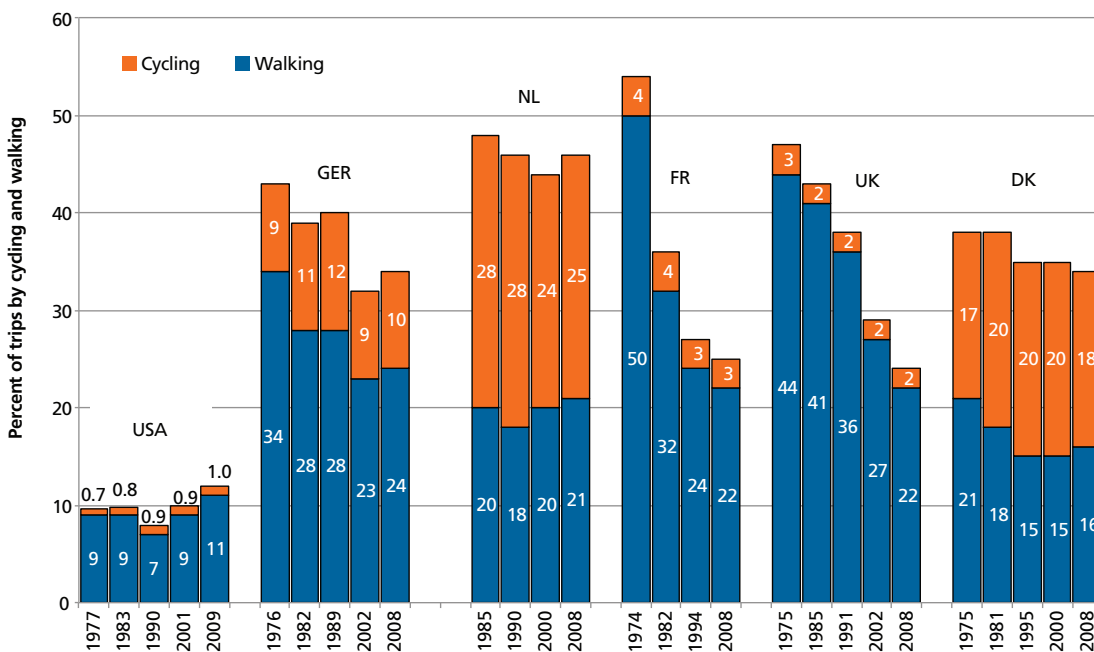


FIGURE 2 Trends in combined cycling and walking share of all daily trips in the United States, Germany (GER), the Netherlands (NL), France (FR), the United Kingdom (UK), and Denmark (DK), 1974–2009.

Note: Dissimilarities in data collection methods, timing, and variable definitions limit the comparability of the modal shares shown. The increase reported for the United States in the combined walk and bike share of trips between 1990 and 2001 probably results from a change in methodology that captured previously underreported walk trips. (Sources: Danish MOT, British DfT, French MOT, German MOT, Netherlands MOT, U.S. DOT, and Norwegian Institute of Economic Research.)



PHOTO: RAHM BUEHLER

Since the early 1970s, an increasing number of German cities have banned automobiles from the city center, as here in Freiburg, Germany.

the early 1970s were roughly comparable, at approximately 40 to 50 percent, but the most recent surveys indicate that active travel in Denmark, Germany, and the Netherlands is at a level almost twice that of France and the United Kingdom. The much smaller declines in active transport in Denmark, Germany, and the Netherlands are attributable to more car-restrictive policies since the 1970s, combined with a range of measures to encourage walking and cycling.

Walking and cycling trends in the United States are difficult to gauge, because the national travel survey methodology changed in 2001, increasing the walk mode share by capturing previously unreported walk trips. The survey results in Figure 2 suggest slight increases in walking and cycling levels in the United States in the past two decades, but in the long term, the walk mode share probably declined. The U.S. Census, which has applied a consistent methodology, reports a substantial decline in walking and cycling to work, from 7.9 percent of workers in 1970 to 3.5 percent in 2009 (10, 11).

Gender and Age Groups

Cyclists comprise virtually all segments of society in Denmark, Germany, and the Netherlands. In the United States, Canada, and the United Kingdom, women account for approximately one-fourth of all bike trips; women in Denmark, Germany, and the Netherlands make approximately half of all bike trips. Cycling is gender-neutral in Denmark, Germany, and the Netherlands but dominated by men in the United States, Canada, and the United Kingdom. In contrast, the share of walk trips made by women shows little variation among countries.

Walking and cycling levels vary significantly by age, but the variation is much less in some countries than in others. The combined share of walking and

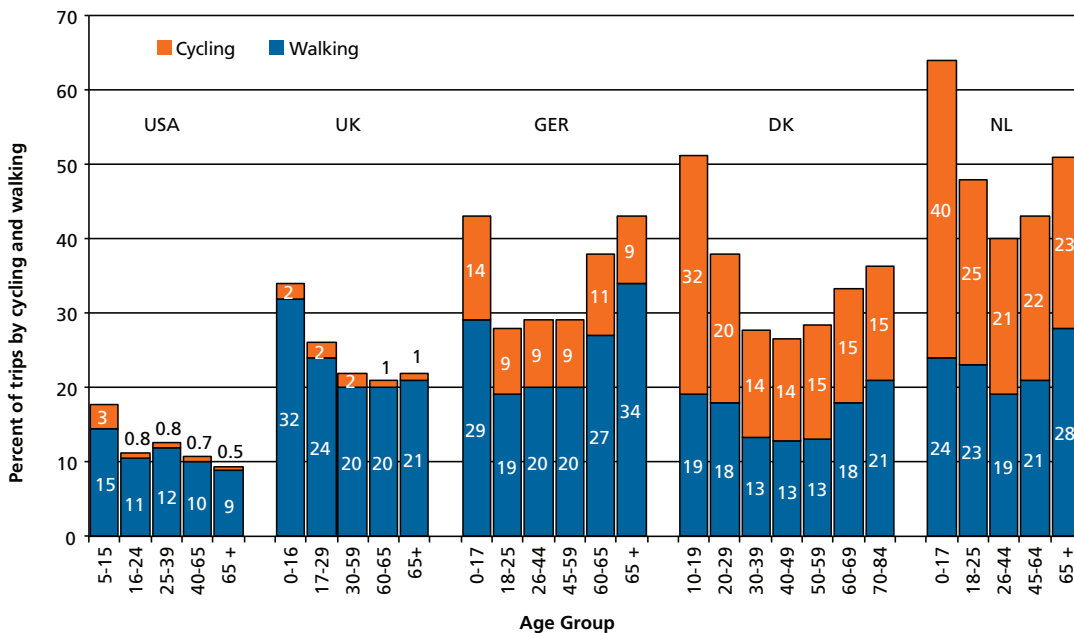


FIGURE 3 Cycling and walking share of trips within each age group in the Netherlands, Denmark, Germany, the United Kingdom, and the United States, 2009, as percent of trips by all modes for all trip purposes.

Note: Each country uses somewhat different age categories in travel surveys. The percentages shown refer to the walking and cycling share of all trips made by persons within each age category. (Sources: Danish MOT, British DfT, German MOT, Netherlands MOT, and U.S. DOT.)

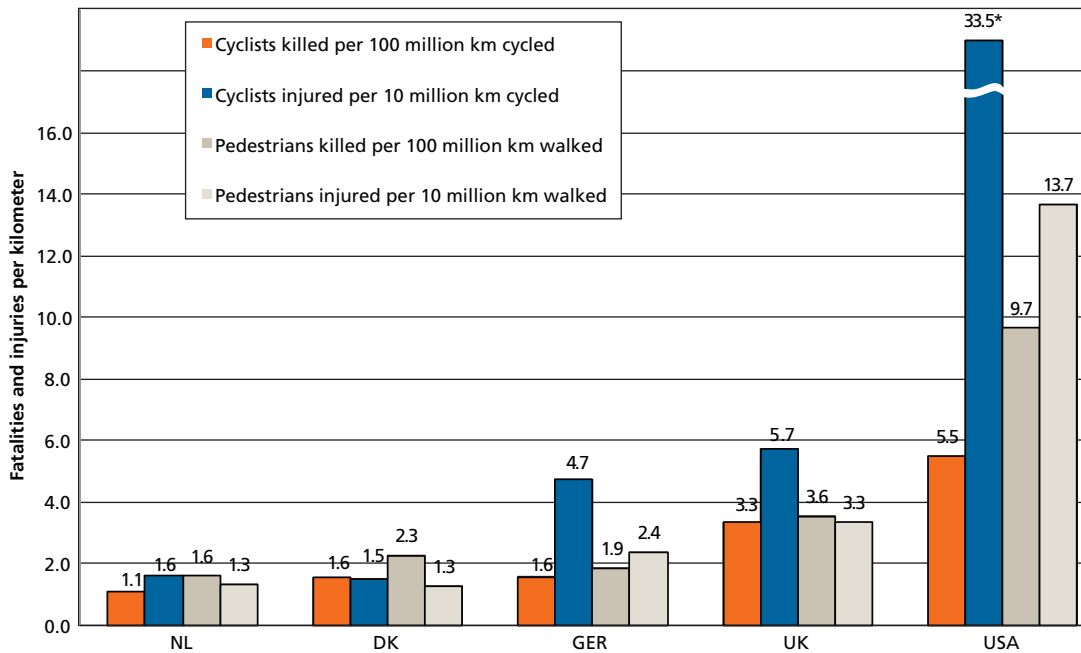


FIGURE 4 Cyclist and pedestrian fatality rates and nonfatal injury rates in the Netherlands, Denmark, Germany, the United Kingdom, and the United States, 2004–2009.

Note: To control for annual fluctuations, a 5-year average (2004–2008) was used for pedestrian and cyclist injuries and fatalities. Trips and kilometers for cycling and walking exposure levels derive from 2008 travel survey data.

* Cyclist injury rate for the United States is off the chart and is shown with a discontinuous bar. (Sources: Danish MOT, British DfT, German MOT, Netherlands MOT, U.S. DOT.)

cycling trips increases with age in Denmark, Germany, and the Netherlands (see Figure 3, page 36). Walking and cycling account for roughly half of all trips by Danish, German, and Dutch elderly, compared with one-fifth of the trips by British elderly and one-tenth of trips by U.S. elderly.

Differences among countries in rates of cycling are striking. The cycling share of trips made by the elderly is 23 percent in the Netherlands, 15 percent in Denmark, and 10 percent in Germany but 1 percent in the United Kingdom and 0.5 percent in the United States.

Safety Issues and Trends

Studies show that traffic danger deters walking and cycling, especially by women, children, and the elderly (12–14). The lower rates of walking and cycling in the United States may be attributable to greater dangers faced by pedestrians and cyclists. Cyclist fatalities per kilometer are 3 to 5 times higher in the United States than in Denmark, Germany, and the Netherlands (see Figure 4, above).

Walking in the United States is even more dangerous, with pedestrian fatalities per kilometer 5 to 6 times higher than in Denmark, Germany, and the Netherlands. Walking and cycling are about twice as dangerous in the United Kingdom as in Germany, but still much less dangerous than in the United States. Nonfatal injury rates for pedestrians and cyclists also are much higher in the United States.

Walking and cycling were not always as safe in Northern Europe as they are today. Annual cyclist fatalities in Denmark, Germany, the Netherlands,

and the United Kingdom declined by 60 to 80 percent between 1970 and 2008. By comparison, cyclist fatalities in the United States fell by less than 10 percent, mainly reflecting a sharp decline in cycling by children (15, 16). Similarly, part of the decrease in cyclist fatalities in the United Kingdom was attributable to a decrease in the number of bike trips. In Denmark and Germany, by contrast, cycling fatalities fell although the number of bike trips increased.



A bicyclist crosses a roundabout in the Netherlands. Bicycling rates of the elderly reach 10 percent in Germany, 15 percent in Denmark, and 23 percent in the Netherlands, compared with 1 percent in the United Kingdom and 0.5 percent in the United States.

This cycle track in New York City features priority traffic signals for cyclists and physical separation from motor vehicles.



PHOTO: NEW YORK CITY DOT

Bike paths in the Netherlands are designed for safety and comfort for all, including women, children, and seniors. Wide paths enable cyclists to ride two or three abreast, making cycling more sociable.

In all five countries, pedestrian fatalities have declined more than cyclist fatalities. Walking levels fell in most countries over this period, however, so that part of the reduction is attributable to reduced exposure rates. The number of annual pedestrian fatalities dropped more sharply in Europe—by between 80 percent and 90 percent—than in the United States, with a decline of 50 percent. Germany and the Netherlands recorded an impressive 90 percent decline in pedestrian fatalities between 1970 and 2008.

These statistics suggest that traffic safety affects walking and cycling and that greater safety in Denmark, Germany, and the Netherlands has contributed to the higher rates of walking and cycling. The theory of safety in numbers also suggests that more walking and cycling may help improve safety (17).

Walking and cycling levels correlate strongly with safety rates. More and safer walking and cycling in Denmark, Germany, and the Netherlands result from a range of programs and policies designed to encourage walking and cycling while restricting car use.



PHOTO: WARREN SALOMON

Promoting Walking and Cycling

Danish, German, and Dutch transportation policies have emphasized improvements in the transportation infrastructure for walking and cycling. For pedestrians, measures include extensive auto-free zones in much of the city center; wide, well-lit sidewalks on both sides of every street; pedestrian refuge islands for crossing wide streets; clearly marked zebra crosswalks, often raised and with special lighting; and pedestrian signals at intersections and mid-block crosswalks with ample crossing times.

From the mid-1970s to the mid-1990s, separate bicycling facilities—such as bike paths and lanes—expanded in most Northern European countries. In Germany, the bikeway network more than doubled in length, from 12,911 km (8,070 mi) in 1976 to 31,236 km (19,522 mi) in 1996. In the Netherlands, the bikeway network doubled in length, from 9,282 km (5,801 mi) in 1978 to 18,948 km (11,843 mi) in 1996 (3).

Comparable nationwide aggregate statistics for the period since the mid-1990s are not available, but data for individual cities suggest continued expansion, although at a slower rate. The current focus is on improving the design of cycle paths and lanes to improve safety, especially at intersections.

Various other measures complement separate rights-of-way: special bike lanes leading directly to and through intersections; separate bike traffic signals with advance green lights for cyclists; bicyclist-activated traffic signals at key intersections; and modification of street networks to create dead ends and slow, circuitous routing for cars but direct, fast connections for bikes.

Danish, German, and Dutch bikeway systems serve practical destinations for everyday travel. By comparison, most separate bike paths in the United States are located in parks or along rivers, lakes, or harbors and are mainly for recreation.

Traffic Calming

Traffic calming in residential neighborhoods in Western Europe limits the volume and the speed—usually to less than 30 km/h (20 mph)—of motor vehicle traffic, both by law and by physical barriers, such as raised intersections and crosswalks, traffic circles, road narrowing, zigzag routes, curves, speed humps, and artificial dead ends created by street closures at midblock. Traffic calming is less common in the United States and is usually limited to isolated streets.

The most extreme form of traffic calming—the *woonerf*, home zone, or *Spielstrasse*—imposes additional restrictions, requiring cars to travel at walking speed—7 km/h (4 mph) in Germany—and to yield to nonmotorized users.

Reduced speeds are crucial in enabling motorists to avoid crashes with pedestrians and bicyclists and in increasing the likelihood of a nonmotorist's survival in a crash. The World Health Organization (18), for example, found that the risk of pedestrian death in crashes rose from 5 percent at 30 km/h (20 mph) to 45 percent at 50 km/h (30 mph) and to 85 percent at 65 km/h (40 mph). In Denmark, Germany, the Netherlands, and Great Britain, a comprehensive review found that traffic injuries fell by an average of 53 percent in neighborhoods with traffic calming measures (19).

Integration with Transit

Coordinating walking and cycling with public transport enhances the benefits of all three modes, encouraging more walking and cycling, as well as more use of public transport. In most countries, trips by public transport usually start and end with walks

PHOTO: JOHN PUCHER



Many bikeway facilities in Europe have parallel walkways for pedestrians, such as here in Münster, Germany.

to and from bus or rail stops.

Bicycling extends the catchment area of transit stops beyond the range of walking and at a much lower cost than neighborhood feeder buses or park-and-ride facilities for cars. Access to public trans-

Many German cities have introduced home zones or *Spielstrassen*, an advanced form of traffic calming, with a speed limit of 7 km/h on neighborhood streets; cars are required by law to yield to cyclists, pedestrians, and children.

PHOTO: PETER BERKELEY



Münster offers secure and sheltered parking for 3,300 bikes at its main train station and bus terminal.



PHOTO: PETER BERKELEY

port helps cyclists make longer trips than are possible by bike alone. Therefore the design of public transport stations should offer safe, convenient, and comfortable pedestrian and cycling facilities, both in the stations themselves and on routes leading to the stops.

Four main categories of measures assist in coordinating cycling with public transportation (20):

1. Bike parking at rail stations and bus stops;
2. Provisions for taking bikes aboard trains and buses;
3. Bike rental facilities near public transportation stops; and
4. Coordination of bike routes with public transportation.

Even inexpensive and easily implemented traffic-calming measures can reduce car speeds in residential neighborhoods, as here in Freiburg.



PHOTO: CITY OF FREIBURG

Compact Development

Trip distance affects levels of walking and cycling. Most walking trips are 1 km (0.6 mi) or shorter, and most bike trips are 3 km (1.8 mi) or shorter. Land use is crucial in determining average trip distances. By promoting or requiring compact, mixed-use development and discouraging low-density sprawl, land use policies in Denmark, Germany, and the Netherlands have established a long-term framework for walkable and bikeable communities.

In the past two decades, many Danish, German, and Dutch cities have revised their land use and transport plans to strengthen neighborhood commercial and service centers. The plans encourage more variety in neighborhood land use by mixing housing with stores, restaurants, offices, schools, and services. The plans emphasize development in the neighborhood centers, not on the suburban fringe; this keeps trip distances short and assures local accessibility by foot and bicycle.

Many European cities have implemented people-friendly urban design to create a safe, convenient, and attractive environment that facilitates cycling and walking into city centers. Wide sidewalks and pedestrian plazas can encourage walking, particularly facilities that are well maintained and include attractive paving, comfortable benches, shade trees, outdoor cafes, public art, and fountains. Short city blocks, pedestrian passageways within longer blocks, narrow streets, midblock crosswalks, and median refuge islands facilitate pedestrian access and safety. Pedestrian-scale signage and lighting also are necessary (21).

Some European countries have improved suburban design as well. Many new suburban developments in Denmark, Germany, and the Netherlands

provide safe and convenient pedestrian and cycling access. European suburbs almost always include sidewalks for pedestrians and often bikeways or bike lanes for cyclists.

Training and Regulations

Driver training is much more rigorous in Denmark, Germany, and the Netherlands than in the United States and pays special attention to avoiding collisions with pedestrians and cyclists (12). Traffic education of children is a priority. By the age of 10, most schoolchildren in Denmark, Germany, and the Netherlands have received extensive instruction about safe walking and cycling—not only in traffic regulations but in walking and bicycling defensively, anticipating dangerous situations, and reacting appropriately.

Traffic regulations in Denmark, Germany, and the Netherlands favor pedestrians and bicyclists. When a crash involves children or the elderly, the police and the courts almost always find that the motorist was at fault and should have anticipated irregular moves by children or seniors.

In addition, Danish, German, and Dutch police are strict in ticketing motorists, pedestrians, and cyclists who violate traffic regulations. Penalties for motorists in particular can be high for minor violations. Not stopping for pedestrians at crosswalks is considered a serious offense. Red traffic signals are strictly enforced, and many intersections in Danish, German, and Dutch cities have cameras that automatically photograph cars running red lights and stop signs.

Complementary Policies

These measures make walking and cycling safer and more convenient in Europe. Many other government policies indirectly encourage walking and cycling—for example, road capacity and car parking facilities are far less generous than in American cities. Many Danish, German, and Dutch cities have reduced roadway and parking supply in the past few decades to discourage car use in the city center. These restrictions reduce the relative speed, convenience, and flexibility of car travel compared with walking and cycling.

Moreover, sales taxes on gasoline and on new car purchases, import tariffs, registration fees, license fees, driver training fees, and parking fees are generally much higher in Europe than in the United States (22, 23). The costs of car ownership and use are two to three times higher in Europe as a result and discourage car use, indirectly promoting alternative, less expensive modes, including walking and cycling.



Photo: CURRAN KELLNER

Climate, Topography, and Culture

Climate, topography, and culture also influence cycling and walking levels but are beyond the control of policy makers and planners; nevertheless, inclement weather conditions and hilly topography do not necessarily prevent walking and cycling. For example, the Netherlands and Denmark have high rates of cycling despite rainy climates, and cities such as Helsinki, Finland; Stockholm, Sweden; Montreal, Canada; and Minneapolis, Minnesota, have high cycling rates despite harsh winters. San Francisco, California, and Seattle, Washington, are among the hilliest U.S. cities but also two of the most bike-oriented.

Culture and habit tend to foster cycling in cities and countries with high levels of cycling, but where cycling levels are low, and where cycling is viewed as a fringe mode, culture and habit can deter cycling—especially among noncyclists (24). Nevertheless, culture and habit can change over time.

Some traditionally car-oriented and sprawling U.S. cities have promoted cycling successfully with the same sorts of measures used in Danish, German, and Dutch cities. For example, Portland, Oregon, and Minneapolis raised cycling levels more than five-fold from 1990 to 2010 (10, 11).

History and culture therefore are not insuperable obstacles to increasing walking and cycling but do not guarantee continued high levels of walking and cycling, either, as shown by the sharp declines in active travel in France and the United Kingdom. Policies appear far more important than history and culture in explaining trends in walking and cycling.

Fuel prices and costs of car ownership are far higher in Europe than in the United States and indirectly contribute to higher rates of active transportation.

On-street bike corrals in Portland offered more than 1,425 parking spaces for bikes in 2012.



PHOTO: RAHM BUEHLER

Comprehensive Approach

The infrastructure, programs, and policies needed to increase walking and cycling are well known and tested, with decades of successful experience in many European cities. One key lesson is that no single strategy is sufficient (25). Communities must implement a fully integrated package of measures like those discussed in this article.

A comprehensive approach has a much greater impact on walking and cycling levels than several individual measures that are not coordinated. The impact of any particular measure is enhanced by the synergies with complementary measures in the same package.

Acknowledgment

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Understanding Right-Turn Car–Cycle Conflicts at Intersections Findings from Site-Based and In-Car Observations

DIVERA A. M. TWISK AND NICOLE VAN NES

Most naturalistic driving studies explore safety-critical conditions from the car driver's perspective. This provides a restricted understanding of the interactions between cars and cyclists in relation to the characteristics of intersections. A combination of site-based and in-car observations, therefore, should provide complementary information about these safety-critical interactions. In-vehicle data collection enables the study of an individual's driving behavior over time and in different situations. Site-based observations offer information about the position and speed of other road users, including cyclists and pedestrians, near the participant's vehicle.

The Dutch field trial for PROLOGUE, the European naturalistic driving project, combined in-vehicle and site-based techniques. The trial equipped a four-legged intersection with cameras for site-based observation. The intersection was regulated with traffic lights and had a speed limit of 50 km/h and adjacent cycle paths. Eight cars of drivers who regularly crossed this intersection were equipped with the naturalistic driving technology.

The phasing of the traffic lights generated potential conflicts between right-turning cars and cyclists who continued along the same road, because both receive a green signal almost



The potential conflicts between a right-turning car and bicyclists in a separated bike lane, also signaled, were the subject of a recent Dutch study.

simultaneously. The green light for cyclists starts a few seconds earlier than that for cars; moreover, the stopping line for cyclists extends a few meters ahead of the stopping line for cars.

The study analyzed the driver's glance behavior, speed, and acceleration, as well as the number of conflicts and the postencroachment time, under two conditions: (a) whether the car driver had to wait at the light—that is, did the driver stop or not?—and (b) whether a cyclist was present or not (see Table 1, below left).

The results showed that the glance duration and frequency were higher, and the driving speed

was lower, when the driver stopped than when the driver did not stop. The intersection layout limited the driver's perception of the possible presence of a cyclist more when the car was stopped than when the car was not stopped. The results indicated that vehicle drivers adapted to this limitation by putting more effort into detecting the presence of cyclists in a timely way.

Moreover, car–cyclist conflicts were less frequent and less severe when the car had stopped than when the car had not stopped, because of the lower speed of approach and because the bicyclist had a head start in time and in distance. Combining the findings from in-vehicle and site-based observations revealed the intricate relationship among intersection design, traffic light phasing, and driver–bicyclist interactions and allowed the interactions to be explored.

TABLE 1 Research Design and Dependent Variables of In-Vehicle and Site-Based Observations

	Variables	Car Stopped	Car Not Stopped
Cyclist Present	In-vehicle	Glance behavior Speed Accelerations (longitudinal, lateral)	Glance behavior Speed Accelerations (longitudinal, lateral)
	Site-based	Speed Number of conflicts Postencroachment time (PET)	Speed Number of conflicts PET
No Cyclist Present	In-vehicle	Glance behavior Speed Accelerations (longitudinal, lateral)	Glance behavior Speed Accelerations (longitudinal, lateral)
	Site-based	Speed	Speed

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Transferring European Bicyclist- and Pedestrian-Friendly Designs and Practices to the United States

The Importance of Comprehensive Approaches That Include Evaluation

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The United States often looks to Europe for inspiration to improve bicycling and walking conditions. As indicated in the feature article by Buehler and Pucher (page 34), many factors contribute to higher rates of pedestrian and bicyclist safety and to higher mode shares for walking and biking in European countries. An international scan team assembled by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) concluded that higher levels of walking and biking safety and mobility result from a deliberate combination of policies, funding priorities, and design approaches (1).

U.S. cities that already are in the forefront of best practices—such as New York City; Minneapolis, Minnesota; Portland, Oregon; Seattle, Washington; Cambridge, Massachusetts; and Boulder, Colorado—may find that looking outside the United States for inspiration is a useful exercise. Other U.S. cities in the midst of adopting the policies may gain more local buy-in by pointing to the best practices successfully implemented in leading U.S. cities.

Some European practices are easily transferable and can be implemented immediately in the United States. For example, in the late 1990s, the

Safe Routes to School program took hold in the United States, adapted from similar models first implemented in Denmark in the 1970s and later in other European countries and Australia (2). Implementing foreign policies and design practices in the United States, however, requires a context-sensitive approach that acknowledges differences in urban form, culture, and people's behavior. Objective, scientific evaluations must be used to determine which policies and facility design practices would prove most effective in the United States; studies by Dill et al. (3), Hunter et al. (4), and Fitzpatrick and Park (5) are good examples.

Some measures may work better in certain cities or situations than in others, depending on the location's characteristics. For example, separated bicycle facilities should be evaluated and refined in the context of typical motorist and bicyclist behavior and safety experience in the United States before being widely implemented. Separated on-road bicycle facilities may be effective in Denmark, for example, but that may be partly a product of Danish culture and behavior. Scientific evaluation can help identify these interrelationships and determine how facilities can be adapted to work in new contexts.

Nevertheless, separated bicycle facilities and



PHOTO: SHAWN TURNER, TTI

One of several bike boxes in Portland that were evaluated by Portland State University researchers.

PHOTO: KAY FITZPATRICK, TTI



Safety evaluations by the Texas Transportation Institute provided the evidence to include hybrid pedestrian signals (left, in Austin, Texas) in the Manual on Uniform Traffic Control Devices.

other foreign practices should not be dismissed outright simply because American transportation guidelines, culture, and behavior may differ. Culture and behavior can be changed—although the changes often occur over longer periods than those covered by a typical safety evaluation. For example, separated bicycle facilities may be evaluated at a few trial locations in the United States and may show no clear safety benefits in a typical 1- to 2-year safety evaluation. But in 5 to 10 years, as more bicyclists use separated facilities, and as motorist and bicyclist behavior adapts, safety could improve dramatically. Typical evaluations do not track long-term changes in behavior, however, and would not capture this increase in safety.

Many of the countries visited in the FHWA–AASHTO scan tour have undergone a culture change in the past 40 years that has emphasized walking and bicycling safety and mobility. Changes in culture and behavior can occur, therefore, when fostered by a careful, evidence-based approach.

Providing better facility designs following European models is only one component. In some situations, improvements in street design can improve biking and walking safety and mobility substantially, yet simply installing cycle tracks or pedestrian plazas may not achieve the goal. Improving pedestrian and bicyclist safety and

mobility in the United States requires a comprehensive, five-E approach—a concerted combination of engineering, education, enforcement, encouragement, and evaluation. Many groups must work toward solutions from different approaches, involving the contributions and expertise of policy makers, transportation professionals, law enforcement officials, community members, and more.

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Many factors contribute to an area's overall mobility. New tools are allowing transportation planners to measure an area's multimodal mobility more accurately.

PHOTO: RICHARD LAVMAN

Measuring Multimodal Mobility with the *Highway Capacity Manual 2010* and Other New Analysis Tools

MARTIN GUTTENPLAN AND SELETA REYNOLDS

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The ease of a journey by any mode is the measure of an area's mobility. The factors that determine mobility for cyclists and pedestrians differ from those that affect automobile drivers. For instance, for pedestrians, a high level of mobility may result from frequent crossings, short distances between places, and sidewalks wide enough to walk comfortably side-by-side with other pedestrians. In contrast, well-timed traffic signals and a grid with direct connections contribute to mobility for drivers.

For the past several decades, transportation plan-

ners have had limited tools for measuring mobility. Guided by the *Highway Capacity Manual* (HCM) and its automobile level of service (LOS), by the *Trip Generation Handbook* of the Institute for Transportation Engineers (ITE), and by travel demand forecasting software, analysts have measured the performance of roadways in metropolitan areas almost exclusively in terms of driver delay in the peak hour of travel.

Stakeholders and policy makers have had no way of measuring the performance of nonautomobile modes, and the impacts on pedestrians, bicyclists,

and transit riders in the context of environmental and development review could be framed only in qualitative terms.¹ Since the beginning of the housing boom in the early 2000s, developers have funded and built many transportation improvements in response to transportation impact analyses and development agreements. The guidelines that govern these analyses—as well as environmental regulations such as the California Environmental Quality Act—require quantifiable explanations of the impact of the development and of the improvement that will mitigate the impact.

Because automobile LOS and automobile trip generation have been the only widely accepted analysis tools, and because most agencies focus on impact thresholds that maintain a specified amount of driver delay, funding for improvements mostly benefits drivers. What gets measured gets funded, and without tools to measure the quality of the bicycling, walking, and transit environments, cities have struggled to express the value of these modes.

Fundamental Tensions

At the same time that the equations for automobile LOS and trip generation became more widespread and sophisticated, many jurisdictions began to prepare policies for bicycling and walking. The first bicycle plans appeared in the 1970s, followed by pedestrian plans, and in the past five years, by complete streets policies. Complete streets policies emphasize the routine inclusion of all modes in street design and are now in place in 352 jurisdictions throughout the country.

Practitioners began to confront a fundamental tension between their analysis tools and the new policy directions. Although automobile LOS and trip generation have evolved into microsimulation software that requires complex and subtle inputs such as parking turnover, pedestrian crossing volumes, and transit stops, the focus remains on driver delay and vehicle throughput.

To calculate vehicle LOS at intersections and roadway segments, data are required for peak-hour vehicle volume, roadway geometrics, and traffic signal timing. Almost every agency has a threshold for an acceptable vehicle LOS, which improves as driver delay decreases. Increasing the road capacity—that is, adding more lanes—and increasing the speed with fewer intersections are two primary ways to decrease driver delay. Planners and engineers therefore could increase the size of the roadway or limit choke points by adding exclusive turn lanes or by increasing the

¹ Some notable exceptions include analyses by the Florida Department of Transportation; the City of Charlotte, North Carolina; and the City of Fort Collins, Denver.

PHOTO: JESSICA DOWNING, APHA



Bicycle signals and lanes, walking paths, and other pedestrian- and bike-friendly infrastructure contribute to a sustainable transportation system.

amount of green time for major roads.

For local streets, the unintended consequences were unnecessarily large roads, unsafe speeds, and ultimately more congestion. Transportation analysis focuses on accommodating the amount of traffic expected during the peak hour—or even the peak 15 minutes—of a typical weekday. The approach may ensure that congestion is manageable during that window of time but also can create a street that is too wide for most of the day.

Too many lanes on a street can cause wide gaps between cars, so that faster drivers can easily pass others on the road. Speeding has consequences for safety. Wide roads allowing drivers to travel at 35 or 40 mph or faster may not be desirable in town centers, residential areas, or anywhere that pedestrians and cyclists travel. A recent study from the University of Toronto indicates that vehicle miles traveled have increased in almost exact proportion to increased capacity; this suggests that in the long term the traditional approach is not successful at achieving the primary goal of reducing congestion (1).

Three Goals

To match agency policies with transportation analysis, planners and engineers needed a set of tools to balance the guidance of vehicle LOS and trip generation. The new tools would address three primary goals:

- ◆ *Improving traffic safety.* The improvements that reduce driver delay usually increase pedestrian crossing distance by adding vehicle lanes or increasing the speed of traffic at conflict points such as right turns; this increases pedestrian exposure and delays. The speed of traffic, the length of pedestrian exposure, and the increase of conflicts contribute to the severity of vehicle–pedestrian crashes. In addition, pedestrians are more likely to engage in risky crossing behavior to avoid long waits.

◆ *Boosting economic drivers.* Customers who make a trip by bicycle or on foot spend less per retail visit but visit more frequently, so that they spend more annually (see the sidebar, Exploring the Relationship Between Consumer Behavior and Mode Choice, page 29) (2, 3). Many cities have discovered that the retail districts with the slowest speeds and highest congestion are often the most successful.

◆ *Improving livability and sustainability.* Increases in walkability result in increases in property values, because walkable, bikeable neighborhoods are attractive to a range of people, including older adults who may not drive, young families who value compact neighborhoods, and millennials, the generation born in the early 1980s (4). Elements that contribute to comfort for bicyclists and pedestrians include buffers from traffic, such as parking lanes, bicycle lanes, street trees, and wide sidewalks; slower 85th percentile vehicle speeds of 25 mph or less; and lower volumes of traffic. Keys to sustainability include a transportation system that encourages low-impact modes such as bicycling, walking, transit, and car-pooling; that offers opportunities for physical activity, contributing to the long-term health of residents; and that is easy to maintain.

Developing New Tools

Beginning in 1985, the HCM included measures for pedestrian LOS, but the underlying assumption was that reduced delay was as important to pedestrians as to drivers. Therefore, a sidewalk with few people received a high LOS, but a bustling, crowded retail district earned a failure rating. In practice, most planners have applied this tool to determine walkway requirements near large attractions such as stadiums, theme parks, and major central business districts.

To mainstream the planning, design, and opera-

tions of multimodal transportation facilities serving bicycle, pedestrian, transit, and automobile traffic, the National Cooperative Highway Research Program (NCHRP) and state departments of transportation (DOTs) embarked on a decade of research that produced measures and thresholds for all modes, with direct input from the traveling public. Videos from the traveler's perspective were calibrated to in-field surveys and were shown to a national sample to obtain clear guidance on performance measures and their relative weighting. Regression and ordered probit analyses were used to develop equations that weighted multiple variables to reflect the user's satisfaction with travel experience across modes.

NCHRP Report 616, *Multimodal Level of Service Analysis for Urban Streets*,² and the users guide, NCHRP Web-Only Document 128,³ summarize the work, which was field-tested and incorporated into the HCM 2010. The methods can be applied to compare street design alternatives and to measure a network's suitability for various modes. Policymakers must ensure that the tools can be used to meet expanded goals for safety, mobility, and access for all users.

Integrated Multimodal LOS

Each modal methodology reflects the state of the art in LOS analysis procedures, and the HCM 2010 integrates the analysis of all four modes, allowing for a calibrated "what if" analysis across the modes. An analyst can measure the effects of transportation projects on all modes and make adjustments to meet policy objectives.

The following descriptions focus on a roadway segment and transit route in an urban setting. The HCM 2010 also contains multimodal procedures to address intersections, midblock pedestrian crossings, shared-use trails, and rural highways.

Pedestrian LOS

Research has linked the pedestrian's degree of exposure to motorized traffic to the level of satisfaction with walking in a nonmajor metropolitan central business district (5). Statistically significant in this portion of the pedestrian LOS procedure are

- ◆ The presence and width of a sidewalk;
- ◆ The lateral separation of pedestrians and motorized vehicles;
- ◆ The presence of barriers and buffers—such as parked cars and trees; and
- ◆ The volume and speed of motorized vehicles.

² <http://www.trb.org/Publications/Blurbs/160228.aspx>.

³ <http://www.trb.org/Publications/Blurbs/160021.aspx>.

Elements such as the level of separation between pedestrians and cars are part of the pedestrian level-of-service (LOS) methodology.



PHOTO: STEVE PINKUS

In addition to this exposure-based methodology, the HCM 2010 retains the previous methodologies for intersection crossings and sidewalk capacities, as well as an intersection LOS and guidance for the application of the appropriate pedestrian LOS module.

Bicycle LOS

Research showed that when bicycle facility crowding and delay were not an issue, the level of satisfaction with bicycling was linked to the degree of exposure to motorized traffic (6). Statistically significant to this portion of the bicycle LOS model are

- ◆ The proximity of bicyclists to motorized vehicles;
- ◆ The presence of a paved shoulder or marked bicycle lane;
- ◆ The volume and speed of motorized vehicles, and the type of traffic—that is, the percentage of trucks;
- ◆ The condition of the pavement; and
- ◆ The availability of on-street parking,

In addition to the exposure-based model, the HCM 2010 contains methodologies for bicycle facility capacities, intersection LOS, and driveway conflicts. A chapter covers separated bicycle and pedestrian facilities, such as shared-use paths.

Transit LOS

The HCM 2010 provides an equivalent methodology for transit LOS. A good walking environment must be integrated into the transportation system—public transportation and a walkable design around stops contribute to the multimodal potential of an urban area.

Building on methodologies in the *Transit Capacity and Quality of Service Manual, 2nd Edition* (7), transit LOS offers a single measure to facilitate comparisons with other modes, is compatible with the HCM LOS thresholds tied to user satisfaction, and uses the same LOS grades. The transit LOS inputs include factors that (a) are known to influence ridership, (b) are inside the right-of-way, and (c) can be affected by agency actions:

- ◆ Frequency—that is, the headways or transit vehicles per hour;
- ◆ Speed or travel time;
- ◆ Reliability or excess wait time;
- ◆ Stop amenities;
- ◆ Crowding or perceived travel time adjustments; and
- ◆ Pedestrian LOS.



PHOTO: RICHARD LAYMAN

The factors are weighted according to results from on-board surveys. For instance, walk-to-the-stop satisfaction accounted for 11 percent of the overall level of satisfaction.

The distance between bicyclists and motorized vehicles is a statistically significant element of the bicycle LOS model.

Putting It All Together

Multimodal LOS is the degree to which the urban street design and operations meet the needs of each type of user. An analysis yields four LOS grades for each street: automobile LOS, transit LOS, bicycle LOS, and pedestrian LOS. This generates a report card for how well the street meets the needs of its users. These grades are reported separately, because trip purpose, length, and expectation are different for each mode.

An agency can set desired targets or standards to be met by each mode on the facility. This allows the tailoring of a design to the street's purpose, functional class, surrounding land use, and other specific features.

Factors known to influence transit ridership include wait time, crowding, and transit vehicle frequency.



PHOTO: JENNIFER WEEKS

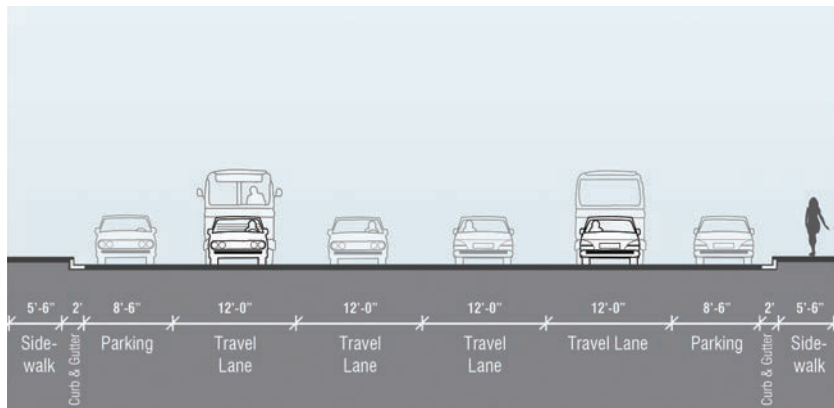


FIGURE 1 Existing 80-ft right-of-way: four lanes with parking.

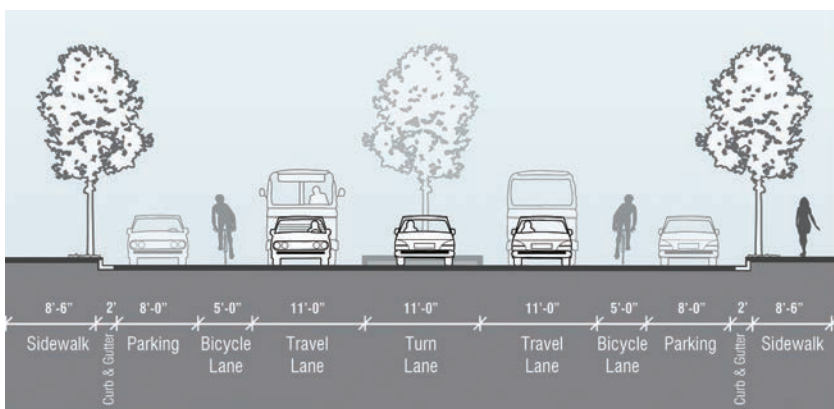


FIGURE 2 Two lanes with median-turn lane, bicycle lanes, and parking.

Complete Streets Analysis

The HCM 2010 methodologies can be used to determine the LOS impacts of converting a conventional street to a complete street for all users. The following example presents a LOS analysis of a proposed complete street conversion using the HCM 2010 methodology from Chapter 17, Urban Streets.

Existing conditions: Four-lane urban undivided arterial street with no dedicated turn lanes, and a 35-mph speed limit with sidewalks on both sides (see Figure 1, above).

Actions: Eliminate one lane in each direction for automobiles but create space for exclusive left-turn lanes at signalized intersections and install a median. Narrow the lane widths to provide space for pedestrian and bicycle features.

Results: Slowed automobiles, slowed buses, but minimal effect on automobile capacity because of the added turn lanes. More automobiles are now closer to bikes and pedestrians, and this has a negative impact on bike and pedestrian LOS; but the reduced speeds and the shortened midblock crossing distances for pedestrians partially offset this.

Action: Add bike lane.

Result: Greatly improved bike LOS; moderately improved pedestrian LOS by further separating pedestrians from automobiles.

Actions: Widen sidewalks to 9 feet. Add street trees as a landscaped buffer between the sidewalk and the roadway.

Result: Greatly improved pedestrian LOS because of the landscaped buffer. The improved pedestrian LOS counterbalances the slowing of transit speeds caused by lane reductions (see Figure 2, left).

The scores for the example by mode are shown in the table below.

	Before	After
Automobile	D	E
Bicycle	E	C
Pedestrian	C	B
Transit	D	D

Other Tools: Case Study

The inclusion of the multimodal LOS tool in the HCM 2010 raises several questions for agencies implementing complete streets policies:

- ◆ What is an acceptable bicycle, pedestrian, or transit LOS?
- ◆ Is the LOS on a commercial collector equivalent to that of an industrial arterial?
- ◆ What is the threshold for impacts in development and environmental review?
- ◆ What types of mitigations are available?

Complicating these questions is the amount of data required to calculate the multimodal LOS. Agencies setting new analysis guidelines and thresholds can use other tools and methods to incorporate bicyclists, pedestrians, and transit riders into a transportation analysis. The following case study describes the approach taken by the City of Seattle DOT in the environmental impact statement (EIS) for the South Lake Union Height and Density Study.

South Lake Union is a rapidly developing neighborhood immediately adjacent to Seattle’s dense downtown core—a high-density, mixed-use development. Instead of creating new thresholds for multimodal LOS, the city leveraged a new trip generation approach to demonstrate that improved bicycle, pedestrian, and transit networks can effectively mitigate vehicle congestion.

Trip Generation Rates

Traditional trip generation methodologies often use the ITE Trip Generation rates, a nationally recognized standard developed from suburban locations with

minimal multimodal transportation options (8). The estimates are often adjusted by factoring the results with mode split data from the city's travel demand model, the U.S. Census Bureau, or engineering judgment. These methods can account for the high share of nonautomobile modes across an entire neighborhood or city but have limited ability to incorporate shifts in mode choice caused by major land use changes—for example, in a confined area such as South Lake Union—for the following reasons:

- ◆ Typical mode split adjustments assume that current trends will continue.

- ◆ Typical mode split adjustments have limited responsiveness to changes in the land use and the built environment, such as increased density or an increased mix of uses, or to changes in the transportation system, such as improved pedestrian and bicycle connectivity or improved transit service.

- ◆ Mode split data often derive from U.S. Census Bureau reports; as time passes and development patterns and socioeconomic conditions change, the estimates may no longer be applicable.

Mixed-Use Development Model

In the EIS, Seattle DOT used an innovative trip generation analysis technique, known as the mixed-use development (MXD) model,⁴ to analyze three land use scenarios. The MXD model focuses on the relationship between travel and the built environment, supplementing conventional trip generation methods to capture effects related to built environment variables known as the D's: density, diversity of land uses, destinations or accessibility, development scale, design for pedestrians and bicycles, distance to transit services, and demographics (9).

The proposed height and density alternatives in the South Lake Union area incorporate changes in several of these variables that could influence the neighborhood's travel characteristics. Projects with higher densities, a rich variety of compatible land uses close to one another, and high-quality bicycle, pedestrian, and transit environments have a lower vehicle trip generation rate than projects in suburban environments. Travelers have more choices of travel mode and of the distances for travel to various destinations. The effect intensifies for projects in urban areas. This method avoids overestimating the num-

⁴ The research was commissioned by the U.S. Environmental Protection Agency (EPA) and the San Diego Association of Governments. Reid Ewing, University of Utah, and Jerry Walters, Fehr & Peers, led the development of the MXD trip generation equation, with guidance and contributions from Michael Greenwald, Ming Zhang, Mark Feldman, Robert Cervero, Lawrence Frank, and John Thomas.

PHOTO: CITY OF SEATTLE



View of South Lake Union, showing downtown Seattle on the right and Lake Union on the left.

ber of vehicle trips that urban infill projects generate and provides a more reasonable picture of how travel characteristics change over time.⁵

Addressing Impacts

After the trip generation was completed for each scenario, a mitigation strategy was assembled to address the identified traffic impacts. The mitigation strategies can increase the supply of facilities, usually by increasing the roadway capacity, or they can decrease the demand for roadway capacity by reducing the number and length of vehicle trips.

The MXD trip generation methodology measures the reduction in demand that results from improving the bicycle, transit, and pedestrian environment. Other proven strategies to decrease vehicle demand include incentives to take transit—such as employer-subsidized transit passes—and disincentives to drive—such as parking management strategies.

From both a policy and a feasibility perspective, increasing the roadway capacity in downtown Seat-

⁵ The MXD model was developed in cooperation with EPA and ITE. More than 200 mixed-use development sites across the United States were surveyed, and the model was validated with data from 16 independent mixed-use sites.

This separated bike path was added to a motor vehicle roadway in Santa Barbara, California. A holistic approach to measuring multimodal mobility includes nonmotorized vehicles in its analysis.

PHOTO: COURTESY DIETZ



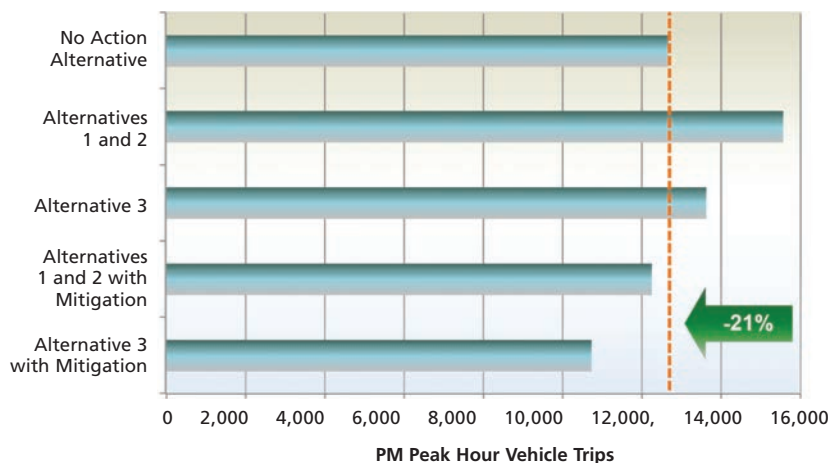


FIGURE 3 Vehicle trip generation: land use alternatives with and without mitigations. (Graphic: Fehr & Peers)

tle is undesirable and cost-prohibitive. Therefore, the mitigation strategy for South Lake Union focused on decreasing the number of vehicle trips and maximizing the number of bicycle, pedestrian, and transit trips, by making these modes quicker, cheaper, and more convenient.

Combining Measures

Four packages of potential mitigation measures were developed for the South Lake Union area: bicycle and pedestrian system improvements, travel demand management (TDM) measures, transit system enhancements, and roadway capacity enhancements.

The output from the MXD model indicated that the proposed bicycle and pedestrian mitigation measures would reduce vehicle trip generation by approximately 7 percent. The MXD trip generation tool predicts mode share primarily from information about land use and demographics and does not take additional TDM measures into account.

An analytical method published by the California Air Pollution Control Officers Association (10) projected that the TDM strategies would reduce vehicle trip generation by 15 percent. Combining the two measures would reduce vehicle trip generation by approximately 21 percent for each land use alternative⁶ (see Figure 3, above).

The EIS identifies a set of mitigation measures to improve the bicycle, pedestrian, and transit environment and to establish parking management and TDM incentives. The City of Seattle has a voluntary fee program that allows developers to contribute to these improvements without having to implement their own mitigations of impacts.

⁶ The combined effects of two trip reduction strategies are not additive, because the two strategies overlap—for example, increased transit use can result from an improved pedestrian environment and from employer-paid transit passes.

Holistic Approach

For local streets, the unintended consequences of applying tools meant to measure automobile mobility are clear: unnecessarily large roads, unsafe speeds, and ultimately, more congestion. To match their agency's policies to transportation analysis, planners and engineers now have a set of tools to act as a balance against vehicle LOS and trip generation.

The benefits of this holistic approach are to reduce traffic-related injuries and fatalities, to boost economic drivers such as home values and retail receipts, and to improve the overall livability and sustainability of communities. The new tools challenge agencies to take a fresh look at the measures of mobility for all.

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Safety Effectiveness of the HAWK or Pedestrian Hybrid Beacon

KAY FITZPATRICK

The author is Senior Research Engineer, Texas Transportation Institute, Texas A&M University, College Station, and chair of the TRB Operational Effects of Geometrics Committee.

The number of people who choose to walk or to ride a bicycle instead of driving has increased in recent years, because of the cost of transportation, the desire for healthier lifestyles, and for other reasons. Pedestrians and bicyclists, however, encounter serious risks—a large number are killed in traffic accidents every year in the United States.

Problem

Many roadway crossing treatments are available to address concerns about the safety of pedestrians (1), but only a few are appropriate for high-speed conditions or for wide crossings. In the late 1990s, Richard Nassi, then transportation administrator for the City of Tucson, Arizona, developed the High-Intensity Activated Crosswalk, or HAWK, pedestrian beacon; the 2009 *Manual on Uniform Traffic Control Devices* (MUTCD) calls the device the pedestrian hybrid beacon (2).

The HAWK is designed to assist in pedestrian crossings, especially at major arterials with minor street intersections (3). The HAWK stops vehicles so that pedestrians can cross the roadway and then permits the drivers to proceed as soon as the pedestrians have passed. Because signal control on a side

street could encourage unwanted additional traffic through the neighborhood, the HAWK was designed with stop control on the side streets.

At a HAWK crossing, drivers receive multiple cues for the possible presence of a pedestrian. The cues include

- ◆ A unique beacon configuration—two red lenses over a single yellow lens;
- ◆ High-visibility crosswalk markings, in a ladder style distinct from two transverse white lines;
- ◆ A stop bar approximately 50 ft from the crosswalk;
- ◆ Solid lane lines, 8 in. wide, between through-travel lanes; and
- ◆ Signs—sometimes illuminated—that read “Pedestrian Crossing” or “School Warning.”

When activated, the HAWK provides a red indication requiring drivers to stop for pedestrians crossing the major roadway. In Tucson, the HAWKs reduce pedestrian waiting time with “hot button” or instantaneous service. The HAWK can be designed to provide synchronization of signals on the arterial street.

PHOTO: MICHAEL J. CYNIECKI



Example of a HAWK treatment in Tucson, Arizona. [Note: The pedestrian is Richard Nassi, developer of the HAWK.]



PHOTO: MICHAEL J. CYRECKI

Anecdotal experience indicates that the HAWK device improves safety. A comprehensive evaluation was needed, however, to establish the beacon's effectiveness.

Solution

The Federal Highway Administration (FHWA) sponsored a study that used a before-and-after, empirical Bayes approach to evaluate the safety effectiveness of the HAWK device (4, 5). The empirical Bayes method is a statistical approach that determines the effectiveness of a treatment from external factors—such as increases in traffic volumes—and from the randomness of crashes. Data were collected on crashes and traffic volume at 102 unsignalized intersections that served as the control sites and at 21 HAWK sites, typically 3 years before and 3 years after the installation. The number of observed crashes that occurred after the installation of a HAWK was then compared with the predicted number of crashes if the treatment had not been installed.

The researchers found the following changes in crashes after installation of the HAWK:

- ◆ A 69 percent reduction in crashes involving pedestrians, statistically significant at a 95 percent confidence level;
- ◆ A 15 percent reduction in severe crashes that result in injury; this was not statistically significant at a 95 percent confidence level, probably because of the low number of these types of crashes; and
- ◆ A 29 percent reduction in total crashes, statistically significant at a 95 percent confidence level.

Application

The 2009 MUTCD provides the information needed to make decisions about the installation and operation of pedestrian hybrid beacons. According to the guidance, “When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then . . . the pedestrian hybrid beacon should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs” (2, Section 4F.02).

All 21 HAWKs in the safety study were located at a minor intersection, with the minor street controlled by a stop sign, or at a major driveway controlled by a stop sign. In June 2011, the National Committee on Uniform Traffic Control Devices, which proposes revisions and interpretations of the MUTCD, recommended removal of the directive specifying installation at a 100-ft distance.

Benefit

This study showed that the HAWK beacons provided

significant reductions in total crashes and in crashes involving pedestrians. Compared with a traffic signal, the HAWK beacon provides faster service to pedestrians and less delay to motorists—drivers are allowed to proceed on the flashing red after pedestrians have crossed their half of the roadway; moreover, the beacon costs about half as much as a traffic signal. As a result, the pedestrian hybrid beacon is rapidly gaining acceptance; in addition to Tucson, more than 14 cities have installed the device. The Tucson area currently has more than 100 installations.

The pedestrian hybrid beacon is a proven countermeasure that increases pedestrian safety at crossings with high volumes, that have wide streets, or that have high operating speeds.

For more information, contact Kay Fitzpatrick, Senior Research Engineer, Texas Transportation Institute, State Headquarters Research Building, Texas A&M University Research Park, College Station, TX 77843-3135; phone 979-845-7321; kfitzpatrick@tamu.edu.

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Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).

CALENDAR

TRB Meetings 2012

July		17–19 10th National Conference on Access Management* Dallas, Texas	28–30 Data Analysis Working Group Forum on Pavement Performance Data Analysis Auckland, New Zealand
8–11 TRB Planning Committee Summer Meeting Irvine, California		17 Economic Census: Uses for the Transportation Community Workshop Washington, D.C.	September
8–11 Waste Management and Resource Efficiency in Transportation Summer Workshop Madison, Wisconsin		25–27 Workshop on the Future of Road Vehicle Automation Irvine, California	10–12 2nd International Conference on Transportation Geotechnics* Sapporo, Hokkaido, Japan
8–12 6th International Conference on Bridge Maintenance, Safety, and Management* Lake Como, Italy		29–Aug 2 TRB–AASHTO Joint Roadside Safety Meeting Irvine, California	12–13 International Transportation Research Information Access Workshop Washington, D.C.
8–12 10th International Conference on Concrete Pavements* Quebec City, Quebec, Canada	August		12–14 13th National Conference on Transportation Planning for Small and Medium-Sized Communities Big Sky, Montana
11 Measuring the Transportation System from a Supply Chain Perspective Irvine, California	3–6 Chinese Overseas Transportation Association International Conference of Transportation Professionals* Beijing, China		17–21 13th International Conference on Mobility and Transport for Elderly and Disabled People (TRANSED)* New Delhi, India
12 7th SHRP 2 Safety Research Symposium Washington, D.C.	20–22 5th National Bus Rapid Transit Conference Las Vegas, Nevada		18–21 International Conference on Long-Life Concrete Pavements* Seattle, Washington
12–13 Better Safety Results Through Information Sharing Workshop Irvine, California	20–24 Transportation Hazards and Security Summit and Peer Exchange Irvine, California		19–21 4th International Conference on Accelerated Pavement Testing* Davis, California
14–19 13th AASHTO–TRB Maintenance Management Conference* Seattle, Washington	28–30 Annual Harbor Safety Committee and Area Maritime Security Committee Conference* Pittsburgh, Pennsylvania		19–22 7th Symposium on Pavement Surface Characteristics* Norfolk, Virginia
15–18 51st Annual Workshop on Transportation Law New Orleans, Louisiana	28–30 Seventh International Conference on Maintenance and Rehabilitation of Pavements and Technological Control* Auckland, New Zealand		October
15–19 Statewide Conference on Heritage* Lancaster, Pennsylvania			8–10 European Transport Conference* Glasgow, Scotland

Additional information on TRB meetings, including calls for abstracts, meeting registration, and hotel reservations, is available at www.TRB.org/calendar. To reach the TRB staff contacts, telephone 202-334-2934, fax 202-334-2003, or e-mail TRBMeetings@nas.edu. Meetings listed without a TRB staff contact have direct links from the TRB calendar web page.

*TRB is cosponsor of the meeting.

Walter H. Kraft

Vanasse, Hangen, Brustlin, Inc.

At the beginning of his career, Walter H. Kraft chose traffic engineering from among a variety of professional directions, wanting to work in a field that had a direct impact on the everyday lives of citizens. Fifty years later, he continues to enhance travel through his work in transportation management and intelligent transportation systems (ITS).

Kraft graduated from the Newark College of Engineering (NCE) in 1962 and began working at Edwards and Kelcey, Inc., as assistant engineer. In his more than 30 years at the firm, Kraft held the positions of senior vice president, director, and partner; he continued to expand his professional knowledge, earning a master's degree in civil engineering from NCE in



“Without research, our methods and capabilities would remain static, and we would not be able to improve them.”

1965. In the years that followed, Kraft also played a major role in the development of NCE's graduate transportation program and jointly initiated a national focus on bicycle and pedestrian facility planning, design, and implementation. In 1975, Kraft received a Doctor of Engineering Science degree from the New Jersey Institute of Technology. While at Edwards and Kelcey, Inc., he led research projects such as traffic signal maintenance and infrastructure redevelopment; his work in traffic signal maintenance led to a training course and state guidelines in Pennsylvania and Maine. He also coauthored and produced traffic signal maintenance manuals for the Institute of Transportation Engineers (ITE).

In 1994, Kraft joined Parsons Brinckerhoff, harnessing the emerging power of computer technology to advocate and implement ITS in traffic management. He continues to be a supporter of technology, noting that it can help “expand our knowledge base and understand concepts that we could not previously, since we did not have the necessary tools.” After retiring from Parsons Brinckerhoff, he joined Eng-Wong, Taub & Associates in 2006 as the company's first executive technical director; since the firm's merger with Vanasse, Hangen, Brustlin, Inc., in 2011, he has served as principal.

He is active in transportation education, and has served as

adjunct professor at NCE and the Polytechnic Institute of New York University. He was an instructor at St. John's University, Carnegie Mellon University, and the Transport Agency of Hong Kong, and he also led courses through ITE.

“Research provides the basis for our profession,” Kraft affirms. “Without research, our methods and capabilities would remain static, and we would not be able to improve them.” Some of his first research involved trip generation at a large shopping center. Kraft and his associates used that information, as well as the gross leasable area, to develop peak-hour trip generation rates. In 1971, he coauthored a National Cooperative Highway Research Program report on optimizing flow in existing street networks. He credits that research with giving him an understanding of valuable basic traffic engineering concepts.

Kraft conducted more research while attending meetings across the country for the American Society of Civil Engineers (ASCE), counting passengers as they entered and exited street transit vehicles. “Using regression analysis to develop relationships, I was able to simulate various combinations of fare payment systems and their effects on transit operations,” he notes. This research was included in the 1985 edition of the *Highway Capacity Manual*.

Kraft's current projects include analyzing accident and travel time data to assist operations at transportation management centers in New York City and Westchester County, with a particular focus on defining recovery time at incident locations for the New York State Department of Transportation (DOT). He is spearheading the development and implementation of performance measures for transportation management and is guiding efforts to improve the safety of all responders to traffic incident management. Kraft also completed an analysis of the effects of weather on roadway travel times in Long Island, New York, that could help travelers predict travel times for future trips.

Kraft observes that his longtime involvement in organizations such as TRB, ITE, and ASCE has cultivated his career-long interest in research. He first joined the TRB Intermodal Transfer Facilities Committee as secretary in 1972, and in 1980 became its chair. He also has served on the Highway Capacity and Quality of Service Committee, the Transportation Education and Training Committee, the Operations Section, and currently is a member of the Freeway Operations Committee. From 2006 to 2012, he chaired the Regional Transportation Systems Management and Operations Committee. Kraft also is past international president and honorary member of ITE.

New transportation professionals should embrace technology and should use research to test current knowledge, Kraft urges. “Realize that the basis of our profession evolves over time as research provides a new or greater understanding. Be a part of the evolution.”

Charles V. Zegeer

University of North Carolina Highway Safety Research Center

Associate director for engineering and planning at the University of North Carolina Highway Safety Research Center (HSRC), Charles V. Zegeer has been a longtime leader in pedestrian and bicycle safety research. For the past 12 years, he has served as director of the Pedestrian and Bicycle Information Center (PBIC), a national clearinghouse for information on bicycle and pedestrian issues. His research areas have included pedestrian and bicyclist safety, countermeasure effectiveness, highway safety programs, geometric design, traffic control devices, and traffic operations. Zegeer earned a bachelor's degree from Virginia Tech and a master's degree in civil engineering with a traffic and transportation specialty from the University of Kentucky.



"Safety research has established that many types of roadway enhancements, when applied properly, can jointly improve motorist and pedestrian safety."

For Zegeer, communication and consensus are key in effectively addressing pedestrian and bicycle safety problems. "Simply recommending an effective solution, without gaining broader support, rarely leads to a successful outcome," he observes. "The professionals who typically are the most successful in getting things done are those who have learned how to work well with a broad array of people—even with different perspectives and opinions in the early stages of a project."

Zegeer's extensive background in pedestrian and bicycle safety translated easily into the leadership position at PBIC. The center, funded primarily by the Federal Highway Administration (FHWA), offers resources for creating safe places for walking and bicycling as well as information on pedestrian- and bicycling-related safety, health, planning, engineering, policy, education, enforcement, and accessibility issues. Zegeer and his staff manage the operation of a national pedestrian and bicycle clearinghouse, compiling and updating a compendium of case studies to document best practices, as well as providing personal and online technical expertise. PBIC also advances the development of educational programs on bicycling and walking—from webinar training to postgraduate-level courses—and disseminates techniques and strategies for improving bicycle and pedestrian safety, such as the Walk Friendly Communities program.

In transportation planning, agencies must consider the needs of nonmotorized road users and motorists together—to the benefit of all users. "Safety research has established that many types of roadway enhancements, when applied properly, can jointly improve motorist and pedestrian safety," Zegeer points out. For example, raised medians on high-volume, multilane arterial roads reduce crashes that involve crossing pedestrians, as well as head-on car collisions; adding paved shoulders to suburban and rural roads can reduce run-off-road car crashes and provide a separate space for pedestrians and bicyclists.

Zegeer also is the technical principal investigator for an ongoing FHWA project developing and promoting pedestrian safety action plans. With a goal of reducing pedestrian-related traffic deaths and injuries across the country by focusing on a group of high-risk cities and states, the project analyzes pedestrian crashes on a macro level, conducts training, and has produced a best practices guide and training modules for localities.

Safety research can help practitioners to discern best engineering treatments for different roads. "Just as an improperly prescribed medication may cause a patient more harm than good, an incorrectly used engineering measure can result in increases in traffic deaths and injuries," Zegeer comments. "It is important that we have the best information available, the result of properly conducted safety research."

Zegeer also works with a team of experts to revise pedestrian and bicycle safety materials for the FHWA Office of Safety, including *Pedsafe*, *Bikesafe*, *Pedestrian Safer Journey*, *Bicycle Safer Journey*, and *Resident's Guide for Creating Safe and Walkable Communities*. As principal investigator for the project, Zegeer aims to disseminate information on best practices and to develop better safety materials for users. He currently is updating *Pedsafe* to include emerging pedestrian crossing enhancements.

For new professionals in pedestrian and bicycle safety engineering and planning, Zegeer notes the importance of developing a network of resources and of examining a broad array of research. "Weigh the impact of your decisions on all types of road users," he recommends.

Zegeer also has been active in general roadway safety research, including safety of horizontal curves and roadway and roadside design. Some of his research has been incorporated into the *Manual on Uniform Traffic Control Devices* and appears in the American Association of State Highway and Transportation Officials' *Highway Safety Manual* and *A Policy on Geometric Design of Highways and Streets*.

A registered professional engineer, Zegeer has served on the Pedestrians Committee at TRB for more than 30 years.

Enhancing Concrete Pavement Sustainability

PETER TAYLOR, TOM VAN DAM, AND MARCIA BRINK

Sustainability is one of the major challenges facing the concrete pavement industry today. The National Concrete Pavement Technology Center at Iowa State University recently released *Sustainable Concrete Pavements: A Manual of Practice*, reimagining how pavements are designed, built, and maintained and outlining best practices and solutions for sustainable pavements. The manual addresses sustainability issues specific to the stages of the pavement life cycle—design, materials selection, construction, preservation, rehabilitation, and end-of-life recycling. Also discussed are special considerations related to urban environments and assessment and rating systems for pavement sustainability.

Pavements in the United States are deteriorating with age; one-third of the road system—about 1.3 million miles—is in poor condition or worse. As traffic volumes and loads increase, placing stress on pavements and producing traffic congestion, roadway budgets are falling short of maintenance and improvement funds by approximately \$116 billion per year. Traditional concrete-based solutions are no longer affordable, desirable, or efficient for repairing or replacing thousands of lane miles of deteriorated pavements.

Sustainable concrete-based solutions include alternative aggregates, such as recycled concrete for use in new concrete and recycled-in-place

concrete for base or subbase. Portland cement alternatives include fly ash, slag cement, and other industry by-products that can help fine-tune characteristics such as concrete durability or setting time, while significantly improving the pavement's environmental footprint. The variety of sustainable pavement designs and construction techniques includes precast, early-opening-to-traffic, and roller-compacted concrete; next-generation surface texturing; and thin concrete slabs with short joint spacings.

Two-lift concrete pavement systems are being demonstrated, optimizing the

use of recycled and industrial byproduct materials in the thicker, lower lift and constructing a thinner top lift with an ultradurable wearing surface. Photocatalytic cements and coatings are being tested to provide additional concrete surface reflectivity and counteract the effects of nitrogen oxide and of volatile organic compounds from vehicle exhaust and drip. Other materials and techniques in development include incorporating recycled asphalt pavement as aggregate in concrete mixtures and systems for bubbling cement plant exhaust gases through pools to nurture carbon dioxide-ingesting algae—which then can be dried and burned in a kiln as fuel. Further advancements, including smart pavement systems, are expected from subsequent research.

To access the manual, visit www.cptechcenter.org/publications/Sustainable_Concrete_Pavement_508.pdf. For information about the availability of printed copies, contact Denise Wagner, 515-294-5798, dfwagner@iastate.edu.

Taylor is Associate Director, National Center for Concrete Pavement Technology, Iowa State University, Ames; Van Dam is Principal Engineer, CTLGroup; and Brink is Senior Editor, Institute for Transportation, Iowa State University.



Photo: Iowa State University

A thin, optimized surface lift is placed on a two-lift concrete pavement demonstration project on I-70 in Kansas.



FIGURE 1 Sustainable pavement solutions support and balance economic growth, social needs, and environmental concerns.

Identifying Priorities for Freight Research

After considering proposals from its research advisory committee, staff, and members of the public, the American Transportation Research Institute (ATRI) has identified seven primary research topics for 2012. These include the impacts of the proposed 34-hour restart provision, one of the hours-of-service (HOS) regulations from the Federal Motor Carrier Safety Administration; the efficacy of scoring formulas and account-



Photo: Tom Saunders, Virginia DOT

ability; analyzing safety trends by age group; the cost of congestion for the trucking industry; shipper involvement in HOS compliance; speed limits and highway safety; and comparing roll stability control and electronic stability control. ATRI conducts transportation research with a focus on the trucking industry.

For more information, visit www.atri-online.org.

Trucks climbing lanes during construction on I-81 in Virginia. Highway safety is one of the topics of research proposed by ATRI for 2012.

Study Compares Highway Financing Methods

Public-private partnership (PPP) financing of highway projects can save a marginal amount of time and money compared with the traditional design-bid-build approach, according to a study by the U.S. Congressional Budget Office (CBO). For both funding mechanisms, taxpayers and road users remain the ultimate source of money for highways, according to CBO.

Privately financing a highway project costs about the same as financing it publicly, once federal government financial transfers to states and localities and the costs associated with the risk of losses—which taxpayers ultimately bear—are considered. The cost savings from PPPs generally result from incentives and conditions established in a project's contract. CBO notes that data on PPP highway projects are relatively limited, however.

Although PPPs do not constitute a significant percentage of highway projects, use of the strategy is increasing; according to one estimate, between 30 and 40 percent of all new miles of urban limited-access highways built between 1996 and 2006 were PPPs. The CBO analysis points out that the financing mechanism of a project may affect who bears its costs: using bonds with federal tax-exempt interest or with funds from federal government subsidies shifts costs from state taxpayers to federal taxpayers but does not reduce the total cost of the project.

In most cases, the investors in PPP projects overestimated toll receipts from the completed roads, according to the report. Recent partnership agreements for highway projects have buffered private partners' exposure to the risk of lower-than-expected toll revenues by guaranteeing payments from public partners and have reduced private partners' debt-service payments.



PHOTO: NORTH TARRANT EXPRESS

Construction on the North Tarrant Express Lanes in Texas is scheduled to be completed in 2015. The project is one of many PPPs in the United States.

The CBO analysis notes that only a few studies have focused on the design and construction of a private highway project including operations and maintenance; these studies found that design-build PPP slightly reduced the cost of building highways and slightly reduced the amount of time required to complete the projects. For projects with contracts for more than \$100 million, the total time required to design and build the road declined by as much as one year on some projects—in part because the PPP bundled design and construction contracts.

For more information and to read the full report, visit 1.usa.gov/CBO-PPP.

Reexamining the Federal Role in Transportation

Better articulation of transportation policy goals to the public, further consideration of the value of trust funds, and a deeper discussion about the role of the federal government in transportation are recommended in a recent Eno Center for Transportation report investigating the context of the federal deficit and funding structures for federal transportation programs.



Based on discussions from a November 2011 forum and authored by Paul A. Lewis, the report notes the need to strengthen communication about the importance of infrastructure. Support for increased funding is unlikely, unless transportation can be articulated as a critical issue; market research and transportation advocacy could serve to raise public awareness.

The report also questions the utility of trust funds to pay for an increasingly multimodal transportation system—especially with more revenues coming from sources with no relationship to users. Historically, as with the construction of the Intercontinental Railroad or the Interstate Highway System, the role of the federal government in transportation was more clear-cut than is it today; according to the report, redefining this role would facilitate communication with the public and could increase support for more funding.

With the possibility of reduced transportation funding, the transportation industry must shift its focus to high-return investments, Lewis observes—these include performance measures, improved project analysis, improving the operation of infrastructure in lieu of adding capacity, considering options such as tolling and vehicle miles traveled as revenue sources for states and localities, and strong leadership.

To access the full report, visit <http://enotrans.com/ctp/eno-publications.php>.

TRB HIGHLIGHTS

SECOND STRATEGIC HIGHWAY RESEARCH PROGRAM NEWS

Videos Highlight Toolkit for Accelerated Bridge Construction

The second Strategic Highway Research Program (SHRP 2) has developed a toolkit for accelerated bridge construction (ABC) techniques. The resource guides bridge owners and local contractors in the use of typical equipment to build bridges quickly and efficiently and to benefit from the techniques most often conducted with specialized equipment on high-profile projects. The toolkit was used in October 2011 to design and construct a bridge over Keg Creek near Council Bluffs, Iowa; the techniques



A video of the Keg Creek bridge installation project features time-lapse imagery of the construction.

reduced the road closure from the standard 6 months to only 2 weeks.

Two videos explain the benefits of the process and the innovations presented in the toolkit and include interviews with the construction contractor, the design team, and transportation leaders involved in the project. “One Design—10,000 Bridges” is an 8-minute overview of the project; “ABC for Everyday Bridges” runs approximately 18 minutes and includes more detail about construction techniques.

To view the videos, visit the SHRP 2 website and follow the download instructions at www.TRB.org/SHRP2/KegCreek.

COLLABORATING FOR IMPLEMENTATION—

Susan Martinovich (*right*), Nevada Department of Transportation (DOT), guides a meeting of the SHRP 2 Implementation Task Force with (*left to right at table*) Kirk Steudle, Michigan DOT; Ann Brach, SHRP 2; and John Horsley, American Association of State Highway and Transportation Officials (AASHTO). The group met March 22 and 23 at the AASHTO headquarters in Washington, D.C., to assess products from the SHRP 2 capacity, renewal, and reliability focus areas. The task force developed priorities with the Federal Highway Administration, and the joint recommendations were presented to the SHRP 2 Oversight and Implementation Committee in June.



COOPERATIVE RESEARCH PROGRAMS NEWS

Guide for the Preservation of Highway Tunnel Systems

Significant amounts of public funding go toward inspecting and maintaining tunnels that were not designed to be easily inspected and maintained. Well-planned preventive maintenance is a cost-effective strategy for keeping tunnels safe and in operation, by preventing, delaying, or reducing the deterioration of tunnels; restoring function; and keeping tunnels in good condition to extend service life.

Although practitioners often apply preservation strategies on the basis of judgment or common sense, translating these strategies into arguments for the support of well-planned highway tunnel preservation programs is difficult. Without a credible, quantitative means for measuring effectiveness, these programs may be inadequately funded.

Gannett Fleming, Inc., has received a \$375,000, 34-month contract (NCHRP Project 14-27, FY 2012) to develop a guide that will catalog highway tunnel preservation actions, quantify the benefits of the actions, provide decision-making tools to optimize preservation, and develop a method to determine appropriate levels of funding and staffing to achieve the agency's goals and performance measures.

For further information, contact Crawford Jencks, TRB, 202-334-2379, cjencks@nas.edu.

Improving Transportation Options for Military Service Personnel

America's military service members, veterans, and their families need improved mobility in their communities of residence. Strategies to assist communities in improv-

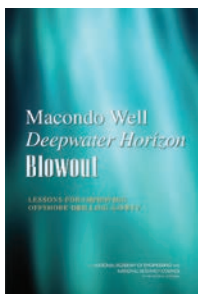
ing mobility for military service personnel should address outreach, planning, coordination, mobility management, services, business practices, communication, and implementation.

KFH Group, Inc., has received a \$200,000, 6-month contract (Transit Cooperative Research Program Project B-42, FY 2011) to develop a toolbox to guide communities in assessing local needs and to assist in improving public transit, specialized transportation, volunteer services, and other community-based transportation options. The toolbox will be adaptable to urban areas of different sizes and to rural communities and will present tested practices as well as innovative ideas.

For further information, contact Dianne S. Schwager, TRB, 202-334-2969, dschwager@nas.edu.

Macondo Well–Deepwater Horizon Blowout: Lessons for Improving Offshore Drilling Safety

National Academy of Engineering and National Research Council. National Academies Press, 2012; 196 pp.; \$47; 978-03-0922-138-2.



The blowout of the Macondo oil well in the Gulf of Mexico on April 20, 2010, caused the deaths of 11 workers on the *Deepwater Horizon* drilling rig and the serious injury of 16 others, and released nearly 5 million barrels of oil, causing extensive environmental damage and economic losses. This study by the National Academy of Engineering and the National Research Council—including the TRB Marine Board and the Board on Environmental Studies and Toxicology—examines the causes of the blowout and provides a series of recommendations, encouraging a system safety approach to anticipating and managing possible dangers at offshore oil rigs. Also discussed is the ultimate responsibility for well integrity and the safety of offshore equipment, the formal system safety education of offshore drilling personnel, and guidelines for well designs that incorporate protection against the risks associated with the drilling and abandonment process.

City Cycling

Edited by John Pucher and Ralph Buehler. MIT Press, 2012; 368 pp.; \$27.95; 978-02-6251-781-2.

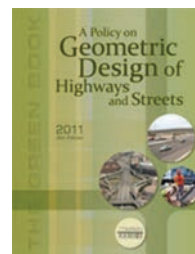


This guide reports on cycling trends and policies in cities of varying sizes in North America, Europe, and Australia. Explored are topics such as cycling safety, infrastructure provisions, bicycle design and equipment, and the integration of cycling and public transportation, with tips for making city cycling feasible, convenient, and safe for

daily transportation. By examining cities that have developed bicycle programs—with and without historical cycling cultures—the guide investigates the role of infrastructure and policy coordination in the successful promotion of city cycling.

A Policy on Geometric Design of Highways and Streets, 6th Edition

American Association of State Highway and Transportation Officials (AASHTO), 2011; 912 pp.; AASHTO members, \$200; nonmembers, \$240; 978-15-6051-508-1.



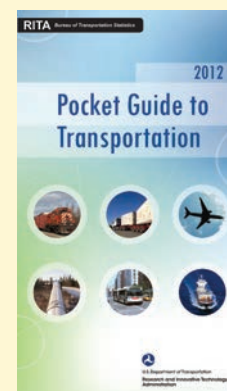
Commonly referred to as the Green Book, *A Policy on Geometric Design of Highways and Streets* shares current design research and practices for highway and street geometric design, assisting the development of design solutions that meet highway user needs while maintaining the integrity of the environment. Design guidelines are presented for freeways, arterials, collectors, and local roads in rural and urban locations. The newest edition incorporates substantive updates and is available as a downloadable PDF or as a multiuser web-based subscription.

The books in this section are not TRB publications. To order, contact the publisher listed.

Pocket Guide to Transportation

Produced annually by the Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation's Research and Innovative Technology Administration, the *Pocket Guide to Transportation* is a compact resource that provides snapshots of the U.S. transportation system and highlights major transportation trends. Statistical information is presented on the topics of safety, the state of good repair, system use and livable communities, economic competitiveness, and environmental sustainability to aid in data-driven, evidence-based decision making.

For more information on BTS and its products and services, call 1-800-853-1351 or e-mail RITAinfo@dot.gov. To access a PDF of the guide or order copies, visit www.bts.gov/publications/pocket_guide_to_transportation/2012.



TRB PUBLICATIONS

Revenue, Finance, and Economics

Transportation Research Record 2221

Funding options for federal surface transportation, mileage-based charges, urban network privatization, and the politics of freeway congestion pricing are among the topics covered in this volume.

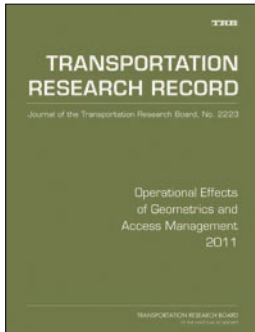
2011; 111 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: *finance; economics; policy*.

Marine Transportation and Marine Terminal Operations 2011

Transportation Research Record 2222

The papers in this volume explore schedule design and container routing in liner shipping, port effectiveness, estimating truck queuing time at marine terminal gates, energy inefficiency in marine transportation, measurement of the ecological





TRB PUBLICATIONS

and carbon footprint of port authorities, and other topics.

2011; 102 pp.; TRB affiliates, \$44.25; nonaffiliates, \$59. *Subscriber categories: marine transportation; terminals and facilities; freight transportation.*

Operational Effects of Geometrics and Access Management 2011

Transportation Research Record 2223

Research is presented on intersection design, two-lane rural highways, travel time evaluation of a U-turn facility, an operating speed model for low-speed rural two-lane highways, operational effects of signalized superstreets in North Carolina, and other topics.

2011; 119 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. *Subscriber categories: operations and traffic management; design; planning and forecasting.*

Freight Systems 2011: Modeling and Performance Measures

Transportation Research Record 2224

Included are papers on supply chain broker operations, emissions reduction in urban pickup systems, an online freight network assignment model, an intermodal container flow simulation model, models for minimizing backhaul costs, and multicriteria freeway performance measures.

2011; 101 pp.; TRB affiliates, \$44.25; nonaffiliates, \$59. *Subscriber category: freight transportation.*

Pavement Management 2011, Vol. 1

Transportation Research Record 2225

A model of road-user costs, axle-load power for pavement fatigue cracking, integrated maintenance and expansion planning, an enhanced pavement distress segmentation algorithm, infrastructure condition data, and asphalt fatigue from full-scale testing are among the subjects explored in this volume.

2011; 164 pp.; TRB affiliates, \$52.50; nonaffiliates, \$70. *Subscriber category: pavements.*

Pavement Management 2011, Vol. 2

Transportation Research Record 2226

The papers in this volume address calibration, prediction mechanisms, modeling, validation, and implementation issues related to the *Mechanistic-Empirical Pavement Design Guide*, as well as a structural analysis of pervious concrete pavement, a perpetual pavement experiment, and more.

2011; 148 pp.; TRB affiliates, \$52.50; nonaffiliates, \$70. *Subscriber category: pavements.*

Pavement Management 2011, Vol. 3

Transportation Research Record 2227

Authors present research on widened pavement systems, the long-term performance of cold in-place recycled pavements in New York, pavement selection for highway rehabilitation, life-cycle environmental analysis, sand mix interlayer, and other topics.

2011; 196 pp.; TRB affiliates, \$57.75; nonaffiliates, \$77. *Subscriber category: pavements.*

Construction 2011

Transportation Research Record 2228

Researchers examine topics including performance bond benefit-cost analysis, green contracting in highway construction, a performance attributes matrix for highway rehabilitation projects, a performance-related specification for Superpave® pavements, and a Wisconsin method for probing portland cement concrete pavement for thickness.

2011; 138 pp.; TRB affiliates, \$49.50; nonaffiliates, \$66. *Subscriber categories: construction; design; pavements.*

Freeway Operations; Regional Systems Management and Operations; Managed Lanes 2011

Transportation Research Record 2229

Validation techniques for microscopic traffic simulations for region-level mass evacuations, the safety benefits of deploying open-road tolling for mainline toll plazas in Florida, and the operational performance of different types of high-occupancy vehicle facilities in California are among the topics explored in this volume.

2011; 109 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. *Subscriber category: operations and traffic management.*

Travel Behavior 2011, Vol. 1

Transportation Research Record 2230

Papers in this volume explore the role of social networks in start time and duration of activities, choices related to bicycle commuting, route choice behavior, travel trends for young Germans and Britons, influences on the use of nonmotorized transport modes, and more.

2011; 142 pp.; TRB affiliates, \$49.50; nonaffiliates, \$66. *Subscriber category: planning and forecasting.*

Travel Behavior 2011, Vol. 2

Transportation Research Record 2231

Nonwork travel behavior, dynamic choice set generation, a subjective measure of car dependence,

The TRR Journal Online website provides electronic access to the full text of more than 12,000 peer-reviewed papers that have been published as part of the Transportation Research Record: Journal of the Transportation Research Board (TRR Journal) series since 1996. The site includes the latest in search technologies and is updated as new TRR Journal papers become available. To explore the TRR Online service, visit www.TRB.org/TRROnline.

TRB PUBLICATIONS (continued)

a dynamic discrete choice model for multiple social interactions, estimating the value of travel time savings, and the propensity to telecommute are among the topics explored in this volume.

2011; 128 pp.; TRB affiliates, \$49.50; nonaffiliates, \$66. Subscriber category: *planning and forecasting*.

Geomaterials 2011

Transportation Research Record 2232

The 10 papers in this volume examine subjects including the management of unsealed gravel roads, the polishing tendency of coarse aggregates, a simple method to identify marl soils, and ultrasonic tomography.

2011; 107 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: *geotechnology; pavements; materials*.

Guidelines for the Use of Pavement Warranties on Highway Construction Projects

NCHRP Report 699

Designed to guide state departments of transportation (DOT) in establishing pavement warranty programs, this report identifies programmatic and project-level decision criteria for implementing and sustaining a program, presents strategies to mitigate project-specific risks, and offers model warranty specification provisions. An accompanying decision tool helps identify program-level issues and project-specific risks.

2011; 64 pp.; TRB affiliates, \$39.75; nonaffiliates, \$53. Subscriber categories: *highways; construction; materials*.

Comparison of American Association of State Highway and Transportation Officials (AASHTO) Bridge Load Rating Methods

NCHRP Report 700

This report documents an analysis of 1,500 bridges with the AASHTOWare Virtis, comparing the load factor rating to load and resistance factor rating for moment and shear induced by design vehicles, AASHTO legal loads, and other permit-legal vehicles.

2011; 93 pp.; TRB affiliates, \$40.50; nonaffiliates, \$54. Subscriber category: *bridges and other structures*.

Proposed Specifications for Load and Resistance Factor Design (LRFD)**Soil-Nailing Design and Construction**

NCHRP Report 701

To assist state DOTs in using soil-nailed structures, this report proposes standard design and con-

struction specifications that can be incorporated into the AASHTO LRFD *Bridge Design and Construction Specifications*.

2011; 132 pp.; TRB affiliates, \$45; nonaffiliates, \$60. Subscriber categories: *bridges and other structures; geotechnology; highways*.

Precision of the Dynamic Modulus and Flow Number Tests Conducted with the Asphalt Mixture Performance Tester

NCHRP Report 702

The current hot-mix asphalt volumetric design method does not include a simple, mechanical “proof” test, similar to the Marshall stability and flow tests or the Hveem stabilometer method. This report describes the development of precision statements for tests conducted with the Asphalt Mixture Performance Tester.

2011; 200 pp.; TRB affiliates, \$52.50; nonaffiliates, \$70. Subscriber categories: *highways; materials*.

Guide for Pavement-Type Selection

NCHRP Report 703

Included in this volume are processes for conducting systematic evaluations of pavement alternatives and for making decisions on pavement-type selection, appropriate for agency- and contractor-based selections and for different pavement types and structures.

2011; 70 pp.; TRB affiliates, \$36.75; nonaffiliates, \$49. Subscriber categories: *design; pavements*.

Transportation Improvement Program Revision Process

NCHRP Synthesis 419

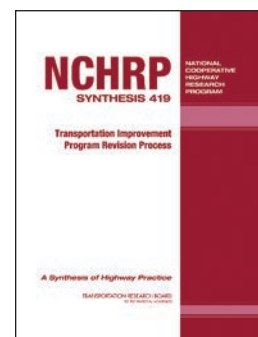
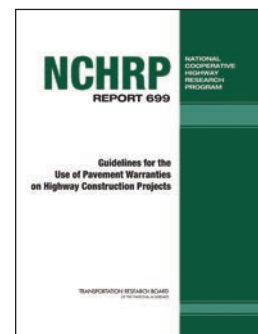
Federal legislation requires metropolitan planning organizations to adopt and regularly update a transportation improvement program (TIP) that identifies a prioritized list of projects for a 4-year period. This synthesis documents different methods for revising a TIP.

2011; 70 pp.; TRB affiliates, \$36.75; nonaffiliates, \$49. Subscriber categories: *highways; administration and management; planning and forecasting*.

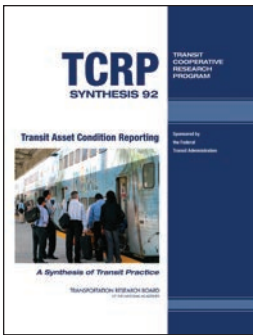
Recycling and Reclamation of Asphalt Pavements Using In-Place Methods

NCHRP Synthesis 421

This synthesis investigates the use of hot in-place recycling, cold in-place recycling, and full-depth reclamation of asphalt pavements to help agencies optimize the value of in-place materials, minimize construction time, and improve traffic flow.



TRB PUBLICATIONS (continued)



2011; 70 pp.; TRB affiliates, \$36.75; nonaffiliates, \$49. Subscriber categories: construction; environment; highways; materials.

Transit Asset Condition Reporting
TCRP Synthesis 92

The current state of the practice in transit asset condition management, a strategic planning process that supports informed capital investment planning and programming, is addressed in this volume.

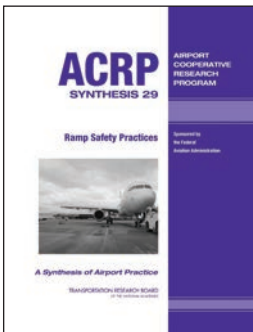
2011; 45 pp.; TRB affiliates, \$30.75; nonaffiliates, \$41. Subscriber categories: economics; finance; public transportation.



Practices to Protect Bus Operators from Passenger Assault
TCRP Synthesis 93

Through a literature summary, survey results from transit agencies throughout the United States and Canada, and interviews with key agency personnel, this synthesis highlights practices and policies to deter and mitigate assaults on bus operators.

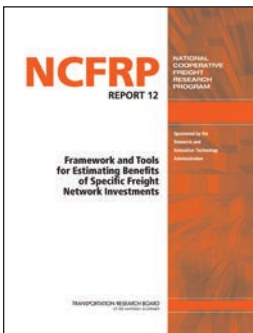
2011; 126 pp.; TRB affiliates, \$45; nonaffiliates, \$60. Subscriber categories: education and training; public transportation; passenger transportation; safety and human factors; society.



Resource Manual for Airport In-Terminal Concessions
ACRP Report 54

This report offers guidance on developing and implementing airport concession programs. Information is included on the airport concession process, goals and potential customers; developing a space plan and concession mix; procurement, contracting, and management; and the Airport Concessions Disadvantaged Business Enterprise program.

2011; 258 pp.; TRB affiliates, \$55.50; nonaffiliates, \$74. Subscriber categories: administration and management; aviation; finance; terminals and facilities.



Passenger Level of Service and Spatial Planning for Airport Terminals
ACRP Report 55

This report examines passenger perception of level of service related to space allocation in airport terminals. Level-of-service standards in terminal planning and design are evaluated, along with the validity of the space allocation parameters in use for more than 30 years.

2011; 61 pp.; TRB affiliates, \$34.50; nonaffiliates, \$46. Subscriber category: aviation.

Handbook for Considering Practical Greenhouse Gas Emission Reduction Strategies for Airports

ACRP Report 56

This handbook assists airport operators in identifying, evaluating, prioritizing, and implementing practical, low-cost strategies to reduce and manage greenhouse gas emissions. AirportGEAR, an interactive decision support tool, is included as a CD-ROM with the print edition and is available as a downloadable file.

2011; 140 pp.; TRB affiliates, \$45; nonaffiliates, \$60. Subscriber categories: aviation; energy; environment.

Ramp Safety Practices
ACRP Synthesis 29

This synthesis addresses the current state of ground handling practices, focusing on safety measures and training, as well as on ramp safety operations, staff roles and responsibilities, safety training, audit and inspection programs, safety violation programs, and collaborative safety initiatives.

2011; 59 pp.; TRB affiliates, \$34.50; nonaffiliates, \$46. Subscriber categories: aviation; safety and human factors.

Framework and Tools for Estimating Benefits of Specific Freight Network Investments
NCFRP Report 12

This report offers tools for estimating the private and public benefits of potential freight infrastructure investments, along with a framework to assess a variety of project types, such as those designed to improve freight operations and those that generate capacity.

2011; 123 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: finance; highways; marine transportation; planning and forecasting; railroads.

Freight Facility Location Selection: A Guide for Public Officials

NCFRP Report 13

The location of freight facilities can have positive and negative economic and social effects on local communities, regions, and states. This report describes the key criteria considered by the private sector when deciding where to build new logistics facilities.

2011; 69 pp.; TRB affiliates, \$36.75; nonaffiliates, \$49. Subscriber categories: economics; environment; freight transportation; marine transportation; motor carriers; railroads; terminals and facilities.

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INFORMATION FOR CONTRIBUTORS TO

TR NEWS

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FEATURES are timely articles of interest to transportation professionals, including administrators, planners, researchers, and practitioners in government, academia, and industry. Articles are encouraged on innovations and state-of-the-art practices pertaining to transportation research and development in all modes (highways and bridges, public transit, aviation, rail, and others, such as pipelines, bicycles, pedestrians, etc.) and in all subject areas (planning and administration, design, materials and construction, facility maintenance, traffic control, safety, geology, law, environmental concerns, energy, etc.). Manuscripts should be no longer than 3,000 words (12 double-spaced, typed pages). Authors also should provide charts or tables and high-quality photographic images with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes, whether they pertain to improved transport of people and goods or provision of better facilities and equipment that permits such transport. Articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by one or two illustrations that may improve a reader's understanding of the article.

NEWS BRIEFS are short (100- to 750-word) items of interest and usually are not attributed to an author. They may be either text or photographs or a combination of both. Line drawings, charts, or tables may be used where appropriate. Articles may be related to construction, administration, planning, design, operations, maintenance, research, legal matters, or applications of special interest. Articles involving brand names or names of manufacturers may be determined to be inappropriate; however, no endorsement by TRB is implied

when such information appears. Foreign news articles should describe projects or methods that have universal instead of local application.

POINT OF VIEW is an occasional series of authored opinions on current transportation issues. Articles (1,000 to 2,000 words) may be submitted with appropriate, high-quality illustrations, and are subject to review and editing.

BOOKSHELF announces publications in the transportation field. Abstracts (100 to 200 words) should include title, author, publisher, address at which publication may be obtained, number of pages, price, and ISBN. Publishers are invited to submit copies of new publications for announcement.

LETTERS provide readers with the opportunity to comment on the information and views expressed in published articles, TRB activities, or transportation matters in general. All letters must be signed and contain constructive comments. Letters may be edited for style and space considerations.

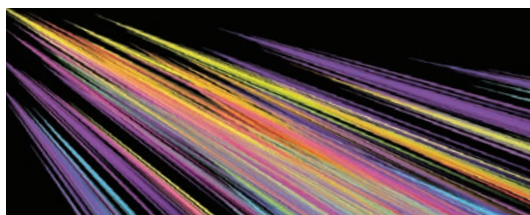
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- ◆ All manuscripts should be supplied in 12-point type, double-spaced, in Microsoft Word, on a CD or as an e-mail attachment.

- ◆ Submit original artwork if possible. Glossy, high-quality black-and-white photographs, color photographs, and slides are acceptable. Digital continuous-tone images must be submitted as TIFF or JPEG files and must be at least 3 in. by 5 in. with a resolution of 300 dpi. A caption should be supplied for each graphic element.

- ◆ Use the units of measurement from the research described and provide conversions in parentheses, as appropriate. The International System of Units (SI), the updated version of the metric system, is preferred. In the text, the SI units should be followed, when appropriate, by the U.S. customary equivalent units in parentheses. In figures and tables, the base unit conversions should be provided in a footnote.

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Transportation Research Board 92nd Annual Meeting

January 13–17, 2013 • Washington, D.C.

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