FHWA Study Tour for Pedestrian and Bicyclist Safety in England, Germany, and The Netherlands

October 1994

INTERNATIONAL TECHNOLOGY

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FHWA International Technology Scanning Program

Summary Report on

FHWA Study Tour for Pedestrian and Bicyclist Safety in England, Germany, and The Netherlands

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EXECUTIVE SUMMARY

This report documents the findings of a U.S. study team that visited England, The Netherlands, and Germany. The trip sponsored by the Federal Highway Administration was taken September 3-19, 1993. Members of the study team also spent 1 day in Basel, Switzerland, and obtained a limited amount of information from that visit. The purpose of the trip was to learn as much as possible about practices and policies for improving pedestrian and bicyclist safety and promoting use of these modes. Topics covered included roadway facilities, educational and promotional programs, traffic enforcement issues, and relevant pedestrian and bicyclist safety research.

Study team members met with local and federal officials, visited pedestrian and bicyclist facilities, and compiled relevant literature and other written documentation. Some of the major findings of this trip are discussed below.

REDUCING VEHICLE SPEED

Reducing vehicle speeds was found to be of major importance in the effort to improve the environment for pedestrians and bicyclists. To be effective, facilities should be self-enforcing; for example, roadways should be designed so as not to permit vehicles to exceed speed limits easily.

A variety of traffic calming strategies are used to reduce speeds on neighborhood streets. These methods can be of great benefit to pedestrian and bicyclist safety. They include

- Speed humps;
- Raised crosswalks, which are basically speed humps at crosswalk locations;
- Road narrowing (chokers);
- Chicanes (barricades and posts are used to create a slalom-type effect in the street);
- Midblock street narrowing by extending the curb and allowing only one direction of traffic at a time;
- Midblock street closures that result in cul-de-sacs but still allow pedestrians and cyclists to pass through;
- Angle parking on alternating sides of the street;
- Pedestrian refuge islands, which also narrow the street; and
- Diagonal diverters at intersections to cut off a through street route.

Signs and paint alone are generally ineffective in slowing vehicle speeds, and roadways need to be designed for slow speeds using measures such as those listed above.

RESTRICTING TRAFFIC MOVEMENTS

To improve safety and promote more bicycling and walking, a city should be designed to keep through traffic out of the city center and to encourage travel by modes other than the automobile. Incentives and disincentives (the carrot-and-stick approach) should be provided to keep through traffic out. High motor vehicle parking costs also need to be emphasized. Dutch cities such as Delft, Groningen, and Houten prevent motorists from cutting across zones within the urban area but still allow access between zones for bicyclists, pedestrians, and transit users. A ring road in those cities for vehicles leaving one zone to travel to another greatly reduces the convenience of motor vehicles. This design also allows bicyclists to move freely through the city on separate paths; bicycling and walking are encouraged and made safer.

REDUCING TRAVEL DISTANCES

Travel distances should be shortened to encourage safer and increased levels of bicycling and walking. Shorter travel distances require high-density development and the location of employment near places of residence. Strict land-use controls are very important in high-density development. Land area is limited in some European countries, and careful planning is exercised to ensure maximum efficiency of space.

High-density development does not necessarily lead to a crowded feeling. The crowded feeling is due largely to traffic congestion and traffic noise. Shorter travel distances may result in a change of lifestyle. Traveling by foot and by bicycle is much slower than traveling by motorized transportation. This slower traveling leads to a slower pace of life for many people.

HIGHWAY CAPACITY PROBLEMS

The issue of highway capacity is treated much differently in Europe than in the United States. In the United States, problems with traffic congestion are typically addressed by adding new roadways, increasing the number of lanes, building parking garages, or other measures that accommodate more motor vehicles. In cities such as London and Frankfurt, these problems are often handled by increasing parking costs, reducing the number of available parking spaces in the downtown area, turning downtown streets into pedestrian malls, and encouraging more use of public transit.

In some cities in The Netherlands, in particular, extensive networks of bicycle lanes and paths are provided to encourage more use of bicycles. In cities such as Delft, Groningen, and Houten, motor vehicle traffic is prevented from moving freely through the cities through the use of one-way streets, physical traffic diverters, and dead-end streets. Through such physical traffic barriers, motorists are forced to go out to ring roads to go around a city to get to most destinations instead of traveling directly through the city. Other facilities allow pedestrians and bicyclists to travel directly to their destinations. Many downtown streets are designated exclusively for (or give priority to) pedestrian or bicycle use.

PHILOSOPHY OF NONMOTORIZED TRANSPORTATION

Many European city planners believe in bicycling or walking as a form of local transportation, particularly those who themselves bicycle or walk to work. Some of these cities have had a long-standing commitment to facilitate pedestrian and bicycle transportation, and the political climate allows such activities. Also, many of those cities with successful bicycle and pedestrian program projects have had the planners and engineers involved from the beginning.

Encouraging bicycling and walking is justified by some cities (e.g., London) on business and economic grounds. Retail activity is often improved in areas where many people walk and bicycle. Local business owners often resist pedestrian malls and traffic calming prior to their installation, but they usually experience a considerable increase in business afterward. It is important to mention, however, that the success of pedestrian malls requires more than just closing streets to motor vehicle traffic. Careful planning is required to ensure that there are historical or other attractions to encourage pedestrians to use the malls. Furthermore, bicyclist and pedestrian facilities should be separated whenever possible, since walking and bicycling are incompatible at the same facility.

PEDESTRIAN CROSSINGS AND FACILITIES

A wide range of facilities for pedestrians was found within different cities in the countries visited. Some traditional measures are used, such as pedestrian signals, safety islands, sidewalks and walkways, and overpasses and underpasses. Also, many types of experimental and innovative measures (as compared to U.S. practices) are also used. For example, there are pedestrian pushbutton devices that light up after they are activated, letting the pedestrian know that the signal will change soon to a WALK indication. Such a feature is intended to increase pedestrian compliance with pedestrian signals.

Pedestrian crossing types used (mostly in Great Britain) that differ from those in the United States include the following.

- Zebra Crossings. Zebra crosswalk stripes with flashing lights on poles (belisha beacons) are used in Great Britain. Pedestrians have the right-of-way and drivers must yield to crossing pedestrians. Zebra crossings are preceded by zig-zag pavement markings on the vehicle approaches.

- "Pelican" Crossings. These are crossings controlled by traffic signals—pedestrian "green man" or "red man" signals with fully automated pedestrian push buttons—and with no zebra marking. Dotted lines or road studs (square metal studs) mark the crosswalk. These crossings are only used at midblock pedestrian crossings. A flashing "green man" indication is used for clearance. On the vehicle approach, a flashing amber with steady red signal precedes the green ball. These are also commonly used in Great Britain.

- "Puffin" (Pedestrian User-Friendly Intersection) Crossings. Traffic and pedestrian signals with infrared pedestrian detectors and barriers are used to channel pedestrians to cross within the crosswalk lines. Infrared or pressure mat detectors are used to determine the presence of a pedestrian and go to a red traffic signal and "green man" pedestrian indication. Motion detectors extend the green interval to accommodate very slow walking speeds.

- "Toucan" Crossings (i.e., cyclists "too can" cross together). These are shared crossings for pedestrians and bicyclists. The preferred layout includes a tactile warning surface, audible signals, or tactile rotating knobs; pushbuttons with a WAIT display on each corner of the crossing; red lamp monitor; and vehicle detection on all approaches.

- Automated Pedestrian Crossings. These are experimental devices, tested in England, France, and The Netherlands, which have pedestrian presence detector mats, near-side pedestrian signals, and infrared detectors that extend the clearance interval for pedestrians until they are safely across the street.

BICYCLE MEASURES

A variety of bicycle measures are used to increase bicycle travel and safety in many European towns and cities. Networks of on-street bicycle lanes and separated paths are common in many areas. In urban areas where right-of-way is limited, bicycle lanes are often provided along with bicycle pavement marking symbols or words. Separate bicycle signal indications are sometimes used in urban areas. At some intersections, stop bars for motor vehicles are positioned before the intersection, but bicycles stop at the intersection. Thus, bicyclists begin the green signal in front of motor vehicles, making them more visible. Since bicyclists both have the right-of-way and are in front of the motor vehicle operator, the problem of right-turning motor vehicles striking bicyclists attempting to proceed straight or turn left at intersections is reduced. It also enables bicyclists to make left turns without having to merge left in motor vehicle traffic.

Separate paths are provided in many areas. Some paths allow joint use by pedestrians and bicyclists. In The Netherlands, separate facilities are commonly provided for bicyclists and pedestrians. Some paths are striped, with one side for bicyclists and the other for pedestrians, or colored pavement designates the bicycle path. Various types of railings and physical barriers prevent motorcycles and mopeds from using the paths. Separate bike paths are

1. INTRODUCTION

BACKGROUND

The conflict between motor vehicles and pedestrians and bicyclists has been a serious problem in the United States for decades. For example, in 1992, a total of 5,546 pedestrians were killed on our nation's highways.[1] In addition, more than 100,000 pedestrians are seriously injured each year in the United States,[2] approximately 700 to 900 bicyclists are killed each year in collisions with motor vehicles, and many thousands are seriously injured. It has been estimated that over a half-million people in the United States are treated each year in hospital emergency rooms for bicycle-related injuries, though many of these do not involve a motor vehicle.[3]

In spite of these statistics on bicyclist and pedestrian injuries, recent surveys have shown that bicycling and walking are among the most popular activities of Americans of all ages. For example, it has been estimated that 131 million Americans regularly walk or bicycle for exercise, recreation, or simply relaxation and enjoyment of the outdoors. Bicycling and walking, however, have still not reached their potential in the United States. According to the Nationwide Personal Transportation Study (NPTS) in 1990, only 0.7 percent of all travel trips (i.e., trips with a purpose) are currently made by bicycling, with 7.2 percent made by walking.[4]

In recent years, there has been renewed interest in the United States in improving the safety and use of bicycling and walking at the national as well as State and local levels. A federal report entitled *Transportation Choices for a Changing America: National Bicycling and Walking Study*[4] has recently been completed. This report, usually just called the National Bicycling and Walking Study, was mandated by Congress approximately 4 years ago to recommend ways to encourage more people in the United States to bicycle and walk. The recent Intermodal Surface Transportation Efficiency Act (ISTEA) legislation passed by Congress encourages State and local agencies to provide for nonmotorized as well as motorized transportation.[4]

The National Bicycling and Walking Study report discusses numerous benefits that can result from increasing bicycling and walking in our society in place of motorized transportation. Such benefits include improved personal health and fitness, a cleaner environment from reduced auto emissions, reduced congestion, reduced dependence on foreign oil, and many others. However, U.S. society has primarily focused on providing roadways to accommodate more and faster motor vehicle traffic, and many improvements are needed for bicyclists and pedestrians.[4]

Bicycle and pedestrian topics are now areas of national emphasis within the U.S. Department of Transportation (DOT), and many States—Florida, Oregon, Minnesota, North Carolina, and others—are working to enhance pedestrian and bicyclist facilities and programs. In addition, many U.S. cities have, both in the past and more recently, taken a strong interest in improving quality of life for their pedestrians and bicyclists through engineering, education, and enforcement measures. Cities such as Seattle, WA; Portland, OR; Boulder, CO; Palo Alto, CA; Davis, CA; and others have taken a leading role in such nonmotorized programs.[4] However, while there is some encouraging activity relevant to making life easier for those who bicycle or walk, there is still much that needs to be done in the United States.

While looking for ways to improve programs and facilities for bicycling and walking in the United States, it is critical to review practices that have been used successfully in other countries. Much has been written in recent years regarding many of the successful nonmotorized programs in western Europe, including The Netherlands, Germany, England, and Switzerland. A 1992 report for the Federal Highway Administration (FHWA) (A Study of Bicycle and Pedestrian Programs in European Countries) documents some of the successful activities found in these and other countries throughout Europe.[5] For example, a variety of speed reduction measures (often called traffic calming techniques) are used in cities throughout western Europe to slow motor vehicle traffic and enhance the safety and movement of bicyclists and pedestrians. Auto restrictive zones, pedestrian and bicyclist streets, street narrowing measures, speed humps, and other traffic diversion techniques have all been successfully used in different ways to reduce motor vehicle volumes or speeds, particularly on selected downtown and residential streets. Traffic calming is most successful when done on an areawide basis as opposed to "spot" traffic calming measures.

Many kinds of pedestrian treatments and facilities used in some of these European countries differ greatly from the standard U.S. practices. In addition, bicycle transportation is a way of life in some parts of Europe (e.g., as much as one-third or more of all trips in some cities are made by bicycling or walking), and facilities such as well-designed bicycle lanes and paths have become an integral part of the transportation network in many areas. Pedestrian and bicyclist research, policies and practices, and roadway strategies and educational efforts are all components of a whole program of bicyclist and pedestrian safety.

There is much that can be learned in some of these European countries for direct application or transfer to U.S. experiences. However, in order to thoroughly understand the details of many of these pedestrian and bicyclist practices, it is necessary to review such facilities and programs firsthand. It is also important to talk directly with key policy makers, engineers, and planners who are instrumental in these pedestrian and bicyclist programs and to learn from their successes. Then specific State and local agencies must find the programs and measures that are most suited to their own situations to improve the quality of life for pedestrians and bicyclists in their own areas.

STUDY OBJECTIVES AND SCOPE

The purpose of this report is to document the findings of a European project team visit to England, The Netherlands, and Germany, which was sponsored by FHWA and conducted on September 3-19, 1993. Discussions of practices in Great Britain in this report refer to those generally used in England, Scotland, and Wales, and not those in Ireland. Certain study team members also spent 1 day in Basel, Switzerland, and a limited amount of information is provided from that visit. The report documents findings from many areas, including planning practices for pedestrians and bicyclists, roadway facilities, educational and promotional programs, traffic enforcement issues, and some of the relevant pedestrian and bicyclist research that has been conducted in these countries. It is hoped that the findings in this report can be used in the United States to accelerate our progress toward improving the quality of life and safety for pedestrians and bicyclists in the years ahead.

STUDY TEAM MEMBERS

The study team consisted of the following FHWA, university, city, and State representatives:

Charles Zegeer Team Leader	Associate Director	Highway Safety Research Center University of North Carolina
Michael Cynecki	Traffic Engineer	Street Transportation Department City of Phoenix, AZ
John Fegan	Bicycle Program Manager	FHWA Office of Environment and Planning
Brian Gilleran	Highway Engineer	FHWA Office of Highway Safety
Peter Lagerwey	Pedestrian and Bicycle Coordinator	Seattle Engineering Department Seattle, WA
Carol Tan	Research Engineer	FHWA Office of Research and Development
Robert Works	Transit/Bicycle Programs Manager	Minnesota DOT

To document information learned during the trip, study team meetings and group discussions were held in the evenings and study team members were assigned to write daily summaries. These summaries—along with a large assortment of reports, articles, planning reports, and brochures—were then used in writing this report.

EUROPEAN CONTACTS

During the period of September 3–19, 1993, study team members visited officials from national transport departments, cities, universities, consulting firms, and other organizations in England, The Netherlands, and Germany. The representatives who met with U.S. study team members are listed below.

England

Barry Louth	Principal Transport Planner	Cambridge City Council
Councillor Beth Morgan	Chair	City of Cambridge Environmental Committee
Brian Human	Principal Planning Officer	Cambridge City Council
Andy Walford	Chief Traffic Engineer	Cambridge County
Fred Offen	Traffic Policy Division	U.K. Department of Transport
Raymond Gercans	Traffic Policy Division	U.K. Department of Transport
Dr. Meyer Hillman	Policy Analyst	Policy Studies Institute, U.K.
John M. Morgan	Transport Researcher	Transport Research Laboratory Great Britain
Richard B. Jones	Road Safety Division	U.K. Department of Transport
Joe Weiss	Assistant City Engineer	London Engineer's Department

The Netherlands

Andre Guit	Representative	Organisatic and Adviezen, Amsterdam
Ton (A.G.) Welleman	Representative	Ministry of Transport, Public Works and Water Management
Johan De Boer	City Planner	Groningen Department of City Planning
Marcel Bloenkolk	Senior Policy Advisor	City of Groningen
Henks Heijman	City Traffic Engineer	City of Groningen
Jan Kerkhof	City Traffic Engineer	City of Groningen
Amy Liefferink	City Planner	City of Houten
Ewald van Kouwen	Public Relations Officer	City of Houten
Henk Tromp	Consulting Engineer	
Dirk ten Grotenhuis	Representative	Delft City Planning Office
Rob Methorst	Representative	International Federation of Pedestrians

Roelof Wittink	Education Specialist	SWOV Institute for Road Safety Research
Peter Levelt	Research Psychologist	SWOV Institute for Road Safety Research
Divera A.M. Twisk	Research Psychologist	SWOV Institute for Road Safety Research
Boudewijn van Kampen	Project Manager	SWOV Institute for Road Safety Research
Pim Slop	Project Manager	SWOV Institute for Road Safety Research

Germany

Tilman Bracher	Consultant	Member of German Cyclists Union
Stephan Bohme	Traffic Engineer	City of Munster
Martina Guttler	City Planner	City of Munster
Alexe Hergeth	Public Relations Official	City of Munster
Dr. Wetterling	Director of City Planning	City of Frankfurt
Norbert Gobel	Amtsleiter Tiefbauamt	City of Freiburg
Dr. Geyer	Housing Department	City of Freiburg
Detlef Rump	Representative	City of Freiburg

Switzerland

Peter Huber	Head of Planning	City of Basel

Each of these contact people was very helpful in providing information to U.S. study team members. The draft study report was sent to select contact personnel for review and comment to ensure accuracy. Also, plans were made for continuing interaction and information exchange on pedestrian and bicycle safety and accommodation.

2. PLANNING FOR PEDESTRIANS AND BICYCLISTS

BACKGROUND AND GOVERNMENT OBJECTIVES

Great Britain

Promotion of bicycling and walking in Great Britain is becoming more important. Safety has been the criterion previously used for bicycle and pedestrian programs. However, the use of areawide traffic calming schemes is now replacing isolated improvement of "black spots" (i.e., high-accident locations). In addition to safety considerations, traffic calming is used to reduce vehicular speed, enhance health, reduce the fear of traffic and crime, reduce automobile pollution, and enhance the environment for bicyclists and pedestrians.

In Great Britain, a broader range of incentives for bicycling is being required than in the past: bicycle lanes or separate paths, secure parking at destinations, employer-provided changing facilities, and a general social change in attitudes toward the bicycle and its use. Political decisions, such as reallocating some pedestrian space to bicycle lanes, were also discussed.

The use of traffic calming in the form of 20-mph zones is being extended from residential streets to commercial areas as well. Multidisciplinary design teams use the themes of "community" and "quality of life". Reducing speed is the primary goal. While safety has been the motivating factor in the past, traffic design now promotes increased levels of bicycling and walking. Recent guidelines on traffic calming are available to local areas. Traffic calming as an areawide approach is preferred over "black spot" improvements.

To discourage the increased use of motor vehicles, particularly for commuting into downtown London, the number of parking spaces is limited to approximately 18,000 in London. Also, parking costs in downtown lots are 25 pounds (approximately $40 to $45 U.S.) per day to encourage the use of public transit over the personal car.

One of the concerns expressed involved reduced mobility for children in recent years. For example, Meyer Hillman discussed the concept that children are given significantly less license to travel independently than previously, due largely to lack of adequate walkways and street networks that allow safe walking and bicycling. A comparison of 1971 and 1990 survey data seemed to indicate a "dramatic" reduction in the free mobility of children. He felt this had implications for their rights and for their physical, social, and emotional development. Considerable controversy also exists with respect to the use of bicycle helmets in Great Britain, as discussed elsewhere in more detail.[(6)]

In Cambridge, England, land use planning is designed to create jobs adjacent to housing areas as a way of reducing the future flight from congested areas and associated problems. This tactic gets at an overall solution—reducing overall travel—instead of simply treating the symptoms with reactive traffic engineering treatments.

The Netherlands

Bicycles are allowed on approximately 96 percent of roads in The Netherlands, and are prohibited on only about 4,000 km of roads that are generally comparable to U.S. interstates. Most roads are intended for joint bicycle and motor vehicle use. Approximately 4 percent of roads have separate cycle paths for bicyclists and mopeds running along both sides. Outside the urban areas, approximately 13 percent of roads have bicycle lanes. The success of nonmotorized travel as part of the transportation system depends largely on well-planned zoning policies. A key element of successful zoning practices is to establish clear urban boundaries. Strip development along suburban arterials (which is common practice in the United States) rarely, if ever, exists in The Netherlands. Zoning practices are oriented to providing short trips. For bicycle and pedestrian programs to be successful, local agencies need to get citizens involved in their design, and citizens must have "authorship or ownership."(7, 8)

Some of the safety objectives in Amsterdam include enforcing safe traffic behavior, providing publicity about safe bicycle riding, and encouraging motorists not to park their cars on bicycle lanes. Identifying and correcting unsafe roadway features are also important objectives.

In The Netherlands, increasing bicycle use and improving safety for bicyclists are intertwined. Measures for increased mobility are the same as those for increased safety. For example, extensive networks of bicycle lanes and separate bicycle paths are used. "Hot spots" have been improved, and more areawide improvements are being implemented.

The report, "Sign Up For the Bike,"(9) is especially significant, since it is a manual containing the Dutch experience with the infrastructure needed by bicyclists. It is an important result of the Dutch Bicycle Master Plan. The five criteria used for the design of the infrastructure measures include traffic safety, directness of connection, aesthetic value, comfort, and social safety. An earlier policy on transport and transportation in The Netherlands had been developed with no mention of bicycle use. Both bicycle activists and citizens noted the omission. The policy was later rewritten, and a group of government officials, activists, tourist organizations, and railway representatives was formed. The Bicycle Master Plan was developed by this group and then passed by the Parliament. The plan enumerates clearly stated goals, and the means of reaching them. A five-step integrated approach was developed with subgoals in the following five areas:(9)

- Replacing short car trips with bicycle trips;
- Increasing connections between bicycle routes and public transportation;
- Reducing injuries and fatalities to cyclists;
- Reducing theft of bicycles; and

- Permanently incorporating bicycle policies into all traffic and transportation policies at all levels of government.

The vision of the Master Plan includes an overall increase in mobility, which provides opportunities to engage in economic and social activities.

One bicycle planning tool that has been developed in The Netherlands is a bicycle forecasting model. The model is useful for planning the best cycling network and allocating the budget among possible projects. The cycling model includes a traffic model to determine how many cyclists use a particular roadway segment each day and their origins and destinations. An evaluation model shows where new cycling facilities are needed, partly on the basis of traffic safety needs.(10)

The bicycle planning model forecasts bicycle use on the basis of where people live, work, shop, and go to school, and also considering the shortest routes and the unique habits of the population. The model has a three-part formula, which considers

- Modal split (car, bike, and transit);
- Safety, accidents, and environment; and
- Economic viability.

On the basis of these inputs, the model is adjusted until the desired balance of transport modes is accomplished.(10)

Several outputs of the bicycle forecasting model may be produced, including(10)

- A map that shows projected bike use of every route under current conditions (varying line widths indicate different volumes);
- A map that shows the location of facilities that are needed to reach a particular use level;
- A map that shows facilities needed to resolve high-accident intersections;
- An analysis of whether cyclists will use a proposed facility to determine whether it will be cost effective; and
- Projection of the number of conflicts that will occur at a particular intersection if a new facility is built.

The model has been successfully applied in The Netherlands and other European countries and will be studied for application in the United States.

Groningen

Groningen has been named by the Bicycle Federation of America as the number one city in the world for bicycling. It is the sixth-largest city in The Netherlands, with approximately 170,000 residents (350,000 in the region). The city is nearly 1,000 years old and residents have an average age of 35 years. Of all the jobs available in the city, about half are filled by people living outside the city.

City officials state that the main reason to promote bicycling and walking is to improve the quality of life. The city has three major priorities for making transportation improvements:

- Develop a compact city.

- Develop environmentally friendly transport.

- Take an integrated approach with coordinated policies.

Developing a compact city involves building housing close to the old city. Businesses are located where they are accessible by transit or by bike. The hospital is located near the city center (they are rebuilding on the site of the existing hospital). Shopping centers are not allowed on the edge of the city. Officials ensure that shopping, with the exception of car dealerships and furniture stores, is close to all residential areas.

Parking is limited to make bicycling faster than driving. Only one parking spot is allowed for every five employees. Bicycle parking is required, but no specific number of spaces is required. A new university library was built near downtown and near the old university area to reduce trip lengths.

Developing environmentally friendly transport involves giving priority to economically important vehicles (e.g., delivery vehicles, etc.). Circulation is intentionally made difficult for cars but not for bicycles. Traffic circulation policy includes dividing the city into four sectors so it is not possible for motor vehicles to travel from one sector to the other. Motor vehicles must go out to the ring road to travel to any other sector. Bicycle use is stimulated by

- Creating a network of main cycle routes;

- Reducing cycling distance by creating short cuts;

- Paving cycle routes (asphalt);

- Creating special measures to give cycles priority over cars at intersections (i.e., bikes can go in front of cars at intersections);

- Creating inexpensive facilities when possible (e.g., by using traffic calming to deny cars through access);

- Giving buses priority (i.e., buses override signal so that it turns green upon approach; special priority routes for buses); and

- Working slowly to eliminate all on-street parking in inner city area (i.e., encourage car pooling by creating park-and-ride lots on city edge and new lots next to city center).

The third major transportation objective in Groningen is to take an integrated approach with public policy. The major point is that all public policy must be coordinated. For example, the following steps are being taken in the inner city:

- Controlling and decreasing the number of cars;

- Using power buses (electric and diesel);

- Making improvements to streetscapes for shop owners;

- Reorganizing public space to make it less crowded and confusing; and

- Getting rid of clutter in open spaces to allow free flow of people.

In addition to these three primary objectives, several other ideas and goals are also part of the Groningen transportation plan.

- **Bicyclists and pedestrians**. Always separate bicyclists and pedestrians. They are incompatible on the same facility.

- **New buildings**. New buildings are required to have shower facilities.

- **Growth of car traffic**. City officials are concerned that car use may increase. Therefore, they are looking at ways to discourage car ownership. For example, they are developing a program to provide (free ?) car rides for people so they will not buy a car for the few times they need one.

- **Economy of cars**. They believe that cars are bad for the economy, since they cause congestion, thereby reducing the quality of life.

- **Bicycle parking lots**. Many lots are provided in the inner city. Also, you can have your bike fixed while you are at work.

- **Street parking for cars**. No parking is allowed on streets in the inner city. They are now building new lots on the edge of the city center.

- **Residential parking permits**. Residents who live on the edge of the city center must buy a permit at a nominal fee so they can park their cars. This guarantees a parking spot, since others are not allowed to park. This policy is implemented only at the request of area residents. However, it is routinely requested, since without it, it is almost impossible to find a parking spot.

- **Carrot-and-stick philosophy**. In general, both incentives and disincentives are needed. Facilities are needed to encourage bicycling and walking and to create disincentives for using a motor vehicle.

- **Buses**. Priority routes are created for buses to improve travel time.

- **Bike rental**. Bike rental is provided at the train stations.

- **Shopkeepers**. Originally shopkeepers did not like the idea of limiting motor vehicle access. However, within 2 years of implementing the program to limit motor vehicle access, sales were better than before the program was implemented. The problem occurred initially when city officials did not work closely enough with all interested parties, including shopkeepers. Today, the government does lots of outreach to all interested parties before implementing new policies. As a result, they now have a broad base of support for new policies prior to their implementation. The city's focus is not on what will be lost, but on what will be gained (e.g., when looking at a policy to reduce car access, the focus is on what will be gained, such as improved quality of life).

Houten

Houten was given "new town" status in 1979 by The Netherlands' central government in response to a national housing shortage. Under this new town concept, the central government has input on the decisions of where and when new housing is to be built and also provides financing for housing. Houten was chosen as a new town project because of its proximity to the rail line, the freeway, and the town of Utrecht.

Old Houten (prior to 1979) had a population of 4,500. The population of Houten is currently 27,000, and the population will expand to 30,000 by next year when additional housing units are completed. There are 8,000 new homes in Houten, which have allowed this growth. The central government is considering a plan to build 6,000 or more additional houses in Houten in the next few years. However, an alternative solution being considered is to leave Houten as is and build a whole new town around a neighboring village.

Houten is 5 km in length and has 17 district neighborhoods. There is a ring road around the city that provides direct access to each neighborhood, but cars cannot drive directly between neighborhoods without going to the ring road. Pedestrians and bicyclists are not allowed on the ring road, and grade-separated pedestrian and bicyclist crossings are provided outside of the city. All neighborhoods are connected by direct bicycle and walking paths, which provide convenient access to school, shopping, and other areas.

A greenbelt 50 to 200 meters wide passes through the center of Houten. Offices and retail businesses that employ many people are located near the city center, therefore encouraging shorter trips that can more easily be made by bicycle. Lower-density employers are located outside of Houten.

As a result of these and other planning strategies, Houten has 25 percent less car use than other towns of similar size in The Netherlands. Twice as many people use the train as in other comparable Dutch cities. Furthermore, no fatal traffic accidents have occurred in Houten in the past 5 years.

Delft

Delft has a population of 90,000, who collectively bicycle approximately 500,000 km per day. The street system operates at various levels: the urban network, the district network, and neighborhood networks. Bicycle paths link the railway lines and city center.

The Delft policy on cycling encourages public participation. The cycle plan has no stated objectives specifically related to reducing motor vehicle traffic; rather, it encourages people to travel more frequently by bicycle and to feel safer and more comfortable while doing so. In 1985, the Ministry of Transport and Public Works sponsored a film that documents bicycle policies and facilities in Delft. One bicycle promotion program in Delft includes a poster with the message "Delft can do better without your car."

Germany

With the unification of eastern and western Germany, the population of Germany reached 79.8 million in 1990. (West Germany had a population of just below 60 million prior to unification.) Over the past 20 years, bicycle sales, use, and crashes have increased. For example, bicycle ownership per 1,000 increased from 429 in 1973-74 to 593 in 1980 and to 726 in 1985-86.[11]

Germany's current goal is to reduce carbon dioxide levels by 25 percent by the year 2005. Another is to promote more local travel by bicycle as an alternative to motor vehicles, particularly for short commuting trips. The former city of East Berlin has dense land development in a mixed residential and business layout, which is conducive to mass transit, bicycling, and walking. Trip distances there are one-quarter the length of those in other German cities. The former East German government had previously promoted mass transit much more than bicycling and walking. The German government is also interested in promoting bicycle and pedestrian use for recreational travel on holidays and weekends.

Noise reduction and other environmental legislation drives some programs. Both vehicle speed and volume are used as criteria for 30-km/hr zones, but speed reduction is a more important goal. For locations with up to 2,500 vehicles per day, shared use of the roadway is acceptable. For roadways outside of local areas, separate bicycle facilities are being provided.

Sight distance at roadway junctions is considered critical so bicyclists and motor vehicle operators can have a clear view of each other. Pathways should cross roadways near the junctions of roadways. The minimum width for separate facilities is 1.6 m.

There is a new manual on Planning, Engineering, and Designing Bicycle Facilities. The easier problems in design were addressed initially. The more difficult facility problems are now being worked on.

As in The Netherlands, bicycle theft is a major problem in Germany. In fact, bicycle theft is the most common type of reported theft. Insurance (costing about 100 marks a year) is available to replace bicycles that cost around 500 marks. In the summer months, financial incentives are given to employees to cycle to work.

Frankfurt

Frankfurt, with a population of 680,000, has an estimated 300,000 commuters daily: 200,000 by automobile and 100,000 by trains and buses. This distribution is quite different from 1961, when 100,000 commuted by train and bus and only 30,000 by auto. Frankfurt is a vibrant commercial center with a strong financial district in the city center. There are no special efforts made exclusively for bicyclists, such as those in Munster, Freiburg, and Erlangen.

Officials are keenly aware of the need to increase shopping activity in the city center. In some areas that are clearly for pedestrians, various planting amenities (e.g., flower boxes, trees) and opportunities for very slow, winding auto traffic (e.g., chicanes) are successful draws. These measures are intended to attract people into the downtown rather than to the four outlying shopping mall developments that compete for Frankfurt's shoppers.

Munster

Munster is 1,200 years old and has 280,000 inhabitants, with 130,000 inhabitants in the town center. The regional population is estimated at 1,500,000. There are 1,016,000 jobs in Munster, with 64 percent white collar jobs, 29 percent blue collar jobs, and 7 percent self-employed. Munster also has the second-largest university in Germany, with 58,000 students. There are about 140,000 cars (about one car for every two people) and an estimated 300,000 bikes in the city.

The city is focusing on promoting environmentally friendly modes of travel, including cycling, public transit, and walking. This occurs in a number of ways, such as building new transit stations and bus facilities, improving transit scheduling, and building park-and-ride or park-and-bike facilities. There are also efforts to reduce car traffic in the downtown area, including creating more pedestrian malls and reducing the number of parking spaces in the downtown area (approximately 7,400 parking spaces currently exist).

Freiburg

In Freiburg, the politics of transportation are no longer the hottest topic. In fact, the subject of adequate living space (housing) is on the forefront of political debate. City officials anticipate that Freiburg (with a population of 190,000, of whom 27,000 are university students) will soon have housing built for an additional 10,000 people in one part of the city.

Political decisions in Freiburg are a matter of compromise and coalition building, with a city parliament of 48 members from a wide spectrum of political backgrounds. The Lord Mayor of Freiburg is directly elected and serves along with five burghermeisters. With this arrangement, the city has, over 25 years, successfully developed progressive transportation improvements for pedestrians and bicyclists. Other positive steps have been the institution of traffic calming and 30-km/hr zones, along with the development of the city's electric tram (streetcar) system. One city official indicated that Freiburg considers itself fortunate to have both the planning and the implementation functions concentrated within one office, thereby keeping the project development process under their own control.

About 80 percent of the city's buildings were destroyed during World War II. Because of the efforts of one dedicated city planner, Freiburg rebuilt itself on the model of its own medieval street layout, with many destroyed buildings replicated in the process. The actual remains of the medieval town are located about 3 m below the current street level. Along many of the streets, mountain spring-fed viaducts flow gently alongside the sidewalks and trolley rails, adding the calming background sound of running water to the city's hustle and bustle.

The newer sections of Freiburg have not been quite so successful. The once-popular Le Corbusier model of tall buildings surrounded by a patch of green has proven to be a less satisfactory living arrangement than the older, more traditional layout. In the 1970's, architects were allowed to purchase and rehabilitate one old building apiece. This restriction was intended to prevent a single developer from buying all of the buildings, then simply leveling them and building blocks of flats.

The old town center has a ring road around it, with adjacent parking facilities. This makes it possible to enter the town center without a car, but it also means that all car traffic comes very close to that town center.

Every year, 2,000 new cars are added to the city; currently there are about 95,000 private automobiles in Freiburg. There is no free parking near the town center's pedestrian area. Metered parking is 2 Deutsche marks (DM) ($1.20 U.S.) per hour, with no parking at all in the town center. In outlying areas of the city, the metered parking is usually between 1 DM ($.60 U.S.) and 1.50 DM ($.90 U.S.) per hour; in residential areas, between 30 percent and 70 percent of total parking capacity is reserved for residents. In addition to paying 100 DM ($60 U.S.) per year, residents who want reserved parking must obtain a certification that they do not have another reserved space elsewhere in a public parking facility. A visitor in the residential areas may park for 2-1/2 hours; overnight visitors must use an off-street parking facility. In many residential areas, parking has been removed and streetscape improvements (trees, flower beds) have been built, making the street a nicer place to live.

Switzerland

Basel is another European city with several centuries of history, and one that is actively trying to retain and recreate the historical features of its street system. In some cases streets are resurfaced with cobble and other stone. The city is actively identifying locations to eliminate parking in the downtown area.

Basel has very good public transportation, with train, trolley, and bus transportation in the city. A transit (trolley and bus) pass that can be purchased for 50 Swiss Francs ($30 to $35 U.S.) per month allows unlimited travel and is transferrable to other family members to encourage greater use. Recently, the residents voted for a 20 percent increase in vehicle fuel tax to support improvements in public transportation.

The city has a policy to reduce vehicle parking in the central part of the city and has set up a permit parking system for the residents most affected. It is also city policy not to build any more parking garages in the city.

USAGE RATES

Great Britain

About 33-percent of trips in Great Britain are made by foot. Improvements for pedestrian safety are usually made at the local level. It is estimated that the 20-mph zones have resulted in a 70 percent casualty reduction overall and an 80 percent reduction in casualties to children.

In Cambridge, England, about 35 percent of peak hour journeys by city residents are cycle trips, while 46 percent are by car.

The Netherlands

In The Netherlands, 27 percent of trips are by bicycle, 17 percent by walking, and 6 percent by public transportation. There are between 18,000 and 19,000 km of bicycle facilities in the country, but the Dutch would like to construct more. One-quarter of car trips could "easily" be made by bicycle, according to a survey of motorists.

Groningen

Approximately 48 percent of all trips made in Groningen are by bicycle, 31 percent by car, 16 percent by walking, and 5 percent by public transport. This use of bicycles in Groningen is about 10 percent to 15 percent higher than for similar-sized cities in The Netherlands.

However, of the 40,000 daily commuters from outside the city, approximately 84 percent travel by car, 4 percent by bicycle, and 12 percent by public transport.[12]

In surveys, citizens support bicycling because it is inexpensive, healthful, good for the environment (compared to motor vehicle travel), and it allows people to "stay in touch" with the environment. Reasons given for not bicycling include inclement weather, long distances to travel, and concern over status. Fear of motor vehicle traffic was not given as a major deterrent to bicycling.

Delft

In Delft, approximately 40 percent of trips are made by bicycle, and approximately 60 percent of the people claim to cycle to work at least some of the time. City officials survey the need for bike racks and install them. They cite that 12 bicycles can fit into one motor vehicle parking space. Thus, conversion to bicycles is touted as an important way to save space, which is a valuable resource in The Netherlands.

Germany

A 1986 survey indicated that bike trips accounted for 6 percent of travel in West Berlin and 2 percent in East Berlin. It is now 7 percent in Berlin versus 10 percent for work trips throughout Germany. Walking now accounts for 12 percent to 14 percent of all work trips. It was also reported that on a distance-of-travel basis, cars are 8 times safer than bicycles and 20 times safer than motorcycles. When factoring travel time, bicyclists have 30 percent higher risk than motorists of being involved in a crash.

Munster

Bicycling is a frequent activity in Munster. About 43 percent of trips are by bike and 48 percent are by car, which is a very high percentage of bike travel compared to most German cities. The city has an advertising campaign (poster and postcards) to compare the space used by various modes of travel and the advantages of using public transit and bicycling. The campaign compared the amount of space needed to transport 72 people with the following statistics:

- Car: Based on an average occupancy of 1.2 people per car, 60 cars are needed to transport 72 people, which takes 1,000 square meters.

- Bicycle: 72 people are transported on 72 bikes, which requires 90 square meters.

- Bus: 72 people can be transported on 1 bus, which only requires 30 square meters of space and no permanent parking space, since it can be parked elsewhere.

Freiburg

Bicycles are becoming more expensive; a new mountain bike can cost as much as 3,000 DM ($1,200 U.S.). This means that more and better locking facilities, which allow locking the frame of the bike, are needed. Within Freiburg's historic town center, cycle parking lots have been created by removing car parking spaces. Freiburg has 170,000 bicycles and 95,000 cars.

Within Freiburg, 80 percent of all trips do not exceed 5 km in length, and 60 percent of trips do not exceed 3 km. These short trips are likely candidates for conversion to transit, bicycling, or walking. In terms of modal split, private cars captured 60 percent of the trips in 1976 but only 46 percent in 1992. Public transit increased from 22 percent to 27 percent between 1976 and 1992, while bicycle use increased from 18 to 27 percent.

Switzerland

A 1991 study of trips within the city of Basel (i.e., where both ends of the trip are within the city) showed 20 percent pedestrian, 20 percent bicycle, 30 percent transit, and 30 percent automobile use.

ACCIDENT STATISTICS AND PROBLEMS

Great Britain

According to the official statistics of Great Britain's Department of Transport, there were 51,587 road crashes resulting in injury to pedestrians in 1992. Of those, 1,347 pedestrians were killed, 12,841 seriously injured, and 37,399 sustained minor injuries. Approximately 1 in 6, or 17 percent, people injured in road crashes is a pedestrian. Since 1966, pedestrian deaths have dropped by more than 50 percent and are at their lowest level since such records were first kept in 1926.[13]

Pedestrian groups most vulnerable to injuries include the very young and the very old. Children under the age of 15 years account for 39 percent of pedestrian casualties (i.e., injuries or deaths), with the highest casualty rate to the 12- to 15-year-old age group. Fatality rates were highest for pedestrians aged 70 years and above. In terms of accident cause, 31 percent of child pedestrian casualties involved a pedestrian masked from the driver's view by a stationary vehicle. Built-up roads account for 95 percent of pedestrian casualties, and pedestrian crossings accounted for only 9 percent of pedestrian casualties. British officials claim to have one of the best overall safety records in Europe, but there is still a problem with pedestrian injuries, particularly involving children. Since many drivers claim that they failed to see pedestrians prior to crashes, efforts are made to encourage pedestrians to wear fluorescent material in the day and reflective material at night.[13]

In terms of bicycle injuries in 1992, 24,962 accidents were reported, in which 204 cyclists were killed, 3,787 were seriously injured, and 20,764 received minor injuries. The cyclists most at risk in Great Britain include children and teenagers. In terms of the cause of cycle injuries, over half of child cycle accidents resulted from children playing or doing tricks, while three-quarters involve no other vehicle. (Note that unlike accident statistics in many other countries, which include only crashes involving motor vehicles, Great Britain's Department of Transport also includes bicycle injuries that do not involve a motor vehicle.) As with pedestrian casualties, 90 percent of bicycle casualties occur on built-up roads. Approximately 74 percent of bicycle casualties occur at intersections.[13]

The underreporting of bicycle accidents has been found to be a major problem in Great Britain. A Transport Research Laboratory (TRL) hospital-based study found that as many as 68 percent of cycle accidents may not be reported to the police. The study also found that slightly more than half of the cycle casualties involved head injury, including 29 percent injury to the cranium, meaning skull fractures, concussions, and abrasions. As a result of the high incidence of head injuries to young bicyclists, the Department of Transport encourages the use of good quality helmets to reduce the seriousness of accidents. Helmets that adhere to established British standards and/or American National Standards Institute (ANSI) or Snell standards are available,[13] but the percentage of bicyclists wearing helmets is unknown. Although the Department of Transport does not support a mandatory helmet law, it does support their use.

Lack of visibility caused about 20 percent of bicyclist accidents in which more than one vehicle was involved. Bicyclists in Great Britain are encouraged to wear fluorescent material in daytime, to use lights, and to wear reflective material at night to increase their visibility.[13]

In Cambridge, England, approximately half of the recorded road crashes involve bicyclists, which corresponds to an annual average of 363 out of 711 accidents involving cyclists from 1989 to 1993. In recent years the number of accidents involving cyclists has decreased, from a peak of 400 in 1990 to 330 in 1993, but the high level of cyclist casualties remains of concern. The reduction in cyclist casualties in recent years corresponds to a reduction in vehicular traffic over the same period, largely due to recessionary effects. The city has adopted a planning and transport strategy with the aim of preventing a further increase in car traffic in the city once the recession lifts, in order to maintain the benefits to cyclists and the general environment.

The Netherlands

Each year in The Netherlands, official statistics show approximately 50,000 road users are injured (minor or severe injuries).[8] In 1991, 13,303 severely injured road users were officially reported; of those, 1,281 people died and the rest were admitted to hospitals. Thirty-nine percent (5,236) of these serious injuries involved car passengers, 23 percent (3,115) were cyclists, and 10 percent (1,347) were pedestrians, as shown in Table 1. Moped riders accounted for 17 percent (2,234) of the injured victims. Among persons aged 65 and older, pedestrians and bicyclists were greatly overrepresented, compared to car passengers.[7]

Road accident victims are shown in Table 2 by mode of travel, speed limit of road, and collision pattern. Note that most pedestrian and bicycle injuries occur on the 50-km/hr roads, indicative of built-up (urban) areas. Collisions between cyclists and cars occurred most frequently at intersections.(7)

To better quantify the level of underreporting of road injuries, the SWOV Institute for Road Safety Research conducted a survey of the Dutch population. The survey resulted in an estimated 430,000 road user casualties (i.e., injuries, including fatal injuries), of which about 210,000 qualified as "injured" by the international definition, that is, the event occurs on a public road, at least one moving vehicle is involved, and there is an injury (as defined in The Netherlands, more than a scratch). Of those 210,000 injuries, the police reported 45 percent of them (95,000), but only 50,000 were included in official statistics. Only about 24 percent of all road accident casualties are reported in The Netherlands. The study also concluded, however, that the official statistics were much more complete for the more serious injuries. In fact, nearly 100 percent of fatalities were reported, and about 79 percent of hospital in-patient injuries were reported. Further, underreporting of crashes was thought to be far greater for bicyclists than for automobile drivers.(10)

Personal (or social) safety concerns are an important but not overriding concern in facility design in The Netherlands, according to government officials. Near misses are not reported, and accident data are difficult to obtain. Accident data are used to justify 30-km/hr zones, but are not usually used to justify expenditures. Indices of comfort are also important. Politicians believe that safety is not a major problem. Bicycle helmets are not thought necessary in lower-speed traffic situations, and it is believed that mandating their use would discourage bicycle use.

Table 1 Number of seriously injured road accident victims in The Netherlands in 1991, by transport mode and age of victim.[7]

	Age not known	00-04 years	05-09 years	10-14 years	15-17 years	18-19 years	20-24 years	25-49 years	50-59 years	60-64 years	≥65 years	Total, all ages
Passenger car	54	58	67	58	111	348	1,129	2,179	453	162	617	5,236
Lorry	0	1	0	0	0	5	15	54	12	1	1	89
Van	1	5	4	2	2	28	109	179	35	6	12	383
Bus	0	0	0	0	0	1	4	2	0	0	1	8
Motorcycle	2	0	0	3	13	39	269	473	23	4	3	829
Moped	18	0	2	45	958	393	267	325	69	39	118	2,234
Bicycle	12	33	178	436	254	99	204	726	306	161	706	3,115
Pedestrian	6	119	239	112	42	38	54	245	83	46	363	1,347
Train	0	0	0	0	0	1	2	2	0	0	0	5
Other Modes	0	0	1	4	6	4	3	14	6	2	15	55
Total	93	216	491	660	1,386	956	2,056	4,199	987	421	1,836	13,301

Table 2 Number of seriously injured road accident victims in The Netherlands in 1991, by transport mode, collision partner, and type of road.[7]

	50 km/hr roads	80 km/hr roads	100 km/hr roads
Car passengers			
- single car	569	1,417	365
- car versus other car	1,212	1,578	499
- rest	51	117	8
Total	1,732	3,112	872
Pedestrian			
- versus car	925	127	26
- rest	239	29	1
Total	1,164	156	27
Bicyclist			
- versus car	1,688	473	10
- rest	707	237	0
Total	2,395	710	10
Moped rider			
- versus car	1,112	337	4
- rest	564	216	1
Total	1,676	553	5
Motorcyclist			
- versus car	321	190	25
- rest	111	151	35
Total	432	341	60
Rest	39	31	0
TOTAL	7,924	4,903	974

Groningen

In Groningen, a common accident pattern occurs at intersections where cars turn right across bicycle paths. One solution tried in that city is to bring the path as close as possible to the intersection (so the bicyclists are in view of the motor vehicle operators) or to pull the path back away from intersection so a motorist can turn the corner and then wait for bicyclists crossing the street. Intersections with high accident levels are identified and then fixed when the whole intersection is rebuilt. In other words, they attempt to work for a comprehensive solution. Bicyclists hitting pedestrians is generally not a problem. If such accidents do occur, they are usually not serious, because speeds are low.

Houten

No fatal accidents have occurred within the ring road in 5 years, on any mode of transportation. The keys to safety are that cars yield to bikes, cars travel slowly, good sight distances are provided at intersections, and there is no through traffic in the neighborhoods.

Germany

Statistics on bicycle crashes have been documented in several sources. In 1979, 1,174 bicyclists were killed, representing 9 percent of all traffic fatalities. Also, 47,704 crashes involved bicyclist injuries, which represented just under 10 percent of all traffic-related injuries.[11] A study by Pauen-Hoppner reported that more than 60,000 bicyclists were injured in crashes in 1984.[14]

The fatality rate (in deaths per 1 million inhabitants) was reported to be 138 for all traffic and 13 for bicyclists. Furthermore, compared to other European cities, bicyclist accident rates in German cities are considerably higher. For example, between 1982 and 1985, the rate of bicycle injury crashes per 100,000 working population was approximately 80 in West Berlin, compared to 33 in Amsterdam, 22 in Copenhagen, and 16 in Stockholm.[11, 15]

For motorists, the prevalent safety issues include speed and alcohol use. In Freiburg, Germany, accidents involving bicyclists have remained relatively constant over the past 10 years, in spite of the increasing volumes of bicycle traffic. Official police statistics are used, but a supplemental form has also been employed. Hospital injury reports are three times the number of police-reported accidents. Politicians do not look for accident reports for program backup. Accident data are not used to justify expenditures.

Frankfurt

Overall traffic accidents are high due to the recent influx of new drivers into Frankfurt as a result of the destruction of the Berlin Wall and the increased immigration from East Germany. Last year the city experienced 30 more bicycle accidents than the previous year and recorded an increase in pedestrian accidents as well.

There is an Accident Commission in Frankfurt, as in other German cities, which collects and reports accident statistics uniformly. The recent increase in pedestrian and bicycle accidents seems to have been the result of

- The "other person's fault";
- Too many traffic signs (people are confused); and
- Congestion that creates more aggressive car driver behavior.

Frankfurt has experienced a rash of false insurance claims from pedestrians claiming to be hit and injured by motorists in one very congested part of the city, but these are being handled by the city. In 1992, they recorded more than 3 accidents at each of 54 separate intersections. Recordable accidents must cost more than 3,000 DM ($1,800 U.S.) or result in bodily injury or death. Below 3,000 DM, the claims are settled through insurance firms.

FUNDING PEDESTRIAN AND BICYCLIST IMPROVEMENTS

Great Britain

Safety had been the motivation behind efforts in this area in the past. Three years ago, funds were allocated by the national government in England to local authorities for roadway safety. The "Feet First Project" now provides money to improve the roadway environment. Funding is provided for national efforts and for local city or borough efforts. Improvements designed purely to increase pedestrian mobility are hard to justify on the basis of a "value for money" concept (cost-benefit analysis). However, those schemes designed to reduce accidents can be very cost effective. For example, 20-mph zones pay for themselves in about 16 months, according to one government official.

The Netherlands

Funding for bicycle projects comes from several sources: 50 percent from municipal governments, 15 percent from provincial authorities, and 35 percent from the Ministry of Transport and other national budgets. The concept of "leveraging" national bicycle money is also important. Bicycling improvements cost 2.5 cents per km; walking improvements cost 0.5 cents per km; and 50 times these amounts are spent for mass transit.

The Amsterdam metropolitan area has been decentralized. Although bike facilities are inexpensive in comparison to roadway expenditures, getting funding at the local level is difficult. Quality, not quantity, whether of advocates or of arguments, is important.

In Groningen, the central government used to pay 80 percent of the cost of constructing bicycle facilities. Today, they pay for only 50 percent, which is the same as for motor vehicle facilities. Consequently, there is less incentive to spend money on bicycle facilities than there was a few years ago. However, 70 percent to 75 percent of transportation money is still spent on bicycle facilities.

Germany

On trunk roads and motorways, even in local areas, Federal money may be spent only on increasing the roadway capacity for motorized vehicles. Subsidies provided by the Federal government for local roads and for public transportation cannot be used for bicycle facilities. A new funding program that would provide money for these facilities may become available soon. Local money is currently the only source of funds for bicycle or pedestrian facilities, except in the former East Germany, where Federal shares of 90 percent (with a 10 percent local match) can be used for bicycle/pedestrian projects. Transportation agencies favor automobile flow, while urban and environmental agencies in Berlin favor bicycle and pedestrian travel.

Frankfurt

Frankfurt's annual bicycle budget ranges from 250,000 DM to 500,000 DM ($150,000 to $300,000 U.S.). This budget is small when compared with a much smaller community such as Freiburg, where the annual bicycle budget is 4 million DM ($2.4 million U.S.).

PUBLIC TRANSIT

Frankfurt

There is one company that provides both heavy rail, trolley, and bus services in the Frankfurt metropolitan area. The annual total subsidy is 500 million DM ($300 million U.S.), of which the State pays 20 million DM ($12 million), Frankfurt pays 230 million DM, and the Federal government the remaining 250 million DM.

Currently, there is much discussion about how to fund overall transport and traffic programs in Germany. Since 1956, there has been a simple tax formula on gasoline that has funded program costs. With a downcast economy, new, more complicated schemes are being proposed and debated. There exists a tension between Federal and local agencies on how to fund a balanced transportation system.

3. FACILITIES IN ENGLAND

PEDESTRIAN FACILITIES

The project team observed a variety of pedestrian facilities in England. It should be mentioned that many of these facilities were also used in other countries in Great Britain, but all of them were specifically observed in England. Some of these are mentioned below.

Zebra crossings (see Figure 1) include zebra crosswalk stripes across the road with dashed lines used to mark the crosswalk on both sides. Flashing yellow lamps ("belisha beacons") are mounted on poles on each side of the crosswalk. These crossings are installed at selected midblock locations (never at intersections). At zebra crossings, pedestrians have the right-of-way, and drivers must yield (i.e., slow or stop) to pedestrians in the crosswalk. Zebra crossings are preceded by zig-zag pavement markings next to the curb on the vehicle approach.

Pelican crossings are midblock crossings controlled by traffic signals and pushbutton pedestrian signals. The pushbutton hardware lights up and conveys specific messages to pedestrians during each interval, as shown in Figure 2. A walking green man symbol and a standing red man are displayed, as shown in Figure 3. A flashing green man indicates pedestrian clearance. A flashing green man on the pedestrian approach concurrent with flashing amber and red ball on the vehicle approach precedes the green ball indication on the vehicle approach. Instead of zebra crosswalks, pelican crossings have dashed (not solid) parallel lines to mark the crosswalk. As with zebra crossings, pelican crossings are not used at intersections, but are installed only at selected midblock locations.

Figure 1. Zebra crossing with belisha beacons in London.

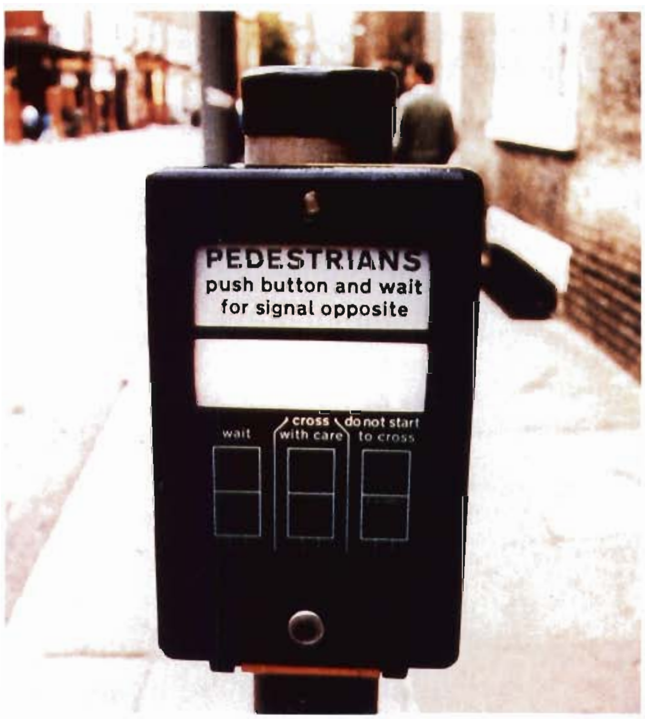


Figure 2. Pedestrian pushbutton hardware in Great Britain gives feedback regarding when to cross.

a.

b.

Figure 3. Pedestrian green man (a.) (WALK) and red man (b.) (DON'T WALK) signal displays.

Toucan crossings (see Figure 4) are shared crossings for pedestrian and bicyclists (cyclists "too can" cross together) at selected crossings at the intersection of roadways with pedestrian and bicycle paths. The preferred layout includes a tactile warning surface, audible beepers or tactile rotating knobs, pushbuttons with "WAIT" display in each corner of the crossing, infrared red lamp monitoring, and vehicle detection on all approaches. The desirable crosswalk width is 4 m; the minimum acceptable width is 3 m. Signal indications include red standing man, green walking man, and green bicycle. The flashing amber with the red ball indication is not used for the vehicle approach. Crosswalk lines are delineated by white squares.

Figure 4. Toucan crossings in Great Britain provide separate pedestrian and bicyclist signals where trails cross roadways.

Puffin (Pedestrian User Friendly INtersection) crossings, generally installed at intersections, consist of traffic and pedestrian signals with red pushbutton devices and infrared or pressure mat detectors. After a pedestrian pushes the button (or stands on the mat), a detector verifies the presence of the pedestrian. This helps eliminate "false signal calls" associated with children playing with the signal button or people who push the button and then decide not to cross. If a pedestrian is present at the end of a vehicle cycle, the red traffic signal is indicated to motorists, and pedestrians see the green man (i.e., WALK display). A separate motion detector extends the green interval (if needed) to ensure that slower pedestrians have time to cross safely. If a pedestrian pushes the button but fails to wait for the “green man” symbol, the detector will sense that no pedestrian is waiting and will not stop motor vehicle traffic needlessly.

Puffin crossings are recent developments and are said to improve pedestrian safety and reduce unnecessary vehicle delay. Since the motion detector can detect only those pedestrians walking within the crosswalk lines, physical barriers are used on the curbs to channel pedestrians into the crosswalks. At some crossings, tactile surfaces have been introduced that guide a visually impaired person to the crosswalk. Puffin crossings are currently used at 27 demonstration sites in Great Britain. One official stated that they expect to eventually replace all pelican and toucan crossings with puffin crossings if they are found effective based on pedestrian accidents, vehicle delays, detector and equipment adequacy, and other factors.

Pedestrian messages, such as “LOOK RIGHT” or “LOOK LEFT” (see Figure 5), are painted on the street next to the curb to remind pedestrians which direction to look for motor vehicle traffic prior to stepping into the street. These messages are used extensively in London, where many tourists visit. (Many U.S. tourists are accustomed to looking left for traffic before stepping off the curb and looking right for traffic when standing at a pedestrian island in the middle of a two-way street).

Figure 5. Pedestrian pavement messages and refuge islands.

Pedestrian refuge islands are used at many intersection and midblock crossing locations to help pedestrians cross wide streets. Island structures are generally equipped with curb ramps. They frequently have a tactile warning for visually impaired pedestrians, sometimes with midblock pedestrian signals.

Some islands are designed with barrier fencing and a staggered crosswalk to encourage pedestrians to cross each direction separately, thereby making it a safer two-step process.

Pedestrian separators (barriers) are common in some British cities, such as London, to channel pedestrians to specific "safer" crossing locations (see Figure 6).

Special pedestrian crossing prohibitions are installed at a few crossing locations; these signs flash during periods when pedestrians are not allowed to cross due to unsafe motor vehicle conditions (see Figure 7).

Pedestrian overpasses and underpasses (subways) are used in many locations where it is not safe or feasible for pedestrians to cross at street level. For example, a new pedestrian and bicycle bridge has been constructed to span the railway lines near the Cambridge Rail Station (see Figure 8). The facility, which has been in place for 3 years, has generated about a 7 percent increase in bicycle and pedestrian use across that span of railway.

Sidewalks are used on all residential roads. Most of the older arterials already have houses and sidewalks adjacent to them. Tactile warning strips are used on some wheelchair curb ramps to help prevent blind pedestrians from unknowingly walking down the ramp into the street (see Figure 9). Where sidewalk repair and maintenance is under way, visible red-and-white barricades are used, as shown in Figure 10.

Pedestrian malls are used extensively in many English towns and cities to accommodate more pedestrians and promote safer walking in downtown areas. Malls are restricted to pedestrians either full-time (Figure 11) or part-time (Figure 12).

Figure 6. Pedestrian barriers (separators) are used extensively in London to channel pedestrians to preferred crossing locations.

Figure 7. Pedestrian crossing prohibition at midblock crossing in London.

a.

b.

Figure 8. (a. and b.) This new pedestrian and bicycle bridge spans railway lines in Cambridge, England.

Figure 9. Tactile warning strips on sidewalk curb ramps guide visually impaired pedestrians to a formal street crossing.

Figure 10. Pedestrian work zone barricades on sidewalk.

Figure 11. Pedestrian mall in York, England.

Figure 12. Time-restricted pedestrian mall in Cambridge, England.

BICYCLE FACILITIES

A variety of bicycle fatalities occur in Great Britain, particularly in smaller cities such as York and Cambridge, England, which have extensive networks of bicycle lanes and paths. Bicycle lanes are commonly narrow; some were observed by study team members to be 3 feet wide or less in many cases, as shown in Figure 13. Along some city streets, contraflow bike lanes exist; that is, one-way bicycle lanes move in the opposite direction to one-way motor vehicle traffic (see Figure 14). Double yellow lines next to the curb mean no parking.

Bicycle trails are found in some areas of Great Britain, which allow for long-distance cycling separate from motor vehicles (see Figure 15). Entrances onto these trails are designed to prevent most types of motor vehicles (including motorcycles) from entering (see Figure 16). Such barriers cause some problems for bicyclists who enter or exit the trail. Bicyclists are also allowed to use an extensive network of exclusive bus lanes throughout London. In York, an abandoned rail line became an excellent bicycle facility using the existing bridges and underpasses. A 1,000-mile cycle route network for London is planned over the next several years.

Figure 13. Narrow bicycle lane in Cambridge, England.

Figure 14. Contraflow bicycle lane in Cambridge, England.

Figure 15. Bicycle trail on an abandoned railroad right-of-way south of York, England.

Figure 16. Entrance to bicycle trail is designed to restrict entry by motor vehicles.

TRAFFIC CALMING STRATEGIES

A variety of traffic calming techniques are used in Great Britain. Among these are chicanes (i.e., zig-zag routes), width reductions, roundabouts, and road humps. These methods tend to be effective measures for keeping vehicle speeds at reasonable levels once traffic has been slowed down initially via a signalized intersection. The 20-mph zones (see Figure 17), recently introduced, have spread rapidly. They rely on traffic calming measures to ensure that drivers comply with them. Various calming devices, such as speed humps dispersed at regular intervals (see Figure 18) introduce a frequency of auto driver decisions that encourages smoother, lower speeds. Traffic diverters sometimes block motor vehicle movement through intersections, as illustrated in Figure 19.

Innovative portable barricades are used to quickly implement traffic closure plans, as shown in Figure 20. These water-filled, brightly colored plastic barricades can be moved easily if necessary.

Another type of traffic calming technique used in England is speed cushions, as illustrated in Figure 21. Passenger cars and small delivery vans experience the bump's traffic calming effect. However, the tires of transit buses can straddle the raised area and escape the jarring effect of the speed cushion, because these vehicles are wider than passenger cars. In this way, transit riders are spared the uncomfortable jolt that normally occurs when a large transit bus passes over a speed hump or speed table. Passenger car speed is still reduced, as the traffic calming device remains effective for them, while allowing transit and emergency vehicles to pass virtually unimpeded.

One official mentioned that tension exists between city interests to minimize in-city auto traffic, and county residents who want auto access into the city. One city official stated, however, that most of the public strongly supports traffic calming strategies.

Figure 17. Networks of 20-mph zones in British neighborhoods often include signs, narrow streets, speed humps, or other measures. The combination of multiple measures on a neighborhoodwide basis is most effective.

Figure 18. Speed humps slow traffic speeds on residential street in York, England.

Figure 19. Diagonal motor vehicle diverter at a residential intersection in York, England.

Figure 20. Temporary barriers used to block a street to motorized vehicles in London.

Figure 21. "Speed cushions" in use on a residential street in the English city of York.

4. FACILITIES IN THE NETHERLANDS

PEDESTRIAN FACILITIES

Much of the knowledge gained from officials in The Netherlands emphasized traffic calming strategies and bicycle facilities. However, some considerations are also made for pedestrians. For example, for midblock crossings, instead of using zebra crossings (where motorists are supposed to stop and yield to crossing pedestrians, but sometimes don't) they now use "block crosswalks." These show a dashed line across the roadway, at which pedestrians do not assume vehicles will stop. Zebra crossings are used only where motor vehicle drivers could be expected to stop (e.g., lower-speed routes). Special pedestrian signing is sometimes used at zebra crossings (see Figure 22). Providing audible feedback on pedestrian pushbutton devices is largely a local decision. Crosswalks on speed humps are also used.

Pedestrian signal displays include a red standing man (i.e., DON'T WALK) and a green walking man symbol (i.e., WALK). A flashing green man (i.e., you may walk, but the red man display will follow soon) follows the steady green man phase. Pedestrian pushbuttons are also used at some crossing locations (see Figure 23). Pedestrian signals are placed at arterial intersections with high volumes of pedestrians and motor vehicles. They are installed near the vehicle traffic signal.

A flashing yellow indicator has been tested in The Netherlands (along with a legal regulation) in some simple situations instead of a solid red ball for pedestrian signals. The symbol used for the yellow indicator is a triangle with an exclamation point inside it. The flashing yellow tells pedestrians that they may cross at their own risk, but other traffic has priority. The zebra crosswalk markings are removed at such locations to avoid suggesting that pedestrians have priority in crossing. Pedestrians still have the option of waiting or calling for the pedestrian green. The pedestrian green is an exclusive movement and therefore should be conflict free. The motivations for testing this symbol include the following:

- Whether the pedestrian signal phase is actuated or pretimed, pedestrians are allowed to choose between crossing with the green indication or crossing during the flashing yellow indication during an appropriate gap in traffic.

- Since the red indication is replaced by a flashing yellow, the situation allows for 100 percent compliance by pedestrians. Pedestrians no longer cross against the red indication because there is no longer a red indication.

- At actuated locations, less time is consumed by exclusive pedestrian movements. Since pedestrians know that it is legal to cross whenever they want, they may not bother to call for the pedestrian green.

- The Dutch also state that the use of flashing yellow indications enhances the status of the red indication. Red indications will only be used at complex crossing locations.

Figure 22. This pedestrian crossing at the Amsterdam airport includes zebra pavement stripes and pedestrian signing.

Figure 23. Pushbutton at Amsterdam pedestrian crossing.

The disadvantages found with the triangle signal include the following:

- It is unknown if pedestrians understand that they do not have the right-of-way while they are crossing during the flashing yellow indication. However, it appears that turning traffic must give way to pedestrians; therefore, an exclusive turn arrow cannot be combined with a flashing yellow pedestrian indication.

- It is safer for pedestrians to cross with the green indication in conflict-free situations. The situation of crossing during a flashing yellow pedestrian indication is still the same as crossing during a red indication. It is difficult to explain to and convince children that they should wait for the green while they see others crossing at times when the light is yellow or red. Many elderly feel safer crossing in groups rather than alone. Following the crowd, an older person may end up at the tail end of the group, exposed to oncoming vehicles, and unable to sprint to safety.

Another device tested in The Netherlands was a "pedestrian sender." This device provides a means for signal preemption for vulnerable pedestrians, including the visually and mobilely impaired. The pedestrian sender is similar to the emergency beepers used by the elderly and impaired to call for help. This device influences the traffic controller by doubling the pedestrian green time, activating an acoustic signal, and preventing conflicting traffic movements. No information about providing a directional indication to the vulnerable pedestrian was available. The results of a questionnaire indicated great enthusiasm for the pedestrian sender. The survey also indicated no misuse of the device.

While pedestrian improvements in Delft were said to lag behind bicycle facilities, pedestrian signals are installed at selected intersections in that city. A green man, yellow triangle, and red man symbol is used for the WALK, DON'T START (clearance), and DON'T WALK intervals, respectively. Zebra-striped crosswalks are commonly used at pedestrian crossings.

BICYCLE FACILITIES

In The Netherlands, bicycle transportation is a way of life, and the most commonly used bicycles are inexpensive and have chain guards (see Figure 24). One primary reason for these cheap bicycles is the high incidence of bicycle theft. To nonbicyclists, potential theft is a deterrent to use.

Most bicyclists (including commuters) ride slowly. It is not uncommon to see adult passengers riding "sidesaddle" on the rear of the bike, or children being carried in front or in the rear, often using special child seats. While bicyclist dress is often casual, women often wear skirts and dresses while cycling; their bicycles are usually equipped with skirt guards.

In The Netherlands, one of the major goals is to reduce the number of automobiles. On multilane roads, a separate bicycle or pedestrian path is often provided. There are at least two levels of facilities: major, long-distance routes, and shorter, local routes. When roadway space is limited, a lane is not marked for bicyclists. Traffic signals are timed based on motor vehicle and bicycle traffic.

Figure 24. Most Dutch bicycles are not fancy, but they provide basic transportation for their owners.

Bicycle Lanes and Paths

The general philosophy in The Netherlands is to separate bicyclists from motor vehicles whenever speeds increase above 30 km/hr. According to one official, bicycle paths are safer than bike lanes between intersections. At intersections, however, a separate bicycle path will generally have higher numbers of accidents. Separate bicycle paths (see Figure 25) are considered desirable under heavy motor vehicle traffic conditions, but undesirable along streets with low volumes of motor vehicles. Their general approach to bicycle facilities is to avoid making them too sophisticated.

Figure 25. Some bicycle paths parallel roadways, such as this one in Groningen, The Netherlands.

Bike lanes are typically wide enough for two cyclists to ride side by side. The bike lanes are generally red in color, with visible (and well-maintained) white bicycle symbol markings (see Figure 26). Bike lanes are typically located between the motor vehicle lane and the sidewalk and are sometimes part of the sidewalk. Problems sometimes occur with motor vehicles parked on the bicycle lane. Bike lanes are sometimes marked through intersections, as shown in Figure 27.

Figure 26. Typical bicycle lanes in The Netherlands are often reddish in color and wide enough for two cyclists to ride side by side.

Figure 27. Bike lanes are sometimes marked through intersections.

Bicycle Signals

In The Netherlands, separate bicycle signals are commonly used at arterial intersections that have bike lanes and high volumes of bicyclists and motor vehicle traffic. The bicyclist signals are vertical red, amber, and green bicycle symbols mounted on a pole, as shown in Figure 28. They are located either next to the vehicle signal head (i.e., using the same 20-cm-diameter signal face as the vehicle signal) or at a lower level (1-m high) using a smaller size signal face (7 to 7.5 cm).

The signal indications are all steady (i.e., no flashing indications), and there is typically an advanced green phase for bicyclists, with a simultaneous red phase for right-turning motor vehicles. According to one local official, levels of compliance with the signal are generally not very high.

In some cities, such as The Hague and Groningen, a special bicycle phase allows bicyclists in the bike lane to proceed straight before motor vehicles (i.e., right-turning traffic) are allowed to proceed. Motor vehicles are not allowed to turn right on red in The Netherlands, although bicyclists are allowed to do so in certain cities and locations. Bicycle lanes are not typically placed to the right of parked cars, since motorists cannot see bicyclists as easily. It is common for bicycle lanes to end before intersections. Mixing traffic before an intersection promotes anticipation and interaction among road users at the crossing. Otherwise automobile drivers turning right often are not fully aware of bicyclists and moped riders coming from an adjacent bicycle lane.

Bicycle Rental

Renting a one- or three-speed bicycle in The Netherlands is relatively inexpensive, costing approximately 10 guilders (about $6 U.S.) per day or about 50 guilders ($30 U.S.) per week. Bicycle rental shops are located throughout towns and cities, commonly at train stations. Information on bicycle rentals is provided at local hotels.

a.

b.
Figure 28. (a. and b.) Bicycle signals used in Amsterdam.

Separate Bicycle Streets

Separate bicycle streets are provided in some central business district areas, such as Amsterdam. However, the project team noticed that bicycle streets do not work well where there are high pedestrian volumes already on the sidewalk spilling over into the street. Under such conditions, bicyclists are often forced to dismount and become pedestrians (see Figure 29).

In the inner city of Groningen, where there are few cars, no special bicycle facilities (e.g., lanes) are needed, so bicyclists share the travel lanes with motor vehicles. Bicycle lanes and paths are used throughout Groningen. Asphalt is being used to overlay bricks on bicycle paths to provide a smoother ride. A reddish pavement is commonly used for bicycle paths and lanes.

At some signalized intersections, a red zone is placed in front of the motor vehicle stop line, which indicates that bicyclists may proceed in front of motor vehicles at a red signal. This allows bicyclists to avoid engine exhaust, gives bicyclists a head start on a green phase, allows bicyclists to be in a position where they are more visible to motorists, and is more comfortable for bicyclists (see Figure 30). The bicycle red zones also facilitate bicyclists making a left turn and reduce the likelihood of right-turning motorists striking bicyclists.

Other facilities allow bicyclists to cut through neighborhoods, where motor vehicles are blocked by physical barriers (see Figure 31). Railroad crossing arms are available across some bicycle paths when they cross railroad tracks. On joint bicyclist and pedestrian paths, a lip separates walkers from bicyclists to guide vision-impaired pedestrians. Extensive bicycle parking is common at bus and train stations, as shown in Figure 32. Separate bicycle bridges are also common (see Figure 33).

Figure 29. This bicycle street in Amsterdam serves more pedestrians than bicyclists.

Figure 30. Advance bicyclist stop line at intersection in Groningen, The Netherlands.

Figure 31. Barriers are used to block motor vehicles and allow bicyclists through traffic on this Dutch street.

Figure 32. An army of bicycles awaits their owners at this Dutch bus terminal.

Figure 33. This bicycle bridge in Groningen provides easy crossing over a canal.

In Delft, bicycle counts help determine facility needs. Cycle paths generally allow travel in both directions. The minimum width for two-way bike-only paths is 1.4 m. Bicycle bridges and underpasses have been constructed to allow for safer and more convenient bicycle travel, particularly for crossing barriers such as highways, canals, and roadways. Road surface markings are provided on bicycle lanes, and colored cycle paths are also used.

At intersections in Delft and other Dutch cities, right-turn-on-red is allowed only for bicyclists, not for motor vehicles. Wide positioning lanes are also provided at intersections for bicyclists. Bicycle storage facilities are provided in residential areas and in the city center. Bike lock-up stands are also provided throughout the city.

In the new town of Houten in The Netherlands, motor vehicle traffic must yield to bicyclists and pedestrians at intersections. The local transportation network is designed to favor cycling and walking trips, while serving to discourage motor vehicle use for within-town trips. The high quality of the nonmotorized transportation facilities in the center of town is shown in Figure 34.

Figure 34. Intersection design in Houten gives priority to bicyclists and pedestrians over motor vehicles.

White pavement triangles are used in The Netherlands to indicate that motor vehicle traffic must yield to the other intersection approaches. Painted squares are used to accentuate a lane. As shown in Figure 35, motor vehicle traffic must yield to bicycle and pedestrian traffic.

TRAFFIC CALMING STRATEGIES

In general, design is used to control vehicular speeds rather than enforcement. Specifically, 30-km/hr zones are used to force vehicles to slow down. Roundabouts use either bicycle pathways around them or bike lanes marked on the roadway, according to space availability. Roundabouts are one lane only. They are kept small to reduce vehicular speeds.

Figure 35. Triangular pavement marking shapes built into the pavement at this location indicate that motor vehicle traffic must yield to cyclists and pedestrians.

Delft

The concept of the *woonerf* has been used in Delft since the early 1970's. These are streets where no through traffic is allowed and vehicle speed limits are very low. *Woonerven* are designated on selected streets in city centers and in neighborhoods. For the safety of pedestrians and bicyclists, slow vehicle speed is the key element. *Woonerven* should be designed so vehicle speeds are low, and so they can be used correctly without police enforcement (e.g., through such measures as narrow roadways and speed humps). Signs and paint are not effective by themselves in reducing vehicle speeds.

The introduction of *woonerven* was a breakthrough to protect residential areas from speeding motor vehicles. Though it was thought automobiles should drive no faster than pedestrians walk, experiments showed that the goals for safety could be reached by more simple measures that allowed maximum speeds of 30 km/hr. So that is the current policy. In addition to the *woonerven*, other commonly used traffic calming techniques include traffic diverters, street narrowing, and speed humps.

Groningen

A variety of traffic calming measures is used in Groningen, including traffic diverters and roadway narrowing. Various types of speed humps are used, depending on the type of roadway and the amount of speed reduction desired. Along one subdivision street, a basketball pole and goal were installed in the middle of the street, which emphasized the use of the street for neighborhood activities in addition to low-speed local travel. Old construction vehicles, such as tractors, are sometimes used as decorative street closure devices. Pedestrians use pushbuttons to cross streets at selected points.

Houten

The road hierarchy of Houten consists of a ring road around the city, which is about 5 km in diameter. District roads connect the ring road to 17 neighborhood districts. Where district roads enter neighborhoods, houses are taller than surrounding homes to identify entrances and road types. The district roads may narrow upon entering the neighborhood districts. Each neighborhood street name ends with the name of the neighborhood district in which the street is located. This assists travelers and emergency vehicles in finding their destination.

Motorists wishing to travel between zones must go out to the ring road, go around the city, and enter a neighborhood district by a district road. Roads between zones are blocked by physical barriers and may be passed only by bicyclists, pedestrians, and emergency vehicles. Pedestrian and bicycle paths exist throughout the entire length of the city, and bicycle and pedestrian paths connect each of the neighborhood districts. The ring road and the local districts are illustrated in Figure 36.

This circulation pattern reduces the volume of motor vehicles and traffic noise on residential streets. Also, bicycle use is greatly encouraged, since it is often easier and faster to travel between zones by bicycle (using the connector routes) than by motor vehicle (which requires using the ring road). Bicyclists and pedestrians should not have to cross the ring road, since 5 tunnels and 2 bridges are provided for their use. Local officials state that efforts continue to build tunnels that are safe for nonmotorized users.

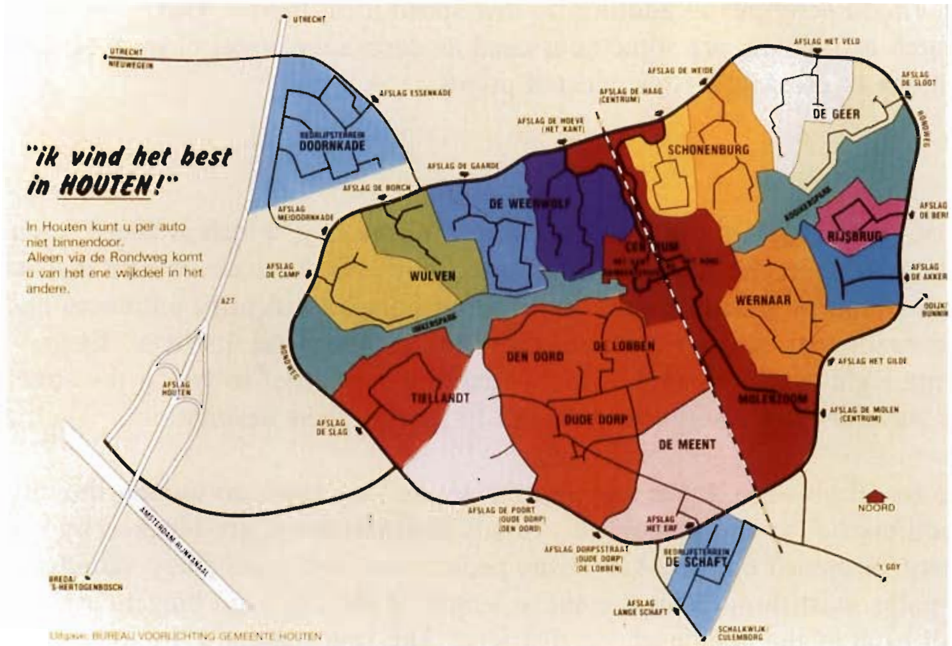


Figure 36. In Houten, motor vehicles must use a ring road to travel between districts.

Neighborhood roads run off of district roads and have sidewalks. Housing roads are smaller local streets that run off of neighborhood roads. No sidewalks are constructed along housing roads, since they are not needed because traffic is infrequent and moves slowly. Motor vehicles may be parked at some housing units, while other areas have lots located away from housing units. Loading zones are located at all units.

Unlike private cars, buses travel between neighborhoods by using electronic devices to open gates. Police and fire personnel also have keys to unlock the gates to allow access among the 17 neighborhoods. A railroad station is located at the city center and has guarded bicycle parking.

At intersections that cross main bicycle paths, cars must yield to bicyclists. The reduced speed of motor vehicles is the key to improved pedestrian and bicyclist safety. All schools in Houten are built next to bicycle and pedestrian paths, and most school children bicycle or walk to school along these paths, starting at age 5 or 6. Bicycle racks are provided at all schools.

5. FACILITIES IN GERMANY

PEDESTRIAN FACILITIES

Various types of pedestrian facilities are used in Germany. These include the following:

Zebra crosswalks, such as those in Frankfurt, are warranted for pedestrian crossing locations where there are more than 350 cars per hour and more than 50 pedestrians per hour. Some of the pedestrian signal heads show both pedestrian and bicycle signal displays during the red and green phases. In Germany, zebra crossings are required to have illumination.

Pedestrian signals are used in German cities with the walking man/standing man symbols. The pushbutton hardware uses the phrase "SIGNAL KOMMT" (i.e., signal is coming), as shown in Figure 37, to tell the pedestrian that the pushbutton works and is responding.

Figure 37. Pedestrian pushbutton device gives feedback "SIGNAL KOMMT" (signal is coming) to waiting pedestrians.

Pedestrian refuge islands are often installed without zebra striping to avoid the requirement to install overhead lighting. This makes the pedestrian refuge island less expensive than the zebra crosswalk treatment. Pedestrian crossing guidelines and criteria have been established for use in the cities. The islands are designed to allow wheelchair access.

Raised crosswalks are speed humps at a crosswalk location. Some crosswalks had zebra striping. When zebra crosswalk striping is installed, overhead lighting must also be provided for the crosswalk.

The Promenade is a paved pedestrian and bike trail and city park that rings the city. This tree-lined route in Munster was formerly the location of the old city walls. A peak hour use of 1,200 bikes per hour is reported.

Pedestrian zones, which can also be used by cyclists during off-peak hours (i.e., evenings), have been established on many downtown streets. Not only are there few conflicts with pedestrians during off-peak hours, but it was claimed that the presence of pedestrian and bicycle traffic helps eliminate crime and adds an element of personal safety. The pedestrian mall shown in Figure 38 allows bus, bike, and taxi travel throughout the day. In Freiburg, on Kaiser Josef, a pedestrian street, cars and bicycles are not permitted. Streetcars and pedestrians have exclusive use of the street, as shown in Figure 39.

Figure 38. Pedestrian mall in Munster, Germany.

Figure 39. Street used for pedestrians and streetcars in Freiburg, Germany.

BICYCLE FACILITIES

Various measures were discussed to allow and promote bicycle use. As discussed by Munster city officials, these measures included the following:

Bike routes are designated by signs only.

On-street bike lanes are installed on the street level and are typically painted red or installed with a red pavement surface. This type of facility is generally less expensive to install than off-street facilities.

Off-street bike lanes are sometimes installed on the sidewalk level, as shown in Figure 40. Generally marked with a distinctive red color (which contrasts with the gray stone used for pedestrians and the clear zone between the street and bike path), these lanes provide a greater separation between the bicyclists and motor vehicles. When a parking lane exists, this separation allows room to open car doors without obstructing the bike path.

Figure 40. Off-street bicycle/pedestrian path in Germany.

As observed in Munster, bike paths are typically 1.6 m wide (one direction on each side of the street), and the separation between cars and the bike path is generally 0.7 m wide. Some areas are narrower in cases where sufficient room does not exist. This type of facility was originally promoted in the 1940's as a means to eliminate the "hindrance" to cars caused by bikes. They are now retained to separate cars and bicyclists for safety purposes. Another variation of off-street pedestrian and bicycle lanes, as used in Freiburg, is shown in Figure 41.

Bike tracks are generally paths through the countryside and are signed routes. They are generally not paved.

Bus lanes that can also be used by bikes require a width of 4.5 m or more to allow buses to easily and safely overtake cyclists when necessary. As shown in Figure 42, these facilities are signed and marked with a bus and bike symbol.

Intersection improvements that facilitate bike travel include an advance stop line that allows bicyclists to exit sidewalk paths to turn left in front of motorized traffic. This allows a safer path for left-turning cyclists, provides better visual contact between bikes and cars, and allows cyclists to be away from vehicle exhaust. This design has been found to be safer than the traditional weave condition. Other signal treatments include special advance green for cyclists, and in some cases signals timed for cycle traffic (based on a signal progression of approximately 9 mph). It was also observed during site visits that traffic signal heads in Munster had 1 green cycle signal and 2 red cycle signal heads. This was done to improve visibility of the red cycle signal.

Bike parking lockers and sheltered spaces are offered at some park-and-ride or park-and-bike lot at a transit station. Sheltered bicycle parking spaces are provided at locations

Figure 41. Asphalt pedestrian and bicycle lanes on Freiburg sidewalk.

Figure 42. Lane used for buses and bicyclists only.

such as transit stations, as shown in Figure 43. Each bike locker can hold two bikes and provides better security than bicycle shelters for more expensive bicycles (see Figure 43). The rental fee for bike lockers is 20 Deutsche marks (DM) ($11.70 U.S.) per month, which is much less expensive than car parking. This particular lot has 108 car parking spaces and is on the outskirts of the built-up area of the city. The construction cost is much less for bike parking facilities than for car parking. Furthermore, about 10 to 12 bikes can be parked in a single car parking space.

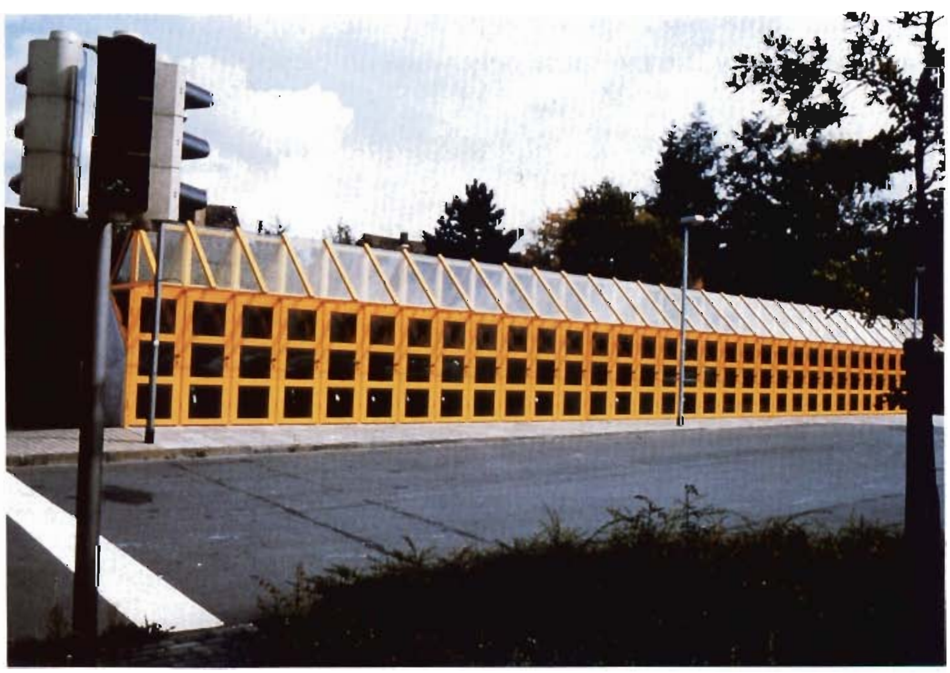
Bike parking at the train station facilitates train-bike combination trips. Bikes are parked in a monitored area and can be parked for 4 days before being moved to a long-term parking area. This allows train commuters to leave their bikes at the train station over the weekend. The city of Munster is also planning a 4,000-space underground bicycle parking facility at the train station.

Separate signal heads for cyclists, as well as separate distinctive signal heads for trolleys, are used where exclusive bus lanes exist (using vertical or horizontal white lines as bus signal displays). This often results in three sets of signal heads side by side (car, trolley, and bike).

Installing bike racks at corners also helps intersection visibility. The study team was shown an intersection where car parking at the intersection had previously created a visibility problem for motorists on the side street. This problem occurred even after NO PARKING signs were posted. Installing bike racks at the corner physically prevented car parking and opened up sight distance for side-street traffic.

Bicycle lanes with continuous lane markings are reserved solely for bicyclists. If the lane line is dashed, cars and trucks may use the space only when no bicycle is present.

a.



b.

Figure 43. Illustrations of bicycle shelters (a.) and bicycle lockers (b.) used in Germany.

Bicycle lanes are slightly elevated, which was mentioned as a potential safety problem, since bicyclists may lose control or overturn when they hit the raised edge of the bike lane.

Frankfurt

City officials in Frankfurt work toward giving more of the street space to bicyclists by permitting bikes to have their own lane near the curb or by sharing in an exclusive bus lane. A separate bicycle track (path) in the financial district near a university has been highly utilized. This separate path has rubberized "C" curbs bolted along the top of the street curbs (76 cm long and 10 cm high). As this track moves out into the street at certain points, the track area is painted green (see Figure 44).

Freiburg

Bicycling is a significant mode of transportation in Freiburg. In 1976, the bicycle path network consisted of 41 km of unconnected, fragmented facilities. By 1987, the system had grown to 135 km of interconnected, efficient pathways and lanes. The bicycle network has been integrated with 30-km/hr zones on neighborhood streets. Freiburg has 800,000 DM ($480,000 U.S.) per year budgeted for bicycleway maintenance of pavements, signs, and markings. The city permits cycles to ride the opposite direction down a one-way residential street using contraflow lanes.

The area east of the town center, near the Schlossberg Castle, has a 1-km cycle road that cost 2 million DM ($1.2 million U.S.), with 100,000 DM ($60,000 U.S.) for pavement markings alone. A pedestrian and bicyclist bridge near the Freiburg rail station carries thousands of people each day (see Figure 45).

Figure 44. Rubberized C-curbs separate bicycle lanes from motor vehicle lanes in Frankfurt.

Figure 45. Pedestrian and bicyclist bridge near Freiburg rail station.

TRAFFIC CALMING STRATEGIES

Many forms of traffic calming strategies are used in Germany. Techniques used in Munster, Frankfurt, and Freiburg are discussed below.

Munster

City officials in Munster stated that many of their traffic calming ideas came from The Netherlands in the 1970's and started in Munster in the 1980's. They stressed that physical measures were needed to control driver speeds effectively. While speed humps are used, they are not liked by cyclists (due to discomfort) and are therefore not a priority treatment. The goal is to create 30-km/hr zones (see Figure 46) on sections of neighborhood streets through designs that are self-enforcing, since there are too few police to do any significant speed enforcement on local streets. Currently, there are 25 such zones established in Munster, with plans for implementing 90 more 30-km/hr zones. They are looking for lower-cost measures that are quicker to install.

Many of the physical designs are very expensive to build. Also, holding public meetings and obtaining approval from the area residents and town council can be a lengthy process. Munster officials are looking into a plan to use concrete bollards (550 kg), which are placed in the street (along with the appropriate striping) to create a road narrowing effect. As shown in Figure 47, the concrete bollards are movable to allow low-cost installation (and to test their effect on traffic operations and neighborhood acceptance). There is virtually no approval needed prior to installation. The bollards are not fixed to the pavement, but are too heavy to be moved by vandals, and have orange and white diagonal striping on them for visibility to nighttime motorists. The estimated cost per bollard was 500 DM ($300 U.S.), which is about six times cheaper than traditional traffic calming measures.

Figure 46. One of many 30-km/hr zones on residential German streets.

Figure 47. Concrete bollards are used in Freiburg for traffic calming.

Most traffic signals have stop signs posted in full view for drivers. These are to be used if the signal goes out, at which time motorists treat intersections as sign-controlled locations. This practice is not in conformance with the U.S. *Manual on Uniform Traffic Control Devices*. Few, if any, stop signs are used elsewhere in the city. Motor vehicle drivers appear to be willing to allow bicycles to get ahead of cars at traffic signals. Drivers also seem to be aware of cyclists and are generally accommodating to cycle traffic in the street.

City engineers in Munster (and Freiburg) are experienced bicyclists, whereas engineers in many other German cities are not. It seemed apparent that special design features and plans for bicyclists are well promoted when local engineers have firsthand knowledge, experience, and personal interest in bicycling.

Other traffic calming measures used in Munster to slow cars, divert through traffic, or reduce volumes include the following:

The German version of the Dutch *Woonerf* or *Vekehrsberuhigung* consist of narrow streets with various speed-controlling features designed for pedestrian walking speed (11 km/hr). This concept allows all modes (car, bike, and pedestrian) in the same space, with the pedestrian having the right-of-way. The entrance to the *vekehrsberuhigung* has special signing to alert motorists (see Figure 48).

Figure 48. The German *vekehrsberuhigung* are similar to the Dutch *woonerven* (living streets).

Speed humps are made of paver stones with ramped approaches. Speed humps can also be used in a series.

Diagonal diverters to cut off a through street route allow bicycle access and, on occasion, one direction of car access. Some of the land in the diverters may be converted into a minipark, with landscaping and other pedestrian amenities. Some diagonal diverters are designed to allow police and other emergency access.

Road narrowing (chokers) at a street entrance to a local street may be done by moving the curb, extending the sidewalk, and landscaping. Street narrowing (see Figure 49) is sometimes accomplished with trees or other landscaping, such as using tree planters in what would normally be the parking area of the street and thereby narrowing the effective street width. Steel tree guards protect the trees. Signs and posts narrow the street at some locations, although this sometimes creates a maintenance problem because of cars running over them. Midblock street narrowing is sometimes accomplished by extending the curb and allowing only one direction of traffic at a time. A combined choker and bus stop treatment prevents car access when the bus is stopped to pick up or drop off passengers.

Figure 49. Example of a midblock narrowing in Germany to slow vehicle speeds.

Street-narrowing techniques are used in Munster only where there are 100 or more cars per hour. This ensures that opposing directions of traffic exist to create the appropriate speed calming effect. Officials also emphasized that there have been no collisions or accident problems caused by the speed calming.

One-way streets that are designated for two-way bicycle traffic (contraflow bike lanes) are used in Munster. Certain streets are designated as one-way streets for motor vehicles, but allow two-way bicycle traffic. The engineers in Munster call these "imaginary streets."

Cul-de-sac street closures sometimes have narrow openings to allow bicycle access.

Chicanes are zig-zag streets designed to slow vehicle speeds. Chicanes are sometimes made of concrete islands along the street, supplemented with signs. They may also be formed with barricades and posts to create a slalom-type effect in the street. Other chicanes are created by strategically placing flower planter boxes along the street. This, however, creates a maintenance problem for the city, since the city, not the residents, has to care for the flowers.

Angle parking on alternating sides of the street is sometimes supplemented with island treatments to create a chicane effect. Angle parking is not intended for major streets, but is used on residential streets to narrow the width and discourage speeding and cut-through traffic.

Frankfurt

There are ongoing efforts to maintain or develop zones with 30-km/hr traffic speeds. In the city, it costs nonresidents about 250 DM ($150 U.S.) to park per month. City residents pay 30 DM to 100 DM ($18 to $60 U.S.) per month. Fifty percent of all available in-city parking is available for residents only. Parking meter rates in Frankfurt are 2 DM ($1.20 U.S.) per hour.

Freiburg

There have been some 15-km/hr zones established on local residential streets, and only residents may enter with their cars. Lanes have been narrowed to provide bicycle lanes and reduce motor vehicle speeds. In one case, speed was reduced from 70 km/hr to 50 km/hr. It was noted that the separation of cyclists and pedestrians has reduced pedestrian accidents.

The city also has many 30-km/hr zones throughout, most in residential areas. It is customary in some areas to parallel park with the two right tires on the sidewalk (see Figure 50) or with the vehicles parked along the curbs, effectively narrowing the street. In other locations, on one-way streets, parallel parking has been converted to angle parking, resulting in narrower usable street width. These types of narrowings are often effective traffic calming measures.

PUBLIC TRANSIT

Freiburg is served by both a north-south and a new east-west tram line. A four-lane ring road surrounds the town center and has many parking lots. The hours in which deliveries may be made to businesses within the town center have been restricted in the past; some of those restrictions may have been loosened lately.

In planning the city's tram system, providing a separate right-of-way for lines within the city limits has been a priority. A roadway bridge over the main railroad tracks near the Freiburg station (see Figure 44) has been converted to bicycle and pedestrian use. It carries about 10,000 cycles and thousands of pedestrians per day.

Cycle and ride lots have been built at outlying tram stations, and bus-tram connections have also been improved. Freiburg's trams are equipped with a bottom step that can be lowered to accommodate the handicapped or elderly. Reduced-cost monthly passes have also been instituted to encourage commuters to leave their cars at home and ride transit. In 1980, there were 27.3 million riders; by 1992, that figure had increased to 54 million. Discount fare passes and new tram line construction, along with other improvements, are credited with a large part of the increase. With 61 percent of operating expenses recovered through farebox revenues, the transit system has an enviable operating record. Nonetheless, a 35 millon DM ($21 million U.S.) annual deficit is incurred.

Figure 50. City parking along a German street.

6. FACILITIES IN SWITZERLAND

PEDESTRIAN FACILITIES

In the city of Basel, efforts to minimize parking and vehicle access in the city and public transit improvements have both benefitted pedestrians. A number of streets are closed to vehicular traffic, creating full-time pedestrian malls in the central city area. Other streets are posted to prohibit vehicle entry during peak pedestrian hours. Streets are posted with signs indicating hours when vehicle access is restricted (see Figure 51). One potential problem of part-time restrictions is that although they provide great flexibility, they can create confusion and enforcement problems if they are too complex.

Basel is also replacing the asphalt street surface in the downtown area with paver and stone surfaces to make the streets more inviting and interesting to pedestrians and better suited to the historical feel of the city. In some areas, streets that are used predominantly as pedestrian and bicycle areas have concrete flower planters as an entry treatment, which has a narrowing effect and discourages traffic entry and high speeds (during off-peak hours). A street that runs along the Rhine was recently closed to automobiles and converted to bicycle and pedestrian use only.

Crosswalks are marked with yellow zebra markings (see Figure 52). Zebra markings are used at signalized and unsignalized crossings. As in other cities, the crosswalk markings are in very good condition. Yellow markings are used because city officials believe that yellow is more visible to motorists than white pavement markings, although no supporting data were provided. The city may eventually convert their zebra markings to white to be consistent with the rest of Europe.

Figure 51. Pedestrian mall with part-time vehicle restrictions.

Figure 52. Yellow zebra crosswalks used for pedestrian crossings in Basel, Switzerland.

Pedestrian signal indications consist of the green walking man and red standing man symbols; a flashing green man is displayed during the pedestrian clearance interval. Various types of pedestrian pushbuttons were observed. Some pushbuttons merely have a black painted silhouette of a hand on the side, as shown in Figure 53. This conveys a simple but understandable message (i.e., push here). Other pushbuttons have a lighted message with the words "signal coming" when the button is pushed, as in Germany. Some pedestrian pushbuttons are supplemented with an audible message, a soft ticking that varies in speed based on the signal phase. No information was available on the effectiveness of each type of pushbutton. Pedestrian refuge islands (see Figure 54) are commonly installed in wide streets to facilitate pedestrian crossings.

BICYCLE FACILITIES

There are many provisions for bicycle travel in Basel, and one city official mentioned (with some pride) that "we have more bikes than we know what to do with." On-street bicycle lanes are marked with yellow lines that stop 20 to 30 meters in advance of an intersection (similar to guidelines from the American Association of State Highway and Transportation Officials). The yellow bicycle lane line is used because officials believe yellow stands out more than white (however, center lines and lane lines in Switzerland are white, unlike U.S. practices).

The white bicycle symbol is used extensively in bicycle lanes. There is also quite a bit of special routing of bicyclists at some of the signals observed, with skip-line extensions through

Figure 53. Pedestrian pushbuttons used at some Basel intersections.

Figure 54. Pedestrian refuge island located in a wide street in Basel.

the intersection, special signal heads, pushbuttons for bicyclists (see Figure 55), and median island openings for bicycle crossings through the intersection (see Figure 56). The study team observed considerable provisions for bicycle parking throughout the city. The most vivid example is outside the train station.

On one street, one vehicle lane has been eliminated and converted into a separate two-way bicycle path on one side of the street (see Figure 57). Separation is achieved using bollards between the bicycle path and street. The path has a white center skip-line and bicycle symbols to indicate two-way bicycle travel. There is a separate sidewalk next to the bicycle path with a slight grade separation (bevelled lip) to delineate between the pedestrian and bicycle paths. In the future, Basel will not use the grade separation because of snow removal complications.

City officials plan to include on-street bicycle lanes in all new street-construction projects, rather than two-way separate paths on one side of the street. Local officials believe that on-street bicycle lanes work better than separate off-street facilities.

There are seldom violations for parking in the bicycle lane, and minimal police enforcement manpower is available. Even though bicycles have the right of way in bicycle lanes, motorists do not always stop or yield to cyclists. However, Basel city officials think that most bicycle collisions are caused by lack of compliance by cyclists. No information was given on the extent of bicycle collisions in Basel or accident reporting levels and problems.

A considerable number of trolley trains runs in the central city area; some run at 40-second intervals during the peak hour. Bicycles were observed being ridden on the same streets with

Figure 55. Bicyclist pushbutton signal in Basel.

Figure 56. Special bicycle lane and routing at Basel intersection.

Figure 57. Two-way bicycle street in Basel.

trolleys without any difficulty. For the most part, street pavement surfaces appeared to be in very good condition, but it appeared that narrow bicycle tires could get caught in the trolley rail openings. Authorities, however, are not aware of any problems of this type, and most bicycles on the streets appeared to have relatively wide tires.

A green line is painted parallel to some of the trolley lines to show the overhang of the trolley vehicle and eliminate parking problems with cars. These lines also appear to guide pedestrians and cyclists.

Other facilities for cyclists include contraflow bicycle lanes on one-way streets to allow two-way bicycle travel. Other one-way streets were signed to allow two-way bicycle travel. These streets reportedly work well, without any unusual accident problems.

Bicycle helmet use appears to be at a low-to-moderate level. No large campaigns encourage increased bicycle helmet use.

TRAFFIC CALMING STRATEGIES

Traffic calming measures used in other European countries have interested Basel city officials, and some are already being used in parts of Basel. Other traffic calming strategies will be introduced in the near future. However, because so little time in Switzerland was available for thorough examination of their traffic calming experiences and plans, little evaluative commentary is possible.

7. EDUCATION AND PROMOTION PROGRAMS

GREAT BRITAIN

In most local jurisdictions, bicycle training for children is offered by training programs approved by the Royal Society for the Prevention of Accidents. Approximately 275,000 to 300,000 children aged 9 and 10 years old take part in the program each year, which is about 21 percent of the population in this age group. One such training program is currently being evaluated with the objective of improving it. Since 1947, when the first Cycling Proficiency Test was given, various cycle training programs have been offered. Programs were revised in the late 1970's and in 1982. The latest revision, in 1992, known as "Righttrack Cycling Awareness Programme," helps young cyclists "learn to assess traffic situations, recognize potential hazards, and be able to make appropriate decisions about what to do."[13]

A publicity campaign has been used in Great Britain since 1990 to raise public awareness of child road safety problems and to suggest ways for parents, schools, and drivers to help reduce child casualties. The campaign, "Children and Roads: A Safer Way," has used national television commercials supported by posters and leaflets. The campaign promotes driver safety with the slogan "Kill Your Speed, Not a Child." This campaign encourages drivers to reduce speeds in residential areas where children often cross streets. The major objective of this campaign is to reduce the chances of death or serious injuries. The use of 20-mph zones on selected residential streets in recent years has accompanied this program. The campaign has also focused heavily on the "Cycle Safe" theme of promoting the use of cycle helmets and other safe cycling actions.[13]

Several other events and initiatives have occurred in Great Britain in recent years to help in the education and promotion of pedestrian and bicyclist safety. These include the following:[13]

- The British Transport Research Laboratory (TRL) is evaluating the effectiveness of the road safety education program "Code of Good Practice," which involves in-service training for school teachers on road safety education (implemented in Hertfordshire and Sheffield). The draft report on evaluation results of the program is expected soon.

- Exhibitions on pedestrian and bicycle safety were run at the annual teacher conferences in 1991 and 1992.

- The Princess of Wales attended a luncheon in October of 1991 and spoke in support of the Department of Transport's road safety campaign.

- A series of new television films, launched in 1992, promotes safer cycling for children and emphasizes the need for drivers to reduce their speeds in residential areas.

- New criteria for setting speed limits were published by the Transport Department in February 1993. Further, a policy document—"Killing Speed, Saving Lives"—was issued in January 1993 to set current and future policy in Great Britain.

- The Department of Transport has published numerous reports to educate and promote pedestrian and cyclist safety:

  - *Cyclist Training in Great Britain - A Report of a Series of Regional Cycling Seminars* (January 1993);

  - *Children and Roads: A Safer Way* (May 1990);

  - *Road Safety Report* (November 1991);

  - *The Older Road User - Measures for Reducing Casualties Among Older People on Our Roads* (June 1991); and

  - *Killing Speed and Saving Lives: The Government's Strategy for Tracking the Problem of Excess Speeds on Our Roads* (November 1992).

In addition to these and other reports, dozens of brochures and leaflets are published and distributed by the Department of Transport. These include

- "Accident Fact Sheet" (e.g., Series 2, No. 2 deals with pedestrian accidents in Great Britain);

- "How to Use a Puffin Crossing," brochure 1993;

- "Lessons for Life—Teaching Road Safety: For Parents of 1-15 Year Olds," 1990; and

- Traffic advisory leaflets (e.g., "Audible and Tactile Signals at Signal Controlled Junctions," December 1991), written primarily to provide technical guidance to engineers on installing traffic control devices.

One of the more interesting aspects of safety education and promotion programs in Great Britain is the private sector involvement, such as the following:

- BBC television has had a series on "Play It Safe—Action for Child Safety," which provides parents with a guide to preventing children's accidents around the home, playground, and on the road.

- McDonald's developed a "safety park" for each store in 1990, which encourages their store managers to support local child road-safety activities.

- Texaco launched a £3 million (about $4.5 million U.S.) television and poster safety campaign in 1990. The campaign included the free distribution of 5.5 million fluorescent/retroreflective stickers, as well as the distribution of a safety education campaign ("Secondary Steps") to schools. In October 1991, a follow-up campaign was held with television advertising and distribution of safety packs containing fluorescent laces and materials. Texaco has continued to support the safety campaign with posters and other activities.

- In May 1990, the Pilot Traffic Club launched a preschool (ages 3 to 5) traffic safety education program in the eastern region of England, with approximately 75,000 children enrolling. The program was launched nationally in June 1993.

- Bell has sponsored the Department's cycle helmet promotion commercial on satellite television.

- Halford's bicycle and auto parts shop has supported the Department's "Cycle Safe" campaign through a national competition on cereal boxes.

- British Petroleum's road-safety teams teach the "Living With Traffic" initiative in schools throughout the country and also provide teachers with resources tied to the national curriculum.

- Other contributors toward traffic safety initiatives in Great Britain include Volvo, Volkswagen, Universal Stores, Britax, and several cycle helmet manufacturers.

THE NETHERLANDS

Current and planned bicycle education programs in The Netherlands have been discussed by Wittink[16] in a recent study. The Dutch have expanded traditional approaches of teaching cycling to young children to include training programs for young people, elderly people, adults who have neglected cycling for years, and children and adults from other countries.[16]

According to Wittink, small children in The Netherlands become familiar with bicycles at age 2 or 3. Until about age 8, they need to devote much of their attention to controlling the bicycle, and thus they often have little awareness to traffic conditions around them. Furthermore, young children must be accompanied and advised by parents, and the learning process lasts several years.[16]

From ages 8 to 12, children's knowledge and understanding grow rapidly, so one educational goal is to consider the child's motivations and needs as they affect the influence of knowledge and skills on behavior. Cyclist education requires a "process of mutual communication" (between cyclists and motorists). Above age 12, cyclist behaviors can change dramatically as peer pressure increases. This age group cares less about rules of conduct. Instead, they must be taught to understand the consequences of various behaviors and the rights of motorists and other road users to help them cycle more safely. Coping with social pressure is another skill that is taught at this level.[16]

At age 15 or above, young people begin thinking more frequently about car transportation, but many still bicycle regularly, particularly for short trips. Many adults cycle to relax and compensate for sedentary desk jobs. In cooperation with private companies, programs have been developed in The Netherlands to encourage bicycling for home-to-work trips and also for short work trips. Training programs teach bus and truck drivers how to leave adequate room for cyclists and how to anticipate their behavior.[16]

Elderly people experience some loss of function, and exercise such as bicycling is very important. They need continued cycling practice and advice on how to cope with complex traffic situations. Behavioral alternatives can also be taught to compensate for reduced functions. Training programs for adults born outside of The Netherlands are important to help them control their bicycle and behave safely in traffic.[16]

To address the educational needs of all cyclist groups, the Dutch SWOV Institute for Road Safety Research has developed priorities and recommendations. Past cyclist education programs have been based largely on proper behaviors and interactions with other road users and on a sense of social responsibility. More emphasis on cyclist preferences and problems has been proposed, in addition to continued efforts to improve bicyclist facilities. Although numerous types of cyclist education programs currently exist in The Netherlands, program extensions and improvements have been proposed to address each target group.[16]

GERMANY

A 1992 report by Briese[17] investigated bicycle safety education in Germany. He concluded that the primary cause of bicycle crashes is not the lack of knowledge of traffic rules and regulations. Instead, he concludes that a major cause is the lack of psychological and motor skills necessary for bicycling, particularly for children younger than 8 years old. As a result, a new bicyclist education program has been developed that focuses on teaching these skills, while stressing that a child cannot be a safe cyclist, even with these skills.[13, 17]

In terms of bicyclist training programs, 9- to 10-year-olds are taught to ride on off-road or on-road bicycle facilities. This training is done by the school system. Kindergarten teachers may also offer basic education to younger children. Until age 8, children must ride on the sidewalk, either alone or accompanied by adults. It was reported that many adults do not know correct behaviors for cyclists.

Munster

Cycling education is given in school starting in kindergarten at age 3. These courses are taught every year by the police, and children are tested at age 9. Children age 8 or younger are required to ride on the sidewalk in Germany.

Frankfurt

Every new school year, a safety campaign is mounted through the schools, and a safety person is designated from each school's teaching staff to focus on overall traffic safety instructions for students. These teachers point out the best and safest ways for students to go to and from school.

SWITZERLAND

Police provide pedestrian and bicycle information to school children in Basel. Children are taken out to the streets for instruction, and education is not limited to classroom experience.

8. ENFORCEMENT AND REGULATION ISSUES

GREAT BRITAIN

A major overhaul of road traffic laws in recent years has resulted in changes in enforcement practices. Police enforce traffic signal violations by traditional means as well as through use of post-mounted cameras to film signal violators who are then mailed tickets. Areas designed for a 20-mph speed must be physically self-enforcing and are redesigned for that speed. The setting of speed limits on local roads in Great Britain is a local prerogative (based on national guidances), except for the national road network, where it is the responsibility of the central government. The national network has some similarities to the U.S. interstate system. At some high-accident areas, automobile speed-readout devices have been deployed to visually warn speeders of their exact speed with a flashing digital readout.

THE NETHERLANDS

Generally, bicyclists are not ticketed in great numbers, although police enforce violations by bicyclists who ride on high-speed roadways where cycling is prohibited. Police ride mountain bicycles and conduct specific campaigns targeting cyclists running red signals, bicycle lighting requirements at night, etc. These campaigns receive wide publicity, which helps make them effective. Cars are ticketed for parking on bicycle lanes. Design rather than enforcement is used to affect behavior.

Groningen

A problem exists with mopeds riding on bicycle paths, and the major problem involves speeding by moped riders. However, little enforcement exists. Bicycle registration is required, since it helps police locate and return stolen bicycles. There is a problem with getting students to register bicycles. It is also very difficult to prevent bicyclists from riding in pedestrian-only areas.

GERMANY

According to a study by Bracher,[13, 15] no correlation exists between the most frequent traffic violations and the most common causes of bicycle crashes. Instead, excessive speeding by motorists is a primary cause of fatal bicyclist crashes.[13, 15, 18] In fact, according to Hass Klau, one-fourth of all crashes in Germany could have been avoided if drivers of motor vehicles had obeyed speed limits. The study team also attributes the low bicycle crash experience in Heidelberg to strict police enforcement of speed limits and widespread traffic calming.[13, 15]

9. RESEARCH AND DEVELOPMENT ACTIVITIES

A considerable amount of safety research on pedestrian and bicyclist safety—including traffic calming strategies—has been conducted in recent years in Europe. To illustrate some of these research results, several recent studies that have been conducted in The Netherlands and Germany are discussed below.

THE NETHERLANDS

Much of the research conducted in The Netherlands on pedestrian and bicycle safety has been conducted by the SWOV Institute for Road Safety Research, located in Leidschendam, near The Hague. A summary is given below of the results of a few of these studies.

Pedestrian Detectors

Several innovative pedestrian signal alternatives have been tested to detect the presence of pedestrians and provide safer crossing intervals. Instead of traditional pedestrian pushbutton devices, which require actuation, the new signal installations use pressure-sensitive mats or infrared detectors (mounted on poles) to detect the presence of pedestrians waiting to cross the street. After being detected, a pedestrian is given a white light, indicating that a WALK signal will follow. If pedestrians wait until the WALK signal is displayed, a second infrared detector monitors their progress within the crosswalk and holds the pedestrian clearance interval (and red signal for motor vehicles) until the pedestrian reaches the other side of the street. Thus, slower pedestrians (e.g., elderly, wheelchair users) are given extended walking intervals. If the pedestrian steps off the curb too soon or leaves the crossing area, the request for a WALK signal is no longer valid, and no WALK interval is given.[(7)]

A Maastricht signal has a pedestrian signal displayed on the same side (near side) of the street as the crossing pedestrian instead of the other side (far side). Pedestrians step off the curb when they see the near side WALK display; they can devote their attention to traffic while crossing, rather than to the pedestrian signal on the far side of the street. This signal needs no clearance display and is therefore simple to understand.[(7)]

These innovative pedestrian signals were termed PUSSYCATS (Pedestrian Urban Safety System and Comfort at Traffic Signals) and were evaluated in England, France, and The Netherlands and the results were reported by Peter Levelt in 1993[(19)] based on observing crossing behavior of 2,953 pedestrians before (at three locations) and 6,145 pedestrians after (at four locations) installation. Also, 1,191 pedestrians were interviewed to determine their understanding and opinions concerning the signals. The efficiency, safety, and convenience of the signals were evaluated. No programming problems or vandalism occurred during the experiments. While the system operated well and efficiently, improvements could be made to the mats. The new system had safety advantages, since all of the pedestrians who began walking on a green (i.e., WALK) display finished crossing in time. One negative opinion was conveyed by pedestrians toward the Maastricht signal position (i.e., near-side pedestrian signal placement only), since pedestrians preferred to see the signal at all times while crossing the street. New research has indicated that pedestrians who are accustmed to this new position no longer object to it. Overall, the new PUSSYCATS were found to be "the best choice at this moment," and lengthening of the pedestrian walking phase could further improve the signals at selected locations.[19] Such devices are now used on a more extensive basis in England under the name puffin (Pedestrian User Friendly INtersection) crossings.

Bicycle Lanes versus Separate Paths

Studies in The Netherlands have attempted to compare the safety of on-road bicycle lanes with separate bicycle paths (termed "bicycle tracks"). A 1988 study by Willeman[20] analyzed bicycle and moped crashes on both types of facilities. The study found that cyclists are involved in fewer crashes on cycle tracks than on bicycle lanes. Bicycle lanes are typically safer at intersections than cycle tracks, however. Moped riders are at greater risk of collisions while traveling on cycle tracks, and most collisions occur at intersections with roadways. Furthermore, moped riders are also more likely to collide with pedestrians and bicyclists when traveling on bicycle tracks than on other roads.[20]

A 1989 study by the Center for Research and Contract Standardization in Civil and Traffic Engineering[21] developed guidelines for moped use of roadways versus separate bicycle paths. One major factor in developing these guidelines was the speed differences between bicycles and mopeds, which is larger than the speed differences between mopeds and other motor vehicles in urban areas. The report recommends that mopeds use the roadway instead of the bicycle path when

- The road is wide, while the bicycle path is narrow, and motor vehicle traffic volumes are low; or
- The road and the bicycle path are both wide, but the motor vehicle traffic is low and bicycle traffic is high.

Mopeds should use the bicycle path when

- Motor vehicle volumes are high and bicycle traffic is low;
- The bicycle path is wide, but bicycle volumes are low; or
- The bicycle path is wide and the volumes of both motor vehicles and bicyclists are high.

Evaluation of 30-km/hr Zones

A 1991 study by Grontmij[22] evaluated the effect of implementing 30-km/hr zones in 15 municipalities in The Netherlands. A before-and-after analysis was conducted, using control areas and accident characteristics such as type of location; weather conditions; time; type of accident; and involvement of pedestrians, cyclists, or moped riders. A statistical analysis revealed that the 30-km/hr zones reduced total crashes by 10 percent to 15 percent, compared to control areas. Crashes involving only motor vehicles dropped by 15 percent, and between motor vehicles and "slow traffic" (assumed to refer to pedestrians and bicyclists), dropped by 36 percent. Less crash reduction was found for bicycle-related crashes, which according to the study team was due to the types of various speed reduction measures used.[22]

GERMANY

Numerous research studies have been conducted in Germany in recent years on pedestrian and bicycle facilities and safety. A 1994 report by Clarke[13] provides an overview of much of the relevant bicycle studies. The following sections summarize some important German research.

Intersection Design

A study in the late 1970's of approximately 4,000 bicycle and moped crashes in the city of Cologne found that more than half occur at intersections. Recent studies in the city of Erlangen revealed that 50 percent to 75 percent of bicycle crashes occur at intersections. According to two separate studies by Alrutz (1980), cited in Clarke (1994), and Bracher (1992), crash problems in Cologne and Erlangen are overrepresented when bicyclists are using sidepaths and when bicyclists ride against the flow of traffic on these paths.[11, 23] Furthermore, Bracher reports that the number of bicycle-car crashes at the intersections of driveways and sidepaths is three times higher than on similar streets with no sidepaths.

It should be mentioned that the designs of sidepaths in many German cities are quite different from those used in The Netherlands and other countries. The German sidepaths are typically marked paths on the left side of a wide sidewalk, while pedestrians use the right side of the same sidewalk facility. Bicyclists use the left, striped portion of the sidewalk, which in many cases separates them from motorists by parked cars. In some situations, the bicycle sidepaths weave back onto the roadway, either for midblock sections or just prior to intersections. Thus, the high accident experience of Germany sidepaths for bicyclists should not necessarily be applied to the effects of bicycle paths as used elsewhere.

To improve the safety of the sidepaths, Alrutz recommended that they be made clearly recognizable for all road users at all points of conflict (e.g., at driveways), that sidepaths provide clear guidance to bicyclists, and that they follow the prevailing right-of-way.[11] Recommendations by Bracher include guiding sidepaths onto the street at locations 15 to 20 m in advance of an intersection, with special lane markings to guide all road users.[11, 23]

In 1987, Richard[24] reported that bicycle crashes at intersections were reduced significantly in a demonstration project in Detmold. The projects involved raising the elevation of bicycle paths at intersections to create motorist speed humps and marking the bicycle route with paint or special paving material.[11, 24] Other types of intersection treatments to accommodate bicyclists (but for which no formal evaluations were found) include the following:[11]

- **Advance stop lines** for bicyclists, where cars stop behind bicyclists during the red interval at signalized intersections and move ahead of them at the beginning of the green interval.

- **Sluice or lock**, which is similar to advanced stop lines, except that bicyclists and motor vehicles are given separate traffic signals and green intervals.

- **Flying change**. Along streets with bicycle lanes on the right side of the road, intersection left-turn bicycle lanes are adjacent to and to the right of the vehicle left-turn lanes. Cyclists who approach the intersection in the bicycle lane can weave over to the left-turn bicycle lane through gaps in traffic.

Traffic Calming

Various traffic calming strategies have been used in Germany since the early 1980's to reduce motor vehicle speeds and access, particularly on neighborhood streets and in shopping areas. A 5-year experiment of 30-km/hr zones in the early 1980's led to the creation of thousands of these zones.(11)

In 1990, Monheim(25) reported the results of a Federal government evaluation of traffic calming projects in six areas: the major city of Berlin; the three medium-sized cities of Mainz, Ingolstadt, and Esslingen; the small town of Buxtehude; and the village of Borgentreich. The results of the study showed that(11, 25)

- Traffic volumes remained relatively unchanged;

- Average motor vehicle speeds were reduced from 39 km/hr to 20 km/hr;

- Average trip times increased for motorists by 33 seconds; and

- Fatalities were reduced by 43 percent to 53 percent, and injuries by 60 percent, even though the number of total crashes remained unchanged.

According to Doldissen and Draeger(26) in 1990, other effects of the traffic calming included a doubling of bicycle use in Buxtehude in the 4 years following the project and an increase in bicycle crashes (primarily noninjury). The proportion of bicyclists considered at fault in crashes dropped from 45 percent to 35 percent after traffic calming measures were implemented.(11, 26) For neighborhoods in the Berlin study area, there was a 16 percent reduction in bicycle-related crashes and a 50 percent increase in bicycle use.(11, 27)

10. MAJOR CONCLUSIONS AND TRANSFERABILITY TO THE UNITED STATES

Based on the findings of bicycle and pedestrian practices and programs in Great Britain, The Netherlands, and Germany, much has been learned that may be transferrable to specific locations or situations in the United States. It should first be mentioned that a wide variety of practices was found, not only among countries but also among cities within the countries surveyed, related to how nonmotorized transportation is handled. Therefore, it should not be assumed that a given practice would necessarily be appropriate for all locations or jurisdictions in the United States. Instead, State and local agencies should consider the relative benefits and problems associated with such practices in light of their own local conditions. Having said this, there are a few ideas that certainly deserve further consideration in the United States.

TRAFFIC CALMING AND SPEED REDUCTION TECHNIQUES

Clearly, the most effective measures for improving the safety of bicyclists and pedestrians on local streets in the countries visited included using traffic calming measures to reduce vehicle speeds or restrict the movements of motor vehicles. On neighborhood streets particular measures such as speed humps, road narrowing (chokers), chicanes, intersection diagonal diverters, cul-de-sacs, and barriers that block off streets for part or all of the day to motor vehicles in downtown areas have been found to be particularly effective. Traffic calming is most effective if done on a neighborhood or areawide basis, and not just at spot locations. While some of these measures have been tried to a limited degree in the United States, more testing of various European traffic calming strategies is needed in U.S. cities. These designs also reduce the need for police enforcement efforts.

RESTRICTION OF TRAFFIC MOVEMENTS

Among the most successful cities, in terms of providing for safer nonmotorized transport, are Houten and Groningen in The Netherlands. Vehicles use a ring road around each city when traveling between neighborhoods within the city. This requires blocking off some streets inside the ring road, thereby greatly reducing motor vehicle cut-through traffic and volumes on the neighborhood streets while providing much freer flows of bicyclists and pedestrians between destinations. While such measures seem extreme to U.S. practice, selective use of diagonal diverters at intersections and other measures reduce unwanted through traffic and also reduce excessive vehicle speeds in neighborhood streets and other areas where pedestrian and bicycle travel is encouraged.

HIGHER DENSITY DEVELOPMENT

Enhancing safe and increased travel by bicyclists and pedestrians requires shortening travel distances. Through well-planned zoning and development practices, local agencies can encourage safer nonmotorized transportation through higher density development and better planning of land use where places of employment are placed reasonably close to neighborhoods. Ideal bicycle trip lengths are 3 km to 5 km.

Trip links are vastly different in the United States from some European cities, which makes bicycling more feasible in those European cities. The United States should direct more attention toward short, utilitarian local trips, as opposed to worrying about interstate travel. We should have the option to ride bicycles, to rent bicycles at train and bus stations, and have a choice of travel modes, as was seen in Groningen and other cities.

PHILOSOPHY OF LIMITING MOTOR VEHICLE CAPACITY AND ENCOURAGING NONMOTORIZED TRAVEL

An important European practice that could be transferred to some areas of the United States relates to rejecting the notion that all current and future motor vehicle traffic must be accommodated to move as freely and quickly as desired by drivers. Instead of adding travel lanes and motor vehicle parking lots to meet any perceived demand, the United States should create safer pedestrian and bicyclist environment, such as the approaches used in London or Frankfurt. Specifically, more can be done to increase costs and reduce the number of parking spaces in downtown areas, turn downtown streets into pedestrian malls, and encourage more use of public transit. Of course, providing safer facilities for nonmotorized users (sidewalks, bicycle lanes, and paths) is also important in conjunction with creating physical traffic barriers to restrict movement by motorists in certain situations. Since the United States does not have the same centralized zoning control that exists in Europe, great care must be taken to avoid chasing businesses and shoppers to outlying suburban areas. Special attractions are needed to keep people coming to downtown areas, including historic redevelopment, street entertainment, pedestrian amenities, and so on. Special care must also be taken to maintaining a pleasant and crime-free environment.

PROVIDING IMPROVED PEDESTRIAN TREATMENTS

This includes careful consideration not only of traditional pedestrian measures such as pedestrian signals, safety islands, curb ramps, sidewalks and walkways, and overpasses and underpasses, but also of innovative treatments. For example, pedestrian pushbutton devices that give feedback to the pedestrian, pavement messages (e.g., LOOK RIGHT pavement messages as used in London next to the curb), and other devices that provide warning information, can be helpful. Infrared pedestrian detectors, as used in England and The Netherlands (to activate pedestrian signals automatically and hold the WALK interval until pedestrians are safely across) may also be beneficial to older or handicapped pedestrians in the United States. These and other pedestrian treatments deserve further testing and use.

BICYCLE MEASURES

Many types of facilities for bicyclists found in Europe certainly have some application to many United States situations. For example, well-planned networks of on-street bicycle lanes and separated paths certainly deserve more consideration in U.S. cities. Special pavement colors and messages and separate bicycle signal indications may also be useful in certain situations. Advance stop lines to allow bicyclists to stop closer to intersections at traffic signals, as found in other countries, can also benefit U.S. bicyclist safety. Other potentially promising measures include bus lanes that can also be used by bicyclists, more extensive use of bicycle lockers and shelters at transit stations, and exclusive bicycle streets in downtown areas. Auxiliary facilities, such as bicycle parking at employment centers, should also be encouraged.

SAFETY EDUCATION AND PROMOTION

Much can be learned from some of the safety education programs for pedestrians and bicyclists in the countries that were visited. For example, bicyclist training programs in school systems in The Netherlands are quite extensive and attempt to teach young bicyclists to handle themselves more skillfully and safely in traffic. Educational messages used in Great Britain tell drivers to, "Kill Your Speed, Not a Child." These appear in conjunction with 20-mph zones on selected neighborhood streets and are certainly worth consideration in the United States. Furthermore, programs to encourage bicycle helmet use and cooperation between private sponsors in providing safety information also deserve additional U.S. consideration.

POLICE ENFORCEMENT

As in the United States, several European officials mentioned the lack of available police persons, which limits the amount of speed enforcement that can be routinely conducted in those countries. One commonly mentioned concept was the idea of roadway designs that are self-enforcing, that is, narrowing down roadways and providing bollards and other devices to force lower speeds. Some types of violations are enforced, however, such as motorists violating traffic signals and vehicles parking on bicycle lanes. The practice used in Great Britain of installing cameras to film signal and speed-limit violators and mailing tickets to offenders seems quite effective, although this could raise privacy issues in the United States. It should be noted that strong opposition to this practice was led by the civil liberties lobby at first, but some of the fears of opponents were reduced by photographing the rear of the violating vehicle and requiring the owner to identify the driver. After a full year of this pilot enforcement program, a 35 percent reduction in deaths and serious injuries and a 20 percent reduction in accidents was found, both of which were statistically significant at the 0.01 level (i.e., with 99.9 percent confidence). (The photo radar concept has been used to a limited degree in the United States and has not been without controversy.)

RESEARCH NEEDS

Some of the pedestrian and bicyclist safety research in these European countries has been useful in investigating many bicycle-related facilities, such as the safety effects of various bicycle path and lane designs, intersection design treatments for bicyclists, and others. More U.S. research may be needed to test and evaluate these efforts.

Evaluation of innovative pedestrian treatments in the United States would also be useful, such as various types of infrared pedestrian detectors, pedestrian pushbuttons with feedback information to the pedestrian, various crosswalk markings, and pedestrian railings to channel pedestrians to safer crossing points. A variety of traffic calming strategies (speed humps, road narrowing, diagonal diverters, raised crosswalks, and others) should also be evaluated for U.S. conditions. Such research will provide more useful information as to which facilities and methods are most appropriate for enhancing the safe and efficient movement of pedestrians and bicyclists in the United States.

Travel planning models also need to be better developed for nonmotorized travelers in the United States, like those used in The Netherlands for bicycle forecasting. Finally, better reporting of pedestrian and bicyclist crashes and all types of transportation injuries should be considered in the United States, including not only crashes with motor vehicles, but also nonmotor vehicle injuries, such as is currently done in Great Britain.

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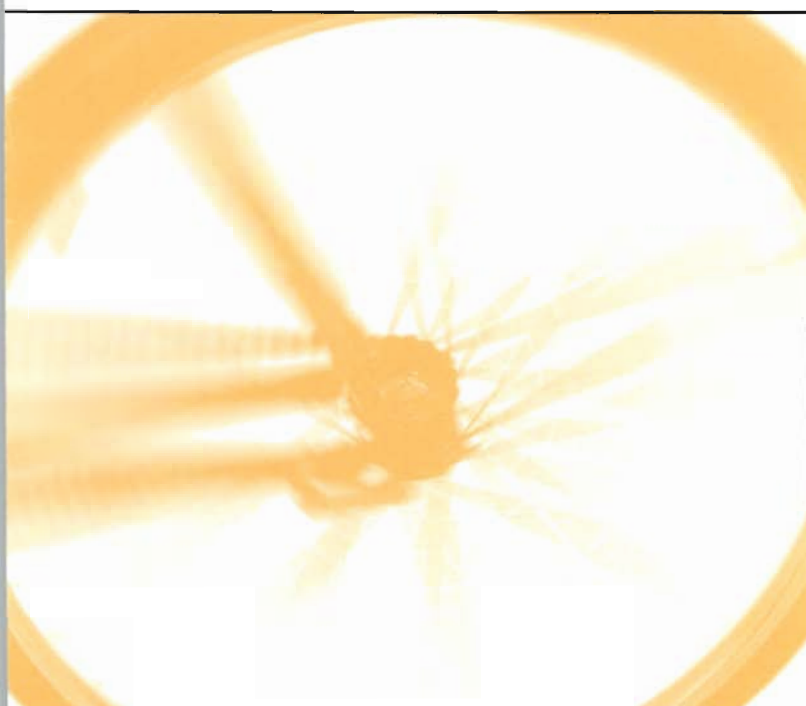

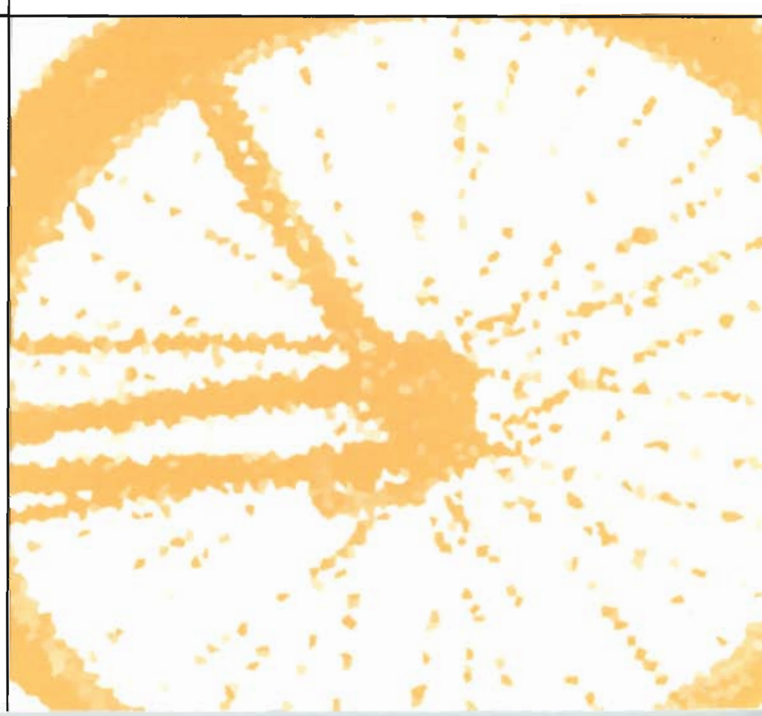

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