
Flexibility in Highway Design



U.S. Department of Transportation
Federal Highway Administration

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A Message from the Administrator

Dear Colleague:

One of the greatest challenges the highway community faces is providing safe, efficient transportation service that conserves, and even enhances the environmental, scenic, historic, and community resources that are so vital to our way of life. This guide will help you meet that challenge.

The Federal Highway Administration (FHWA) has been pleased to work with the American Association of State Highway and Transportation Officials and other interested groups, including the Bicycle Federation of America, the National Trust for Historic Preservation, and Scenic America, to develop this publication. It identifies and explains the opportunities, flexibilities, and constraints facing designers and design teams responsible for the development of transportation facilities.

This guide does not attempt to create new standards. Rather, the guide builds on the flexibility in current laws and regulations to explore opportunities to use flexible design as a tool to help sustain important community interests without compromising safety. To do so, this guide stresses the need to identify and discuss those flexibilities and to continue breaking down barriers that sometimes make it difficult for highway designers to be aware of local concerns of interested organizations and citizens.

The partnership formed to develop this guidance grew out of the design-related provisions of the Intermodal Surface Transportation Efficiency Act of 1991 and the National Highway System Designation Act of 1995. Congress provided dramatic new flexibilities in funding, stressed the importance of preserving historic and scenic values, and provided for enhancing communities through transportation improvements. Additionally, Congress provided that for Federal-aid projects not on the National Highway System, the States have the flexibility to develop and apply criteria they deem appropriate.

It is important, therefore, that we work with our State and local transportation colleagues to share ideas for proactive, community-oriented designs for transportation facilities. In this guide, we encourage designers to become partners with transportation specialists, landscape architects, environmental specialists, and others who can bring their unique expertise to the important task of improving transportation decisionmaking and preserving the character of this Nation's communities. As illustrated in the guidance, we can encourage creativity, while achieving safety and efficiency, through the early identification of critical project issues, and through consideration of community concerns before major decisions severely limit design options.

We believe that design can and must play a major role in enhancing the quality of our journeys and of the communities traveled. This guide will help you achieve those dual purposes.

Sincerely yours,



Jane F. Garvey
Acting Federal
Highway Administrator

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FOREWORD

This Guide is about designing highways that incorporate community values and are safe, efficient, effective mechanisms for the movement of people and goods. It is written for highway engineers and project managers who want to learn more about the flexibility available to them when designing roads and illustrates successful approaches used in other highway projects. It can also be used by citizens who want to gain a better understanding of the highway design process.

Congress, in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the National Highway System Designation (NHS) Act of 1995, maintained a strong national commitment to safety and mobility. Congress also made a commitment to preserving and protecting the environmental and cultural values affected by transportation facilities. The challenge to the highway design community is to find design solutions, as well as operational options, that result in full consideration of these sometimes conflicting objectives.

To help meet that challenge, this Guide has been prepared for the purpose of provoking innovative thinking for fully considering the scenic, historic, aesthetic, and other cultural values, along with the safety and mobility needs, of our highway transportation system. This Guide does not establish any new or different geometric design standards or criteria for highways and streets in scenic, historic, or otherwise environmentally or culturally sensitive areas, nor does it imply that safety and mobility are less important design considerations.

When Congress passed ISTEA in 1991, in addition to safety, it emphasized the importance of good design that is sensitive to its surrounding environment, especially in historic and scenic areas. Section 1016(a) of ISTEA states:

If a proposed project ...involves a historic facility or is located in an area of historic or scenic value, the Secretary may approve such project ...if such project is designed to standards that allow for the preservation of such historic or scenic value and such project is designed with mitigation measures to allow preservation of such value and ensure safe use of the facility.

Aesthetic, scenic, historic, and cultural resources and the physical characteristics of an area are always important factors because they help give a community its identity and sense of place and are a source of local pride.

In 1995, Congress reemphasized and strengthened this direction through the NHS Act, which states, in section 304:

A design for new construction, reconstruction, resurfacing... restoration, or rehabilitation of a highway on the National Highway System (other than a highway also on the Interstate System) may take into account...[in addition to safety, durability and economy of maintenance]...

- (A) the constructed and natural environment of the area;*
- (B) the environmental, scenic, aesthetic, historic, community, and preservation impacts of the activity; and*
- (C) access for other modes of transportation.*

The National Highway System (NHS) consists of approximately 161,000 miles of roads, including the Interstate System, or 4 percent of the total highway mileage. The primary purpose of the NHS is to ensure safe mobility and access. By emphasizing the importance of good design for these roads, Congress is saying that careful, context-sensitive design is a factor that should not be overlooked for any road.

A Policy on the Geometric Design of Highways and Streets (Green Book), published by the American Association of State Highway and Transportation Officials (AASHTO), contains the basic geometric design criteria that establish the physical features of a roadway. This Guide is correlated to a large extent to the Green Book because that is the primary geometric design tool used by the highway design community. Like the Green Book, this Guide contains sections on functional classification, design controls, horizontal and vertical alignment, cross-section elements, bridges, and intersections. There are many good projects highlighted in this Guide that were achieved working within the parameters of the Green Book to obtain safety and mobility and to preserve environmental and cultural resources. These projects used the flexibilities that are available within the criteria of the Green Book. These projects also used a comprehensive design process, involving the public and incorporating a multidisciplinary design approach early and throughout the process.

If highway designers are not aware of opportunities to use their creative abilities, the standard or conservative use of the Green Book criteria and related State standards, along with a lack of full consideration of community values, can cause a road to be out of context with its surroundings. It may also preclude designers from avoiding impacts on important natural and human resources.

This Guide encourages highway designers to expand their consideration in applying the Green Book criteria. It shows that having a process that is open, includes public involvement, and fosters creative thinking is an essential part of achieving good design. This Guide should be viewed as a useful tool to help highway designers, environmentalists, and the public move further along the path to sensitively designed highways and streets by identifying some possible approaches that fully consider aesthetic, historic, and scenic values, along with safety and mobility. It also recognizes that many designers have been sensitive to the protection of natural and human-made resources prior to ISTEA.

The decision to use and apply the concepts illustrated and discussed in the Guide for any specific project remains solely with the appropriate State and/or local highway agencies. In addition, while many of the concepts discussed will clearly aid the decision process, it must be recognized that changes in the design or design criteria will not always resolve every issue to a mutual level of satisfaction.

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INTRODUCTION



An important concept in highway design is that every project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities are unique factors that designers must consider with each highway project. Whether the design to be developed is for a modest safety improvement or 10 miles of new-location rural freeway, there are no patented solutions. For each potential project, designers are faced with the task of balancing the need for the highway improvement with the need to safely integrate the design into the surrounding natural and human environments.

In order to do this, designers need flexibility. There are a number of options available to State and local highway agency officials to aid in achieving a balanced road design and to resolve design issues. These include the following:

- Use the flexibility within the standards adopted for each State.
- Recognize that design exceptions may be optional where environmental consequences are great.
- Be prepared to reevaluate decisions made in the planning phase.
- Lower the design speed when appropriate.
- Maintain the road's existing horizontal and vertical geometry and cross section and undertake only resurfacing, restoration, and rehabilitation (3R) improvements.
- Consider developing alternative standards for each State, especially for scenic roads.
- Recognize the safety and operational impact of various design features and modifications.

This Guide illustrates the flexibility already available to designers within adopted State standards. These standards, often based on the AASHTO Green Book, allow designers to tailor their designs to the particular situations encountered in each highway project. Often, these standards alone provide enough flexibility to achieve a harmonious design that both meets the objectives of the project and is sensitive to the surrounding environment.

When faced with extreme social, economic, or environmental consequences, it is sometimes necessary for designers to look beyond the “givens” of a highway project and consider other options. The design exception process is one such alternative. In other cases, it may be possible to reevaluate planning decisions or rethink the appropriate design.

For existing roads, sometimes the best option is to maintain the road as is or make only modest 3R improvements. Since the passage of ISTEA, States also have the ability to develop new standards outside the Green Book criteria for all roads not on the NHS. It is important, however, to recognize that the Green Book criteria are based on sound engineering and should be the primary source for design criteria. When the impact of the proposed action is evaluated and flexible design considerations are appropriate, they should be investigated.

All these options may give designers flexibility to use their expertise and judgment in designing roads that fit into the natural and human environments, while functioning efficiently and operating safely.

The ultimate decision on the use of existing flexibility rests with the State design team and project managers. Each situation must be evaluated to determine the possibilities that are appropriate for that particular project. Managers are encouraged to allow the designers to work with staff members from other disciplines to aid in exploring options, constraints, and flexibilities.

Chapter 1

OVERVIEW OF THE HIGHWAY PLANNING AND DEVELOPMENT PROCESS

*A successful process includes
designer and community
involvement from the beginning.
(Rt. 123/124 in New Ipswich
Village, NH)*



Highway design is only one element in the overall highway development process. Historically, detailed design occurs in the middle of the process, linking the preceding phases of planning and project development with the subsequent phases of right-of-way acquisition, construction, and maintenance. While these are distinct activities, there is considerable overlap in terms of coordination among the various disciplines that work together, including designers, throughout the process.

It is during the first three stages, planning, project development, and design, that designers and communities, working together, can have the greatest impact on the final design features of the project. In fact, the flexibility available for highway design during the detailed design phase is limited a great deal by the decisions made at the earlier stages of planning and project development. This Guide begins with a description of the overall highway planning and development process to illustrate when these decisions are made and how they affect the ultimate design of a facility.

THE STAGES OF HIGHWAY DEVELOPMENT

Although the names may vary by State, the five basic stages in the highway development process are: planning, project development (preliminary design), final design, right-of-way, and construction. After construction is completed, ongoing operation and maintenance activities continue throughout the life of the facility.

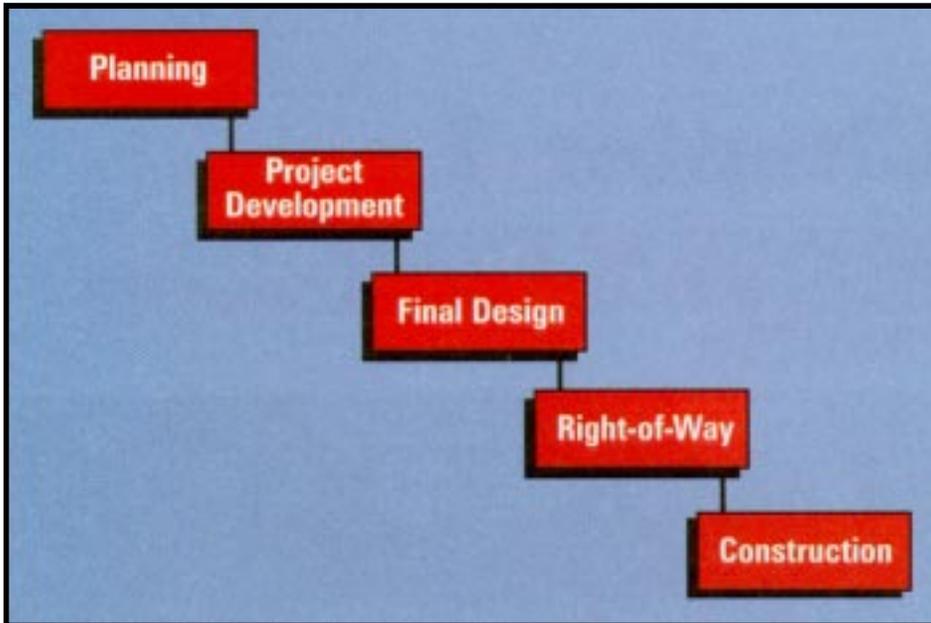


Figure 1.1

Although these activities are distinct, there is considerable overlap between all phases of highway planning and development.

Planning

The initial definition of the need for any highway or bridge improvement project takes place during the planning stage. This problem definition occurs at the State, regional, or local level, depending on the scale of the proposed improvement. This is the key time to get the public involved and provide input into the decision-making process. The problems identified usually fall into one or more of the following four categories:

1. The existing physical structure needs major repair/ replacement (structure repair).
2. Existing or projected future travel demands exceed available capacity, and access to transportation and mobility need to be increased (capacity).
3. The route is experiencing an inordinate number of safety and accident problems that can only be resolved through physical, geometric changes (safety).
4. Developmental pressures along the route make a reexamination of the number, location, and physical design of access points necessary (access).

Whichever problem (or set of problems) is identified, it is important that all parties agree that the problem exists, pinpoint what the problem is, and decide whether or not they want it fixed. For example, some communities may acknowledge that a roadway is operating over its capacity but do not want to improve the roadway for fear that such action will encourage more growth along the corridor. Road access may be a problem, but a community may decide it is better not to increase access,

Increased public involvement in highway planning and development is essential to success.



Obtaining a community consensus on the problem requires proactive public involvement beyond conventional public meetings at which well-developed design alternatives are presented for public comment. **If a consensus cannot be reached on the definition of the problem at the beginning, it will be difficult to move ahead in the process and expect consensus on the final design.**

Planning Occurs at Three Government Levels

State Planning. At the State level, State DOTs are required to develop and maintain a statewide, multimodal transportation planning process. Broad categories of highway improvement needs are defined, based primarily on ongoing examinations of roadway pavement conditions and estimates of present-day and 20-year projections of traffic demands. In addition, each State is required to conduct biennial inspections of its major bridges (and similar, less frequent, inspections of minor structures) to determine their structural adequacy and capacity. In a number of States, regional transportation plans for multiple counties are prepared within the context of the statewide planning process. Every few years, the State selects improvement projects based on the longrange-plan and includes them in the Statewide Transportation Improvement Program, or STIP.

Regional Planning. State efforts are supplemented in urbanized areas with a population of more than 200,000 through the metropolitan transportation planning process. Metropolitan planning organizations (MPOs) develop their own regional plans, unlike non-MPO areas, which must rely on the State planning process. The metropolitan planning process requires the development of a long-range plan, typically prepared with a 20- to 25-year planning horizon. The plan not only defines a region's multimodal transportation needs, but also identifies the local funding sources that will be needed to implement the identified projects. Each urbanized area or MPO then uses this information to prepare a shorter, more detailed listing and prioritization of projects for which work is anticipated within the next 3 to 5 years. The listing of these projects is referred to as the shorrange Transportation Improvement Program, or TIP The TIP is incorporated into the STIP

Local Planning. Most cities and counties follow a similar process of project identification, conceptual costing, and prioritization of the roadways for which they are responsible. Generally, these are roads that are not the responsibility of the State DOT. However, the State must work with localities to get their input into the long-range plan and STIP

Factors To Consider During Planning

It is important to look ahead during the planning stage and consider the potential impact that a proposed facility or improvement may have while the project is still in the conceptual phase. During planning, key decisions are made that will affect and limit the design options in subsequent phases. Some questions to be asked at the planning stage include:

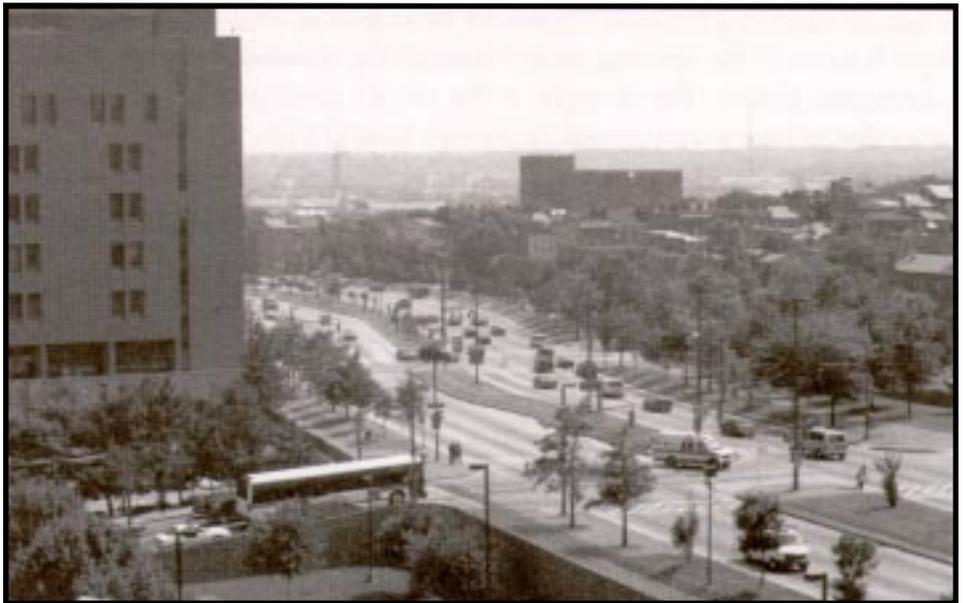
- How will the proposed transportation improvement affect the general physical character of the area surrounding the project?
- Does the area to be affected have unique historic or scenic characteristics?
- What are the safety, capacity, and cost concerns of the community?

Answers for such questions are found in planning-level analysis, as well as in public involvement during planning.



Figure 1.2
Factors to consider in planning.

*An urban boulevard that evolved from
a freeway concept.
(Martin Luther King, Jr., Boulevard
Baltimore, MD)*



PROJECT DEVELOPMENT

After a project has been planned and programmed for implementation, it moves into the project development phase. At this stage, the environmental analysis intensifies. The level of environmental review varies widely, depending on the scale and impact of the project. It can range from a multiyear effort to prepare an Environmental Impact Statement (a comprehensive document that analyzes the potential impact of proposed alternatives) to a modest environmental review completed in a matter of weeks. Regardless of the level of detail or duration, the product of the project development process generally includes a description of the location and major design features of the recommended project that is to be further designed and constructed, while continually trying to avoid, minimize, and mitigate environmental impact.

The basic steps in this stage include the following:

- Refinement of purpose and need
- Development of a range of alternatives (including the “no-build” and traffic management system [TMS] options)
- Evaluation of alternatives and their impact on the natural and built environments
- Development of appropriate mitigation

In general, decisions made at the project development level help to define the major features of the resulting project through the remainder of the design and construction process. For example, if the project development process determines that an improvement needs to take the form of a four-lane divided arterial highway, it may be difficult in the design phase to justify providing only a two-lane highway. Similarly, if the project development phase determines that an existing truss bridge cannot be rehabilitated at a reasonable cost to provide the necessary capacity, then it may be difficult to justify keeping the existing bridge without investing in the cost of a totally new structure.

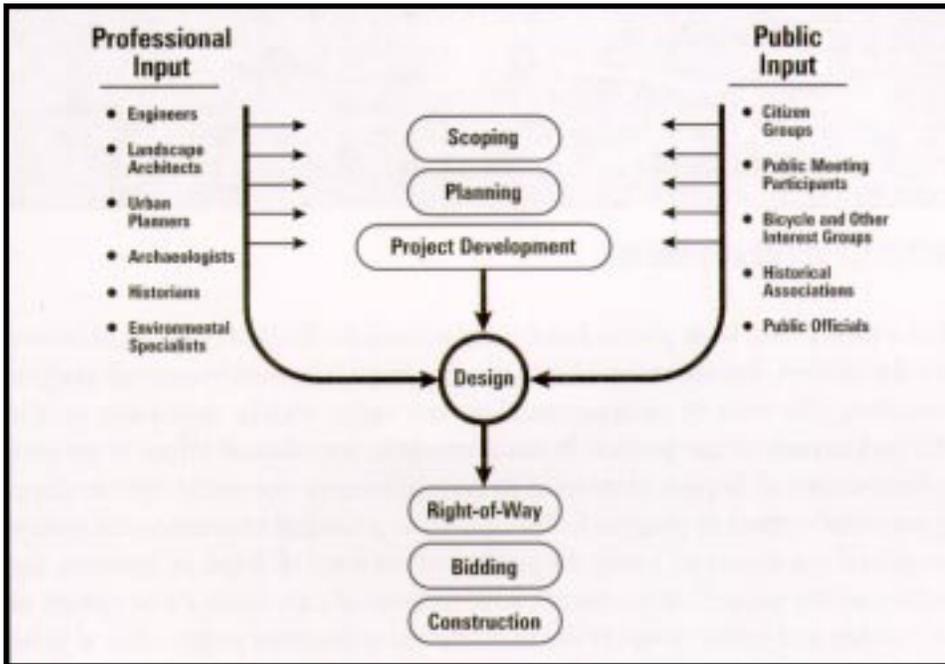


Figure 1.3
Scoping brings all participants into the process.

Scoping

Just as in planning, there are many decisions made during the scoping phase of project development, regardless of the level of detail being studied. Therefore, it is important that the various stakeholders in the project be identified and provided with the opportunity to get involved (see Figure 1.3). Agency staff can identify stakeholders by asking individuals or groups who are known to be interested or affected to identify others and then repeat the process with the newly identified stakeholders. A good community impact assessment will also help identify stakeholders and avoid overlooking inconspicuous groups. The general public should not be omitted, although a different approach is usually needed with the general public than with those who are more intensely interested. The Federal Highway Administration (FHWA) has recently published a guide entitled, *Community Impact Assessment: A Quick Reference for Transportation*, that describes this community impact assessment process.’

Assessing the Character of an Area

In order for a designer to be sensitive to the project's surrounding environment, he or she must consider its context and physical location carefully during this stage of project planning. This is true whether a house, a road, a bridge, or something as small as a bus passenger waiting shelter is to be built. A data collection effort may be needed that involves site visits and contacts with residents and other stakeholders in the area. A benefit of the designer gathering information about the physical character of the area and the values of the community is that the information will help the designer shape how the project will look and identify any physical constraints or opportunities early in the process (see Figure 1.4).

*The physical character of an
area can vary, from a peaceful
countryside...
(Snickersville Turnpike,
Loudoun County, VA)*



*... to an urban corridor.
(Martin Luther King Blvd.,
Baltimore, MD)*



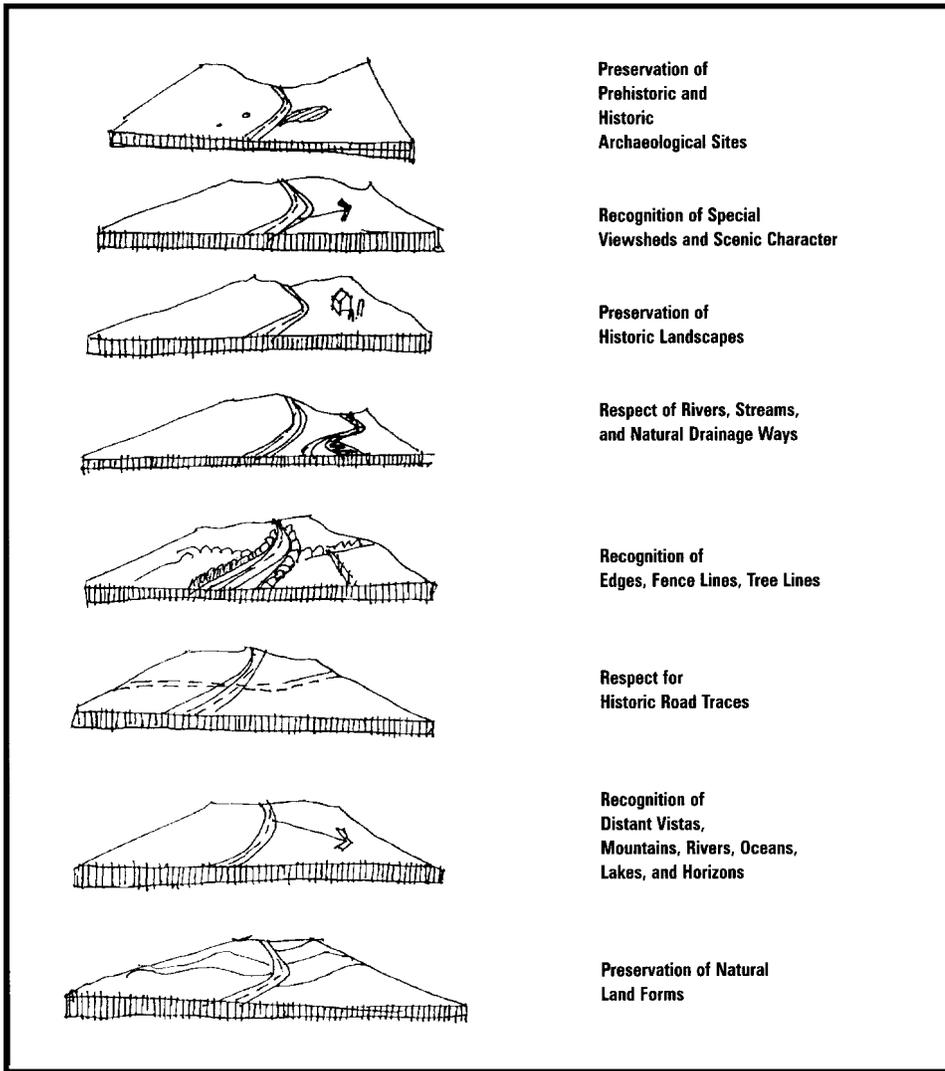


Figure 1.4
Understanding what is important about the land.

Some of the questions to ask at this stage include:

- What are the physical characteristics of the corridor? Is it in an urban, suburban, or rural setting?
- How is the corridor being used (other than for vehicular traffic)? Are there destination spots along the traveled way that require safe access for pedestrians to cross? Do bicycles and other nonmotorized vehicles or pedestrians travel along the road?
- What is the vegetation along the corridor? Is it sparse or dense; are there many trees or special plants?
- Are there important viewsheds from the road?
- What is the size of the existing roadway and how does it fit into its surroundings?

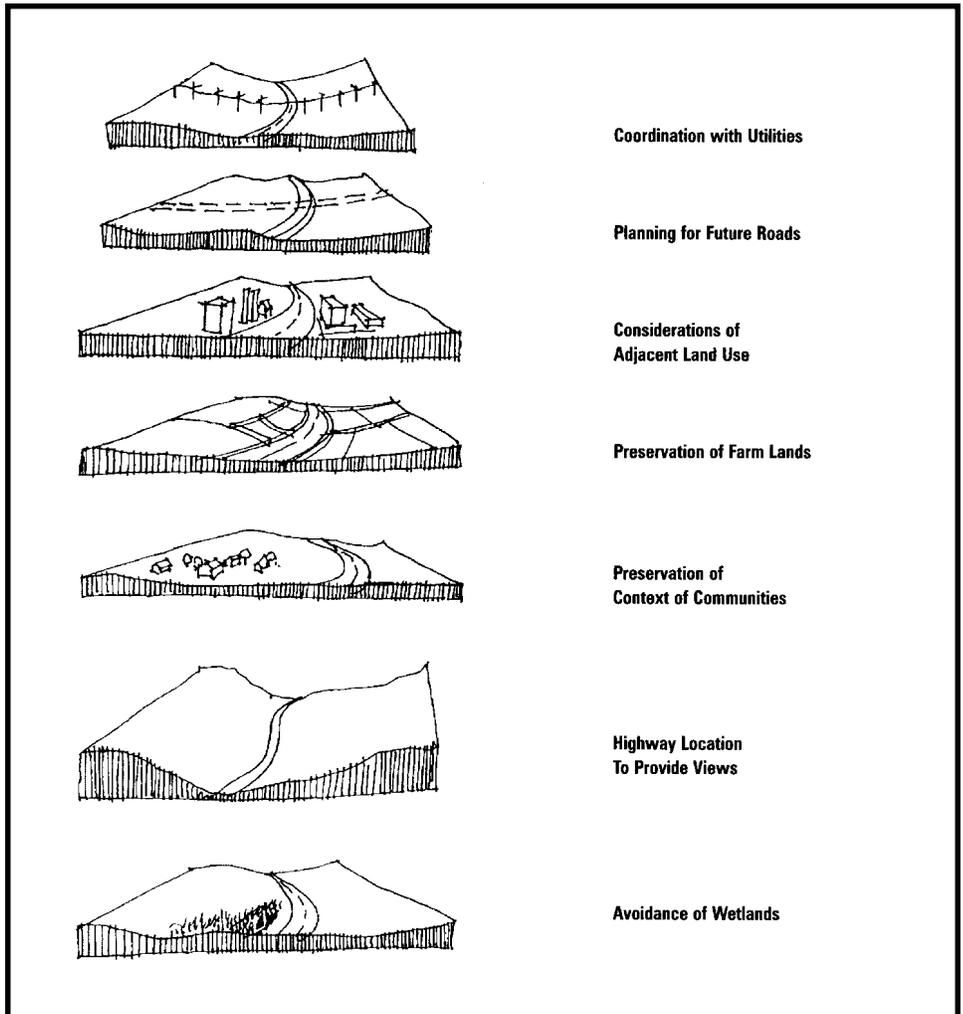


Figure 1.4
(continued)

- Are there historic or especially sensitive environmental features (such as wetlands or endangered species habitats) along the roadway?
- How does the road compare to other roads in the area?
- Are there particular features or characteristics of the area that the community wants to preserve (e.g., a rural character, a neighborhood atmosphere, or a main street) or change (e.g., busy electrical wires)?
- Is there more than one community or social group in the area? Are different groups interested in different features/characteristics? Are different groups affected differently by possible solutions?
- Are there concentrations of children, the elderly, or disabled individuals with special design and access needs (e.g., pedestrian crosswalks, curb cuts, audible traffic signals, median refuge areas)?

FINAL DESIGN

After a preferred alternative has been selected and the project description agreed upon as stated in the environmental document, a project can move into the final design stage. The product of this stage is a complete set of plans, specifications, and estimates (PS&Es) of required quantities of materials ready for the solicitation of construction bids and subsequent construction. Depending on the scale and complexity of the project, the final design process may take from a few months to several years.

The need to employ imagination, ingenuity, and flexibility comes into play at this stage, within the general parameters established during planning and project development. Designers need to be aware of design-related commitments made during project planning and project development, as well as proposed mitigation. They also need to be cognizant of the ability to make minor changes to the original concept developed during the planning phase that can result in a “better” final product.

The interests and involvement of affected stakeholders are critical to making design decisions during this phase, as well. Many of the same techniques employed during earlier phases of the project development process to facilitate public participation can also be used during the design phase.

The following paragraphs discuss some important considerations of design, including:

- Developing a concept
- Considering scale and
- Detailing the design.

Developing a Concept

A design concept gives the project a focus and helps to move it toward a specific direction. There are many elements in a highway, and each involves a number of separate but interrelated design decisions. Integrating all these elements to achieve a common goal or concept helps the designer in making design decisions.

Some of the many elements of highway design are illustrated in Figure 1.5, including:

- (a) Number and width of travel lanes, median type and width, and shoulders
- (b) Traffic barriers
- (c) Overpasses/bridges
- (d) Horizontal-and vertical alinement, and affiliated landscape.

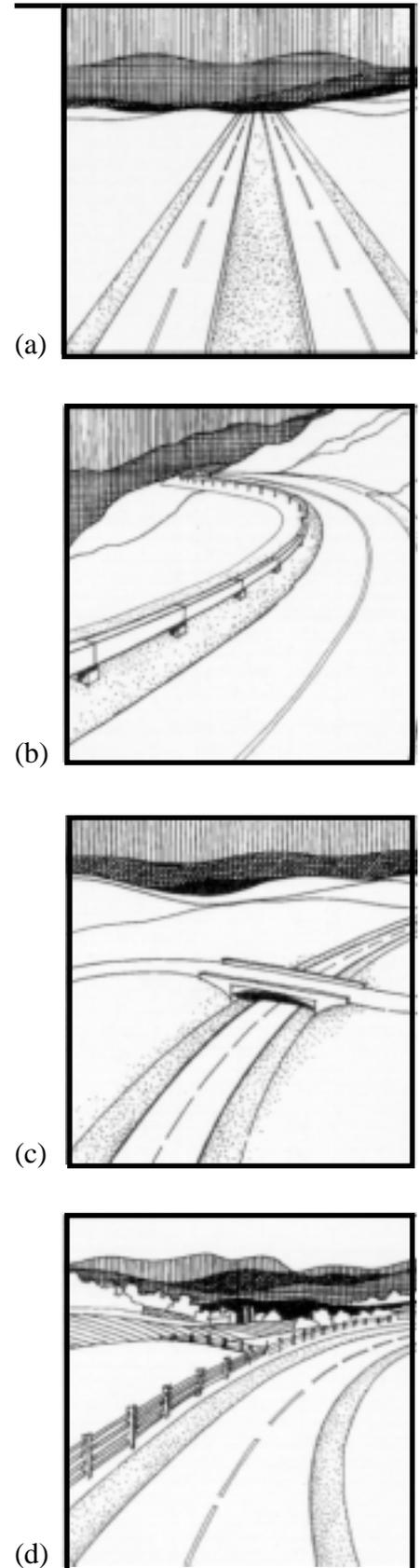


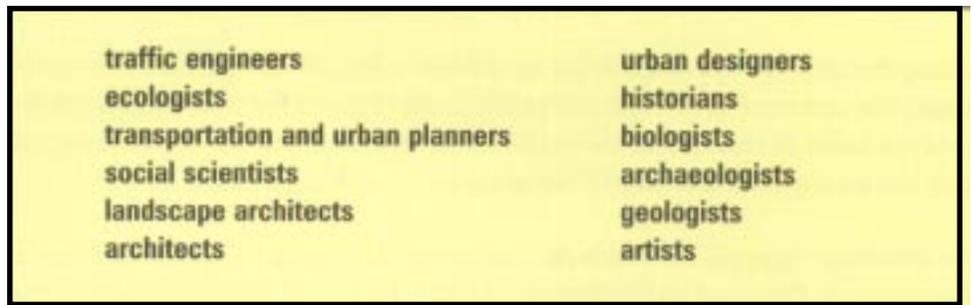
Figure 1.5

All elements of highway design need to be part of an overall concept.

Having a multidisciplinary team can assist in establishing a design “theme” for the road or determining the existing character of a corridor that needs to be maintained. Design consistency from the perspective of physical size and visual continuity is an important factor when making such improvements, and a multidisciplinary design team can assist in maintaining that consistency.

The earlier the multidisciplinary team is formed, the better. As with the public, various professionals need to be involved in the decision-making process early, when they can have the most effective impact on the eventual design of a project. In this way, it is possible to avoid having to force-fit aesthetic design treatments, such as landscape treatments, as “add-ons” to the project to try to “pretty up” a design that isn’t quite right or one that is unacceptable to the community. The opportunities for landscape architects, architects, planners, urban designers, and others will be enhanced, and the chances of a successful project increased, if their skills are utilized from the beginning. A multidisciplinary design team may consist of some of the professionals listed in Figure 1.6, in addition to highway engineers.

*Figure 1.6
A multidisciplinary design team
consists of some of these
professionals.*



*For this overpass, an artist and structural
engineers worked together to achieve a
design that represents the unique
characteristics of the area.
(Thomas Road Overpass, Phoenix, AZ)*





Piers were designed and decorated with art forms from the Hohokam tribe, whose ancient burial ground is near the overpass. (Thomas Road Overpass, Phoenix, AZ)

Using the concept approach helps to achieve a holistic design for the project. Using the surrounding context and public input to guide the development of the concept helps to ensure that the project is in harmony with its surroundings and that the elements of the project are in harmony with each other.

An excellent example of a holistic design approach is the Merritt Parkway in Connecticut. Designed and built in the 1930's, its overall design philosophy was to build a graceful highway set in a natural environment. This was achieved by using long, gradual vertical curves, rounding out rockcuts to produce a natural appearance, and most important, integrating the traveled way into the terrain through choice of alignment and a carefully planned landscape. The result was a highway that not only met traffic demand, but was also a scenic escape for inhabitants of the urbanized areas it served.



The Merritt Parkway is almost undetectable beneath this country road. (Fairfield County, CT)

*Mainline of the Merritt Parkway.
(Fairfield Co., CT)*



Traveling along the 61-km (38-mile) route today, it's easy to see how all the elements of the roadway fit together to achieve this parkway concept. The setting, with its vegetation, appears natural. The pavement width is minimal; opposing traffic is separated by a grass median and most shoulders are covered with grass. Despite the population growth that has developed around the parkway, and in many cases directly up to the parkway, the density of trees and the carefully planned topography hide this development from view. One of the most striking features of the parkway is its bridges. There are 72 in all (35 of which carry intersecting crossroads over the parkway), and each is designed differently. Even the materials used vary considerably, from stone to concrete to steel, yet they all work together, because they are all designed within the same scale. They are all approximately the same length and height, which gives the appearance that they all belong together, despite the fact that some are arch construction and some post and beam.

*A double-span stone bridge
along the Merritt Parkway.*





A stone bridge - another of the unique overpasses on the Merritt Parkway.

For existing roads, where improvements may only involve a small section of the road, there may not be the need to develop an entirely new concept for the roadway. In fact, it would probably be inappropriate to do so, because the result would be that one small section of the roadway looked much different than the rest. It is important in these cases to be consistent with the existing design of the overall route, using the information gathered to assess the character of the area and to design with sensitivity to that character.

An exception might be when the environment of the road changes along a short section. For instance, a rural collector may change characteristics as it enters a town and becomes an urban street for a few blocks, then changes back to a rural collector. Designers working on the urban section of the street do not have to be consistent with the look of the road outside the urban environment, because its character is so different. Both the urban and rural sections should, however, maintain the same general scale in terms of roadway width.

Considering Scale

People driving in a car see the world at a much different scale than people walking on the street. This large discrepancy in the design scale for a car versus the design scale for people has changed the overall planning of our communities. For example, it has become common in many suburban commercial areas that a shopper must get in the car and drive from one store to the next. Except in the case of strip malls, stores are often separated by large parking lots and usually have no safe walkways for pedestrians. This makes it difficult to get around any other way but by car. This type of design scale is in sharp contrast to pre-automobile commercial areas that commonly took the form of “main streets,” where walking from one store to the next, was the norm.

Main streets are much more pedestrian friendly, partly because of their design scale, than the typical modern commercial strip

A typical “modern” commercial strip.



*A “main street.”
(Bellevue Avenue, Newport, RI)*



Trying to accommodate users of the road who have two different design scales is a difficult task for designers; however, designers must always consider the safety of pedestrian and nonvehicular traffic, along with the safety of motorists. Both are users of the road. In many road designs, pedestrian needs were considered only after the needs of motorized vehicles. Not only does this make for unsafe conditions for pedestrians, it can also drastically change how a roadway corridor is used. Widening a roadway that once allowed pedestrian access to the two sides of the street can turn the roadway into a barrier and change the way pedestrians use the road and its edges.



This recently reconstructed urban street preserves the pedestrian scale. (Westminster, MD)

The design element with the greatest effect on the scale of the roadway is its width, or cross section. The cross section can include a clear zone, shoulder, parking lanes, travel lanes, and/or median. The wider the overall roadway, the larger its scale; however, there are some design techniques that can help to reduce the perceived width and, thus, the perceived scale of the roadway. Limiting the width of pavement or breaking up the pavement is one option. In some instances, four-lane roadways may look less imposing by designing a grass or planted median in the center. Grass shoulders, such as those often used in many parts of the southeastern United States, limit the perceived width of the roadway and still provide a breakdown area for motorists. These types of shoulders may be appropriate, depending on the context of the area; volume, type, and speed of traffic; and the needs of pedestrians and bicyclists. Green space between sidewalks or nonmotorized vehicle paths and the travel lanes also helps to break up the perceived width of the pavement.

On this scenic road, grass shoulders were considered to be appropriate and contribute to both the aesthetics and function of the road. (Savannah River Scenic Byway, SC)



Elements (or a lack of elements) along the roadside also contribute to the perceived width of the road and can even affect the speed at which motorists travel. With all else being equal, the wider the perceived road, the faster motorists will travel. Along with horizontal and vertical alignment, cross-section elements, and other elements, such as vegetation along the roadway, buildings close to the road, on-street parking, and even noise walls, may contribute to reducing the perceived width and speed of the road. Considering these elements is important in designing a facility that is compatible with its surroundings.

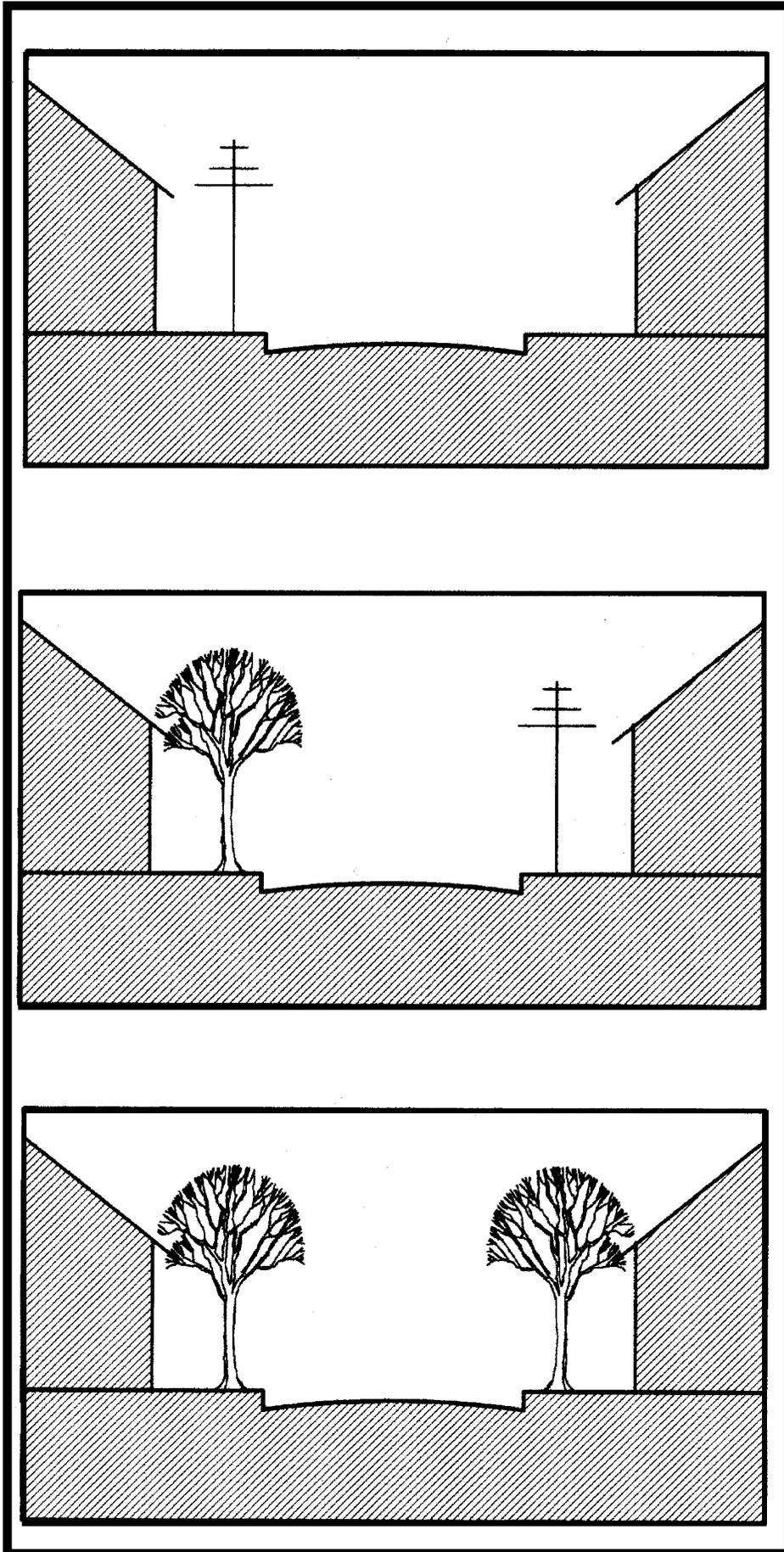


Figure 1.7
Relatively minor differences in roadway cross section and the treatment of the roadway edge can have major effects on perceived width.

Shoulder design and elements along the roadside contribute to the perceived width of the roadway.

Rural highway with no shoulder and vegetation along the roadway.



A two-lane rural highway with paved shoulder and sparse vegetation.



Detailing the Design

Particularly during the final design phase, it is the details associated with the project that are important. Employing a multidisciplinary design team ensures that important design details are considered and that they are compatible with community values. Often it is the details of the project that are most recognizable to the public. A special type of tree that was used as part of the landscape plan, antique lighting, brick sidewalks, and ornamental traffic barriers are all elements of a roadway that are easily recognizable and leave an impression. Because of their visibility, the treatment of details is a critical element in good design.



*A multidisciplinary design team can produce an aesthetic and functional product when the members work together and are flexible in applying guidelines.
(Baltimore-Washington Parkway, MD)*

For instance, the stonewall appearance of the traffic barriers on the Baltimore-Washington Parkway is one of the first elements noticed by drivers using that route. If a plain concrete barrier had been used instead, the overall appearance of the parkway would change considerably. A design that requires no traffic barriers whatsoever may be considered even more aesthetically pleasing than improved barrier designs, even if they are given a pleasing design treatment.

I-35E, which passes through downtown St. Paul, MN, incorporated many design elements (such as ornate bridge rails and lighting, planted medians, and street furniture) to achieve the identified project goals of integrating the freeway into the urban environment, designing a gateway into downtown, providing pedestrian access, and reflecting the history and character of the area.

Such features as traffic barriers (or the lack of traffic barriers), bridge rails, and the treatment of overpasses, medians, and landscape development should be integral parts of the design process, not left to the end or forgotten entirely.

An innovative barrier design was used on the Baltimore-Washington Parkway.(MD)



Much consideration was given to the details of I-35E (St. Paul, MN)



RIGHT-OF-WAY, CONSTRUCTION, AND MAINTENANCE

Once the final designs have been prepared and needed right-of-way is purchased, construction bid packages are made available, a contractor is selected, and construction is initiated. During the right-of-way acquisition and construction stages, minor adjustments in the design may be necessary; therefore, there should be continuous involvement of the design team throughout these stages. Construction may be simple or complex and may require a few months to several years. Once construction has been completed, the facility is ready to begin its normal sequence of operations and maintenance.

Even after the completion of construction, the character of a road can be changed by inappropriate maintenance actions. For example, the replacement of sections of guardrail damaged or destroyed in crashes commonly utilizes whatever spare guardrail sections may be available to the local highway maintenance personnel at the time. The maintenance personnel may not be aware of the use of a special guardrail design to define the “character” of the highway. When special design treatments are used, ongoing operation and maintenance procedures acknowledging these unusual needs should be developed. For example, the Oregon DOT has developed a special set of maintenance procedures for its scenic and historic highways.



Rehabilitated bridge railings along the historic Columbia River Highway. (Hood County, OR)

ELEMENTS OF A SUCCESSFUL PROCESS

Table 1.1 summarizes the five basic stages in highway planning and development.

Stage	Description of Activity
Planning	State DOTs, MPOs, and local governments identify transportation needs and program projects to be built within financial constraints.
Project Development	The transportation project is more clearly defined. Alternative locations and design features are developed and an alternative is selected.
Design	The design team develops detailed PS&Es.
Right-of-Way	Additional land needed for the project is purchased.
Construction	The State or local government selects the contractor, who then builds the project.

*Table 1.1
Summary of the Highway Planning and
Development Process*

In other words, a successful highway design process includes the following:

- Early and continuous public involvement throughout the project
- The use of visualization techniques to aid the public
- Early and continuous use of a multidisciplinary design team
- The application of flexible and creative design criteria

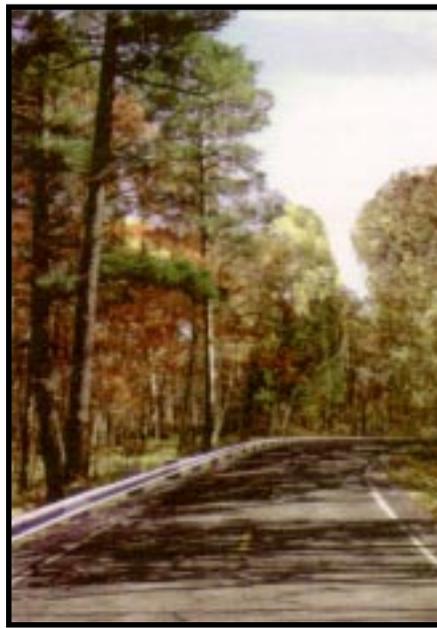
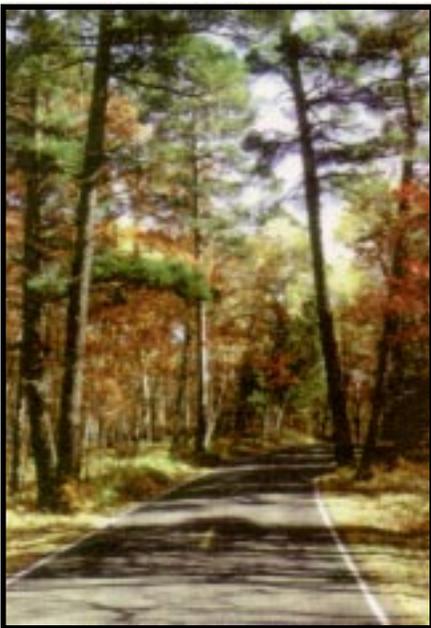
Some of these elements are discussed in the following paragraphs.

Public Involvement. A successful highway process includes public involvement. To be effective, public involvement must be sought from the beginning, during the definition of need for the project. The public should be involved while there are the greatest opportunities for changes in the design. This will result in a smoother and faster process.

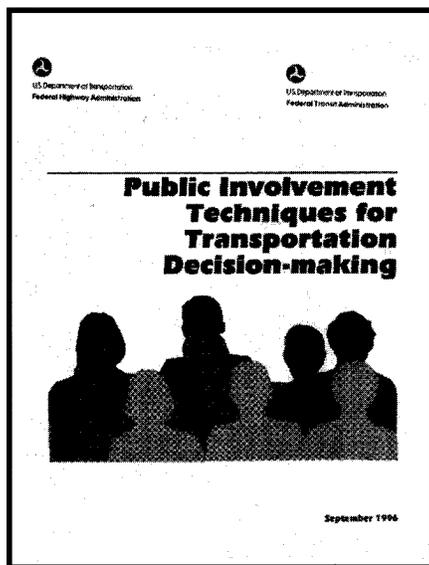
Public input can also help in assessing the characteristics of the area and determining what physical features are most valued by the community, thus having the greatest potential for impact. Knowing the features of an area are valued may help designers avoid them altogether and reduce the need for mitigation and the likelihood for controversy. After working with the community to define the project and assess the physical character, continuous public involvement is important to gain input on possible alternatives.

Identifying community values, defining the project need with the public, gathering information on the area, and solving design conflicts with the public necessitate a proactive public involvement effort going far beyond the usual presentation of well-developed design alternatives at formal public meetings and hearings. For example, by using a workshop meeting format early in project design, highway designers can ask members of the public to identify types of design features that they find appealing or unappealing. In September 1996, the FHWA and the Federal Transit Administration (FTA) issued *Public Involvement Techniques for Transportation Decisionmaking*, which describes a wide variety of these innovative public involvement techniques.'

Visualization Tools. The most effective communication between two parties takes place when both speak the same language. This can be achieved in design using illustrations that show the public what a project will look like before it is built. Increasingly, computer-generated visualization tools are being used for this purpose. Designers can communicate conceptually what they are planning for an area, and citizens can react with a certain degree of confidence that they understand what is being communicated to them. Lower end computer systems use a photograph taken of the existing project area and superimpose a drawing, using computer graphics, of what the new construction will look like. Visualization tools, such as these, help the public gain a better understanding of the proposed improvement project.



*Visualization tools were used to generate these images showing the public a proposed highway improvement.
(State Highway 38, MN)*



REFERENCES

The FHWA and FTA have recently published *Public Involvement Techniques for Transportation Decisionmaking*. This book describes many specific public involvement techniques, such as charettes or interactive video displays. The foreword to the report and the “Taking Initial Steps” sections at the end of each chapter introduce the reader to approaches to developing and carrying out a public involvement strategy. A limited number of copies is available by phoning the Environmental Operations Division of FHWA at 202-366-2065. The FHWA Internet home page has a electronic version that can be downloaded and searched. The FHWA home page address is <http://www.fhwa.dot.gov>. Press the publications and statistics button on the home page for a listing of reports that can be downloaded.

Public Involvement Techniques for Transportation Decisionmaking helps highway designers who are seeking ways to enable the public to contribute constructively to planning and design issues. The project presentations and statements from the public during traditional public meetings and public hearings are often more conducive to taking stands than to solving difficult design issues. This publication offers both highway designers and citizens a wealth of specific ideas and contacts for more information in the following topic areas:

- “Informing People Through Outreach and Organization” provides a variety of ways to orchestrate public contacts to enable a flow of information between the public and the agency, where it can be used effectively in the design process.
- “Involving People Face-to-Face Through Meetings” shows how to make meetings interactive occasions where people can discuss design issues and work together on solutions.
- “Getting Feedback From Participants” provides new ideas and perspectives and helps agencies determine how well citizens understand complex issues. Feedback may indicate that more information is needed for better understanding.
- “Using Special Techniques To Enhance Participation” provides ways to capture and maintain attention in today’s busy environment. Gradually declining attendance and a lack of questions from citizens may indicate that involvement is faltering and in need of rejuvenation.

Another useful guide is *Community Impact Assessment: A Quick Reference for Transportation*, also published by FHWA. This guide discusses the need for the full consideration of possible adverse social, economic, and environmental effects related to highway projects and how to address these concerns during the planning and development stages of a project.

A panel of State DOT and local government technical specialists were brought together primarily to frame a practical process for assessing community impact. The specialists developed the process based on their collective experience with FHWA's National Environmental Policy Act (NEPA) process and ISTEA. The resulting process parallels the FHWA NEPA process and is presented with introductory information on community impact assessment: why an assessment should be conducted, its legal backing, how to define community, the community's role in project development and in the last section available resources.

Much of the booklet focuses on the community impact assessment process, including how it should work and its components. Public involvement is a common thread that runs throughout the process. Sections include:

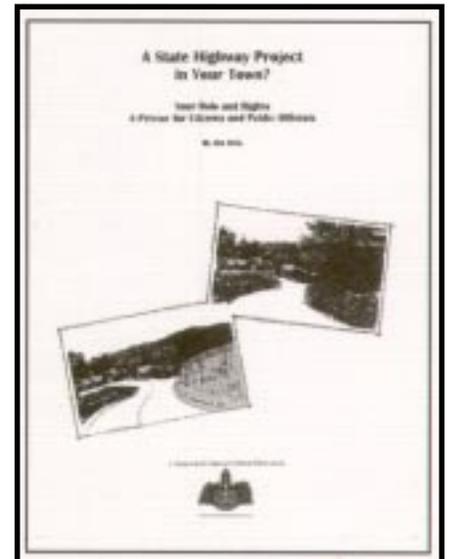
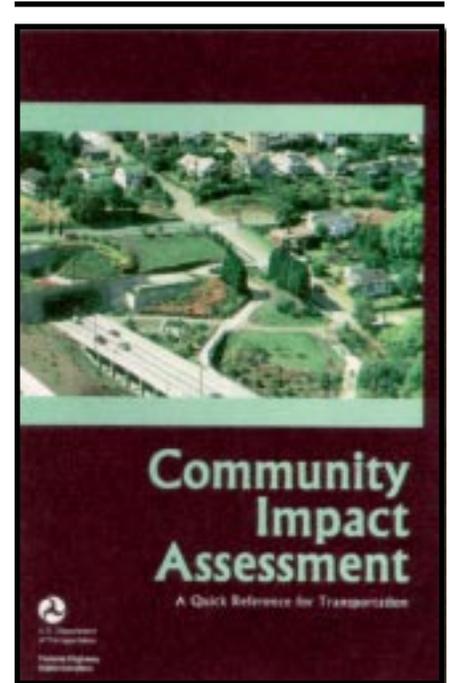
- Defining the Project
- Developing a Community Profile
- Collecting Data
- Analyzing Community Impacts
- Selecting Analysis Tools
- Identifying Solutions
- Using Public Involvement
- Documenting the Findings.

To obtain copies of this brochure, call the FHWA, Environmental Operations Division at 202-366-0106.

A State Highway Project in Your Town? Your Roles and Rights: A Primer for Citizens and Public Officials, by Vermont architect Jim Wick, also approaches highway design from a different viewpoint. Although written specifically for citizens and public officials in the State of Vermont, all will find this handbook useful for gaining a better understanding of the highway planning and design process. It gives tips for how communities can get involved so that towns can achieve the kinds of road projects they want. Included in the handbook are the following sections:

- The Highway Planning and Development Process
- Overview of Highway Design Principles
- Highway Laws, Regulations, and Policies
- Strategies for Your Town

Copies of this booklet are available from the Preservation Trust of Vermont, 104 Church Street, Burlington, VT 05401.



Chapter 2

HIGHWAY DESIGN STANDARDS

The Colonial Parkway connects Jamestown, Williamsburg, and Yorktown, VA.



THE AASHTO GREEN BOOK

What the Green Book Contains

The reference most often used by designers during the design of a highway project is commonly referred to as the Green Book. Its official title is *A Policy on the Geometric Design of Highways and Streets*. It has been published by the AASHTO, in one form or another, since the late 1930's, with the most recent edition issued in 1994.

Although often viewed as dictating a set of national standards, this document is actually a **series of guidelines** on geometric design within which the designer has a range of flexibility. As stated in the forward to this document:

The intent of this policy is to provide guidance to the designer by referencing a recommended range of values for critical dimensions. Sufficient flexibility is permitted to encourage independent designs tailored to particular situations. (p. xliii).

In order for the design criteria in the Green Book to become a standard, they must be adopted by a particular State (or may be set by court decision). The FHWA has adopted applicable parts of the Green Book as the national standard for roads on the NHS. These roads comprise all the interstates and some other primary routes. The design of roads other than those on the NHS is subject to the standards of the particular State. The standards adopted by a State are usually based on the Green Book criteria.

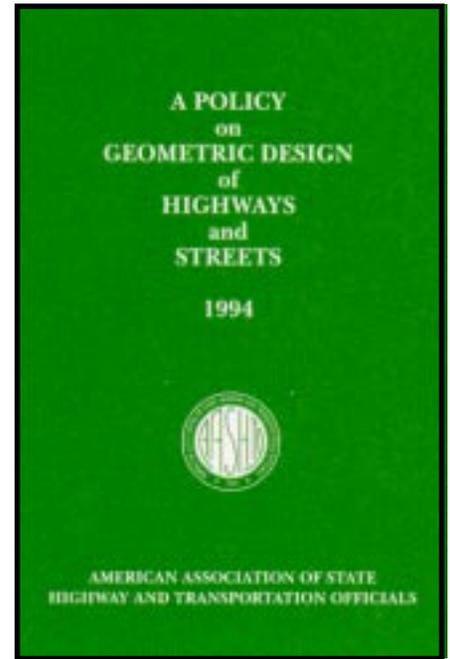
What the Green Book Does Not Contain

The Green Book is not a design manual. It provides guidance on the geometric dimensions of the roadway. This includes widths of travel lanes, medians, shoulders, and clear zones; the width and shape of medians; turning radii; and other dimensions. There are many aspects of design that are not directly addressed in the Green Book. A number of these items are as follows:

- Problem definition
- Project definition
- Definition of the termini of the project
- Development of a project concept
- Aesthetic treatment of surfaces
- Design within the appropriate context
- Selection of the appropriate guardrail/bridge rail
- Determination of functional classification
- Determination of the appropriate functional requirements, capacity, and level of service
- Structure design
- Landscape development
- Selection of light fixtures
- Roadside development
- Traffic operations

Some of these items are addressed by reference in the Green Book, including:

1. *The Roadside Design Guide*, AASHTO, 1996.
2. *The Manual on Uniform Traffic Control Devices for Highways and Streets* (MUTCD), FHWA, 1988.
3. *A Guide for Transportation Landscape and Environmental Design*, AASHTO, June 1991.
4. *Guide for the Development of Bicycle Facilities*, AASHTO, August 1991.



An example of a road designed within the appropriate context-as a gateway to a beach resort. This is a design aspect the Green Book is not intended to address. (Clearwater, FL)



Many fundamental questions that affect roadway design must be answered before the design phase begins and the application of the Green Book and/or State standards comes into play. Decisions are made during planning and project development, and it is then that road design starts. Decisions that are made before the design phase include:

- Whether the proposed improvement will be two, four, six, or eight lanes
- Whether the facility will have a median
- Whether roadway junctions will be at-grade intersections or grade separated interchanges.

Design involves the difficult process of merging these previously determined design decisions with the appropriate design criteria used in the Green Book, working within the existing environmental and other important constraints, and using a designer's best judgment and experience to make decisions.

TYPES OF HIGHWAY IMPROVEMENT PROJECTS

There are four basic types of physical improvement projects, some of which must comply with standards and others that do not have to comply. These types of improvement projects are discussed in the following paragraphs.

New Construction

As its name implies, this action involves the construction of a new highway facility where nothing of its type currently exists. This might take the form of a bypass constructed to carry through-traffic around an existing town or it might be a new two-lane access route linking an existing arterial highway with a State park.

Reconstruction

This typically involves a major change to an existing highway within the same general right-of-way corridor. In many parts of the country, roads that were originally constructed in the early 20th century as two-lane “farm-to-market” roads have been reconstructed over the past few decades into multilane divided arterials to better accommodate the travel demands generated by suburban development. Reconstruction also may involve making substantial modifications to an older highway’s horizontal and vertical alignment in order to eliminate safety and accident problems.

Four types of highway construction:

1. New Construction
2. Reconstruction
3. 3R
4. Maintenance



*Reconstruction of 7th Street.
(Phoenix, AZ)*

Reconstruction can involve a major change to the roadway appearance.

Before reconstruction



After reconstruction.



Resurfacing, Restoration, Rehabilitation (3R)

3R projects focus primarily on the preservation and extension of the service life of existing facilities and on safety enhancements. Under the classification of 3R projects, the types of improvements to existing federal-aid highways include: resurfacing, pavement structural and joint repair, minor lane and shoulder widening, minor alterations to vertical grades and horizontal curves, bridge repair, and removal or protection of roadside obstacles.

Transportation Research Board Special Report 214, *Designing Safer Roads, Practices for Resurfacing, Restoration, and Rehabilitation* (1987), documents the result of a study on the cost effectiveness of highway geometric design standards for 3R projects.¹ Each State was invited to develop and adopt minimum design criteria for nonfreeway 3R projects. The result is that States typically employ design criteria for 3R projects that are lower than those contained in the AASHTO Green Book.



*Ongoing maintenance is necessary to keep facilities in good condition.
(Rt. 136, Westport, CT)*

Maintenance

Typically, maintenance activities consist of those actions necessary to keep an existing highway facility in good condition. Maintenance activities include repainting lane and edge lines, removing accumulated debris from drainage inlets, repairing surface drainage features, mowing, and removing snow.

¹ Transportation Research Board Special Report 214, *Designing Safer Roads, Practices for Resurfacing, Restoration, and Rehabilitation* (1987)

Design criteria apply only to the first three of these actions: new construction, major reconstruction, and 3R projects. In addition, because 3R projects generally do not involve more than minor changes to roadway alignment and geometry, except to improve safety, FHWA and the State DOTS acknowledge that the AASHTO Green Book criteria do not always have to be adhered to for these projects. Because 3R projects have minimal impact, application of the Green Book design criteria may affect character of a roadway.

As stated in the Green Book, existing roads that do not meet the guidelines for geometric design are not necessarily unsafe and do not necessarily have to be upgraded to meet the design criteria:

The fact that new design values are presented herein does not imply that existing streets and highways are unsafe, nor does it mandate the initiation of improvement projects ...For projects of this type (resurfacing, restoration, or rehabilitation [3R]), where major revisions to horizontal and vertical curvature are not necessary or practical, existing design values may be retained. (p.xliii)

RELATIONSHIP OF THE GREEN BOOK TO STATE AND LOCAL DESIGN MANUALS

As stated earlier, in order for the Green Book to become a standard for a particular State, it must be adopted by that State (or may be set by a court decision). Although all the State DOTs may not specifically use the Green Book as their standard, State highway design manuals do derive from, and explicitly reference, the AASHTO Green Book. Despite this common origin, there are some variations in terms of the degree of adherence to all the contents of the document within the State standards. For example, Table 2.1 presents a comparison of the minimum stopping sight distance values for a range of design speeds, as defined in the 1994 edition of the AASHTO Green Book, compared to the most recent versions of the highway design manuals for California, Oregon, and Virginia.

Minimum Stopping Sight Distance (m)				
Design Speed (km/h)	AASHTO (1)	California DOT (2)	Oregon DOT (3)	Virginia DOT (4)
60	74.3—84.6	85	80	80
80	112.8—139.4	130	120	120
100	157—205	190	160	160
120	202.9—285.6	255	210	210
130	N.A. (5)	290	N.A.	N.A.

Table 2.1
Example of design criteria differences
among several States.

Notes:

(1) *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994 p. 120, Table III-1.

(2) *Interim Selected Metric Values for Geometric Design*, California DOT, December 15, 1993, p. 2, Table 201.1.

(3) *Metric Highway Design Manual*, Oregon DOT, 1994, p. 92, Figure 4-10.

(4) *Road Design Manual*, Volume 2 (Metric), Virginia DOT, August 1994, p. 27, Table III-1.

(5) N.A.=Not Applicable

The AASHTO Green Book provides a range of values for the minimum stopping sight distance, while each of the three States provides only one minimum value. In each instance, the California requirement is highest. Moreover, the California stopping sight distance presents an upper limit design speed of 130 km/h (81 mph), although AASHTO, Oregon, and Virginia standards do not acknowledge using a design speed above 120 km/h (75 mph).

The minimum criteria established for Oregon and Virginia typically fall into the lower to middle portion of the AASHTO range of acceptable values. This situation is encountered in most other States, because in the past most States sought to meet or exceed the minimum values established by AASHTO in their designs, and this is reflected in their standards.

New State and Local Standards

Since the passage of ISTEA in 1991, States have been allowed to develop highway design standards outside of the Green Book criteria. A number of States have either developed or are in the process of developing new standards for roads not on the NHS. Idaho and Maine have implemented such separate design standards, Colorado and Vermont are at various stages of developing separate standards, and South Carolina plans to do so in the near future. These standards will give designers a greater range of flexibility when working on improvement projects to non-NHS roads.

The Rhode Island DOT has been particularly innovative in developing new State standards for all State roads. Rhode Island has decided that, because it has historic, scenic, and cultural resources along many of its roads, it would be inappropriate to make major changes to the geometry and alignments that would negatively affect these resources. When possible, the State DOT would prefer to maintain existing facilities by keeping existing alignments and geometries. For new construction, standards based on the AASHTO Green Book would be followed. This new approach will help to preserve the resources along many of Rhode Island's older roads and help engineers maintain the roads in a way that the public feels is appropriate for the communities.

*Scenic roads can benefit from
new State standards.
(Snickersville Tnpk., VA)*



A number of local governments (primarily counties) have also developed their own geometric guidelines in recent years to allow for expanded design flexibility on local roads. In these cases, the local design guidelines are explicitly related to those of their respective State DOT; and/or the AASHTO Green Book.

For example, the *Design Guidelines and Standards for Scenic and Historic Roads*, published in June 1994 by the Prince George's County (Maryland) Department of Public Works and Transportation, was prepared specifically to ensure the adequacy and safety of any new or upgraded roadway within the county in accordance with the guidelines and in order to preserve the scenic and historic values of adjacent areas.



Specific criteria for scenic roads can help minimize impact on valuable resources, such as these rock fences. (Paris-Lexington Road, KY)

THE DESIGN EXCEPTION PROCESS

Despite the range of flexibility that exists with respect to virtually all the major road design features, there are situations in which the application of even the minimum criteria would result in unacceptably high costs or major impact on the adjacent environment. For such instances when it is appropriate, the design exception process allows for the use of criteria lower than those specified as minimum acceptable values in the Green Book.

If the highway project is not on the NHS, the State does not need FHWA approval for a design exception. Under the ISTEA, the State can request an exemption from FHWA oversight on non-NHS projects.

For projects on NHS routes, FHWA requires that all exceptions from accepted guidelines and policies be justified and documented in some manner and requires formal approval for 13 specific controlling criteria. The process of justification and documentation, although not required, can be followed by States with exemption from FHWA oversight on non-NHS projects, as well. These criteria are as follows:

1. Design speed
2. Lane width
3. Shoulder width
4. Bridge width
5. Structural capacity
6. Horizontal alinement
7. Vertical alinement
8. Grade
9. Stopping sight distance
10. Cross slope
11. Superelevation
12. Vertical clearance
13. Horizontal clearance (not including clear zone)

For the most part, design exceptions to these 13 criteria can be easily identified and defined. Two items, horizontal clearance and design speed, warrant further explanation.

Horizontal Clearance

For clear zones, the criteria in the AASHTO *Roadside Design Guide*² should be treated as guidance and not as a national standard requiring a design exception if not numerically met.

Design Speed

Design speed is used to determine individual design elements, such as stopping sight distance and horizontal curvature. Therefore, a design speed exception is an exception to all the various design elements affected by it and should be justified on that basis.

A few points to remember when evaluating design exceptions are as follows:

- Consideration should be given to the effect of the variance on the safety and operation of the facility and its compatibility with adjacent sections of the roadway.
- Consideration should be given to the functional classification of the road, the amount and character of the traffic, the type of project, and the accident history of the road.
- The cost of attaining full standards and any resultant impact on scenic, historic, or other environmental features should also be examined.
- Finally, the following three issues should be considered. What is the degree to which a guideline is being reduced? Will the exception affect other guidelines? Are there any additional features being introduced that would mitigate the deviation?

For preventive maintenance projects, no exceptions are needed for the retention of existing features.

² Roadside Design Guide, AASHTO, Washington, DC, 1996.

TORT LIABILITY AS IT RELATES TO THE GREEN BOOK

Tort claims against highway agencies have steadily risen since the early 1970's, when the AASHTO first began surveying States for information about tort liability claims. This is partly due to the trend of no longer allowing design immunity (sovereign immunity) for highway agencies in almost all States. There is evidence to believe that the majority of these cases involve allegations of faulty traffic control devices or maintenance. Even though the number of cases alleging design defects is relatively small in comparison, tort liability is still a real concern for highway engineers.

Tort is a legal term that refers to a civil wrong that has been committed, in this case by highway agencies. Negligence is a term used to refer to a classification of tort in which the injury is not intentional, but where there was failure to use due care in the treatment of others compared to what a "reasonable man" would have done. Liability is the responsibility to make restitution to the damaged party through an action or payment determined by the court. Finally, States protected with sovereign immunity for design cannot be sued for decisions regarding design. (Sovereign immunity is now only in existence in a handful of States.)

The AASHTO Green Book, other State-adopted highway standards, Federal and State regulations and guidelines, and research publications issued by the Transportation Research Board are often used in tort cases to educate the jury about the standard level of practice for design. In addition, expert witnesses are used, who in turn rely on written text to explain the accepted standard practices for design to the jury.

*Designing a highway that is safe and has a minimal impact on its surrounding environment can be a difficult task for engineers. Sometimes a design exception is necessary, as was the case for this project.
(Bethel, VT)*



This does not mean, however, that adherence to accepted standard practices, such as the AASHTO Green Book guidelines, automatically establishes that reasonable care was exercised. Conversely, deviation from the guidelines, through the use of a design exception, does not automatically establish negligence. The best defense for a design engineer is to present persuasive evidence that the guidelines were not applicable to the circumstances of the project or that the guidelines could not be reasonably met. (It should be noted that an economic defense is not the most effective.) It is highly recommended that designers document their rationales for decisions. If the justification documented by a designer completely describes the physical and environmental factors that make the exception or any design necessary, it is likely that this will be legally persuasive that the correct procedures were followed and ultimately the appropriate decision was made. In addition, it is helpful to have statements by other design experts who concur with the decision in the documentation.

As a result of concerns about litigation, designers may be tempted to be very conservative in their approaches to highway design and avoid innovative and creative approaches to design problems. While it is important for design engineers to do their jobs as thoroughly and carefully as possible, avoiding unique solutions is not the answer. This may undermine design practice and limit growth in the engineering profession. Designers need to remember that their skills, experience, and judgment are still valuable tools that should be applied to solving design problems and that, with reliance on complete and sound documentation, tort liability concerns need not be an impediment to achieving good road design.

Chapter 3

FUNCTIONAL CLASSIFICATION

Refer to Chapter I of the AASHTO Green Book

One of the first steps in the design process is determining the functional classification of a facility.



BACKGROUND

Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of traffic service that they are intended to provide. There are three highway functional classifications: arterial, collector, and local roads. All streets and highways are grouped into one of these classes, depending on the character of the traffic (i.e., local or long distance) and the degree of land access that they allow. These classifications are described in Table 3.1.

- The functional classes:**
- Arterial
 - Collector
 - Local

Each type of road has a specific purpose or function.

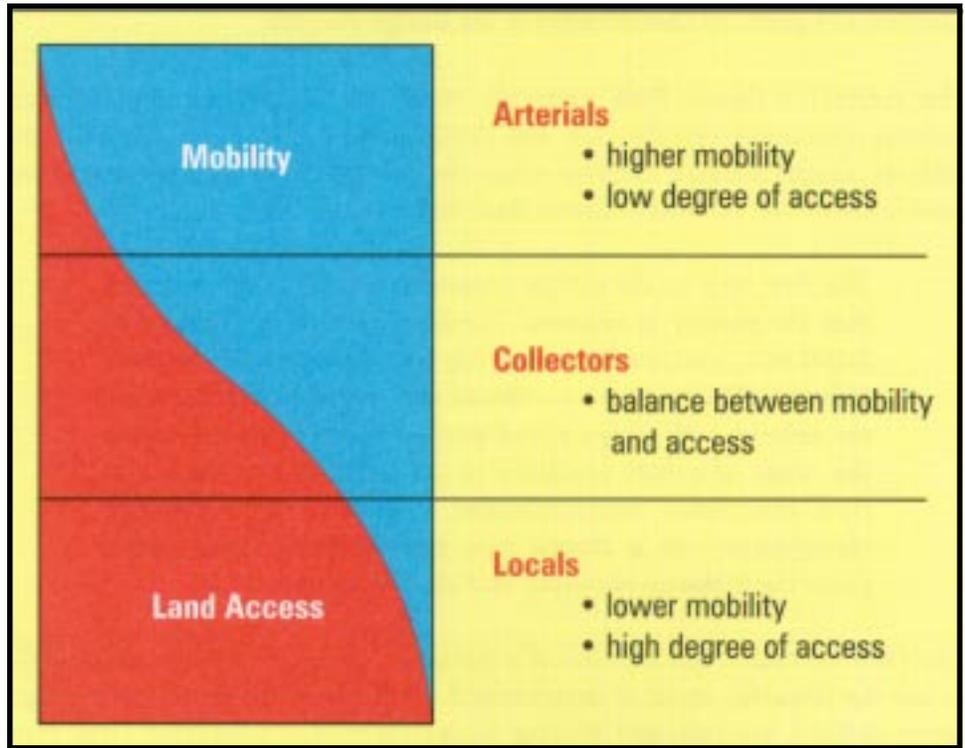
Functional System	Services Provided
Arterial	Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control.
Collector	Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials.
Local	Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

*Table 3.1
Functional Classification Systems*

Typically, travelers will use a combination of arterial, collector, and local roads for their trips. Each type of road has a specific purpose or function. Some provide land access to serve each end of the trip. Others provide travel mobility at varying levels, which is needed en route.

There is a basic relationship between functionally classified highway systems in serving traffic mobility and land access, as illustrated in Figure 3.1. Arterials provide a high level of mobility and a greater degree of access control, while local facilities provide a high level of access to adjacent properties but a low level of mobility. Collector roadways provide a balance between mobility and land access.

*Figure 3.1
Relationship of functionally
classified highway systems in
serving traffic mobility and land access.*



Source: *Safety Effectiveness of Highway Design Features*, Volume I, Access Control, FHWA, 1992

Route 187 in Connecticut was upgraded to provide minimal stops for through traffic, while allowing easy access to development along the road.



The Role of Functional Classification in the Design Process

The AASHTO Green Book explicitly recognizes the relationship between highway functional classification and design criteria. State, county, and city highway design manuals likewise relate design criteria to highway functional classification. The AASHTO Green Book states:

The first step in the design process is to define the function that the facility is to serve. The level of service required to fulfill this function for the anticipated volume and composition of traffic provides a rational and cost-effective basis for the selection of design speed and geometric criteria within the range of values available to the designer (for the specified functional classification). The use of functional classification as a design type should appropriately integrate the highway planning and design process. (p. 17)

Once the functional classification of a particular roadway has been established, so has the allowable range of design speed. With the allowable range of design speed defined, the principal limiting design parameters associated with horizontal and vertical alignment are also defined. Similarly, a determination of functional classification establishes the basic roadway cross section in terms of lane width, shoulder width, type and width of median area, and other major design features (see Figure 3.2).

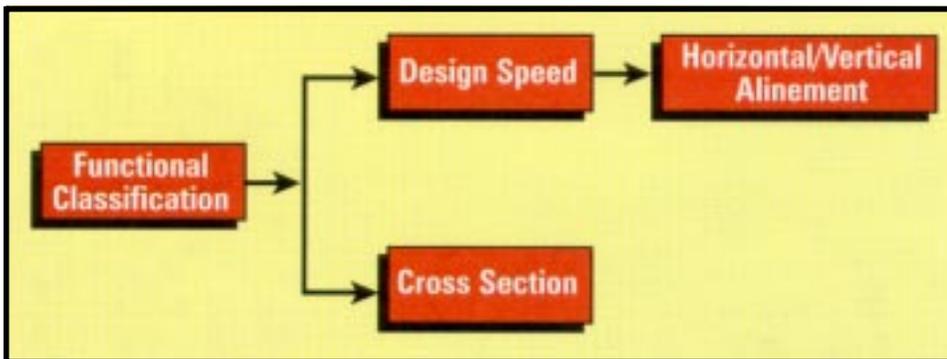


Figure 3.2

The flexibility available to a highway designer is considerably limited once a particular functional classification has been established.

The importance of the functional classification process as it relates to highway design lies in the fact that functional classification decisions are made well before an individual project is selected to move into the design phase. Moreover, such decisions are made on a systemwide basis by city, county, or State DOTs or MPOs as part of their continuing long-range transportation planning functions. Such systematic reassessments are typically undertaken on a relatively infrequent basis. Thus, the functional classification of a particular section of highway may well represent a decision made 10 or more years ago.

Even after the decision has been made to functionally classify a highway section, there is still a degree of **flexibility** in the major controlling factor of design speed. Table 3.2, excerpted from the 1995 edition of the *Roadway Design Manual* of the Virginia DOT, illustrates the manner in which one state has related a range of allowable design speeds to different roadway functional classifications.

Table 3.2
Range of Design Speeds for Various
Highway Functional Classes

*In this example, there are
at least three different design
speeds for each functional classification.*

Functional Classification	20 mph	30 mph	40 mph	50 mph	60 mph	70 mph
Rural Principal Arterial				x	x	x
Rural Minor Arterial				x	x	x
Rural Collector	x	x	x			
Rural Local Road	x	x	x			

Source: Roadway Design Manual, Virginia DOT, 1995.

Note: 1 mph = 1.613 km/h

It is important to remember that there are no “cookie-cutter” designs for arterial highways or collector streets. Because of the range of geometric design options available, arterials and collectors can vary considerably in appearance, as shown in the following photographs.



*Representative freeway.
(I-476/U.S Rt. 1 Interchange,
Montgomery County, PA)*



*Representative urban arterial.
(Windsor, CT)*

*Representative rural arterial.
(Taconic State Parkway, NY)*



*Representative rural arterial.
(Rt. 58, CT)*



Representative Collectors and Local



Representative collector in a residential area. (Greenbelt, MD)



Representative urban collector. (Lambertville, NJ)

*Representative rural collector.
(Easton, CT)*



*Representative local street.
(Montgomery Co., MD)*



Current Highway Functional Classifications

The highway system of the United States consists of slightly over 6.3 million km (3.9 million miles) of road.¹ Of this total, 5.0 million km (3.1 million miles) are located in rural areas, and the remaining 1.3 million km (800,000 miles) are urban streets. Each of these rural and urban streets has been given a specific functional classification, as illustrated in Table 3.3. In terms of jurisdictional responsibility, about 5 percent of the total is administered by the Federal Government, approximately 16 percent is under State control, and the remaining 79 percent is under the control of county and local governments.

Functional System	Percent of Total Mileage	Percent of Total Travel
Interstate	1.2	22.8
Other Freeway/Expressway	.2	6.2
Other Principal Arterial	3.8	24.3
Minor Arterial	5.7	18.4
Major Collector	11.1	7.8
Minor Collector	7.2	2.1
Collector	2.2	5.3
Local	68.6	13.1
Total	100	100

*Table 3.3
Functional System (Rural and Urban)
Mileage and Travel*



The Interstate System represents percent of the total road mileage but serves 22.8 percent of the Nation's total travel. (I-95, VA)

¹ Our Nation's Highways: Selected Facts and Figures, FHWA, Washington, DC, 1995, p. 17-18

ISSUES

The Need To Update Highway Functional Classifications

Traffic service patterns on a roadway and the roadway's function can change over time. If the functional classification system for a specific jurisdiction is not updated on a regular basis, roadways may be designed using inappropriate design standards.

Solution

Clearly, there is a need to reevaluate a locality's functional classification system on a relatively frequent and regular basis to ensure that the functional classification of any particular route accurately reflects the traffic function of the route now and in the foreseeable future. This continuing reassessment process can be viewed as an application of design flexibility even before the decision is made to begin designing a particular project. The decision to change the functional classification should be made based on careful review of changed conditions and sound reasoning.

The Functional Classification Process Is Not an Exact Science

One of the difficulties surrounding the relationship between highway functional classification and design guidelines is that the classification process is not an exact science. The predominant traffic service associated with a particular route cannot be definitely determined without exhaustive surveys of traffic origin/destination patterns on each link of the road network. Engineering judgment based on experience must play a role in making design decisions.

Solution

As a result of variances within the highway functional classification system, design guidelines established either in the Green Book or in other State and local government design manuals have overlapping ranges of values. This allows the designer greater flexibility in choosing a road design that is most appropriate within the determined functional classification (see Figure 3.3). For example, the 1994 Green Book indicates that the width of the traveled way for two-lane rural collector facilities should be between 6.0 m and 7.2 m (20 ft and 24 ft), depending on traffic volumes, while the shoulder widths on each side of the traveled way should be between 0.6 m and 2.4 m (2 ft and 8 ft). Thus, the total width of the roadway can vary from 7.2 m to 12 m (24 ft to 40 ft), which is a considerable amount (see Figure 3.4). Two-lane rural arterials can vary from a total roadway width, including shoulders, of 9 m to 12 m (30 ft to 40 ft). This flexibility allows designers to choose more accurately the specific geometric dimensions that are appropriate for that roadway.

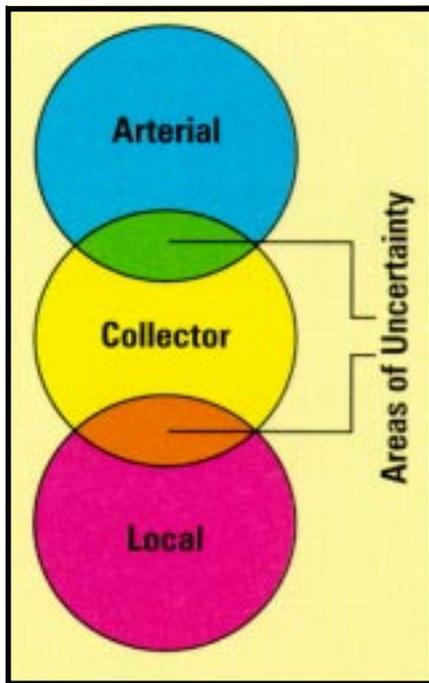


Figure 3.3

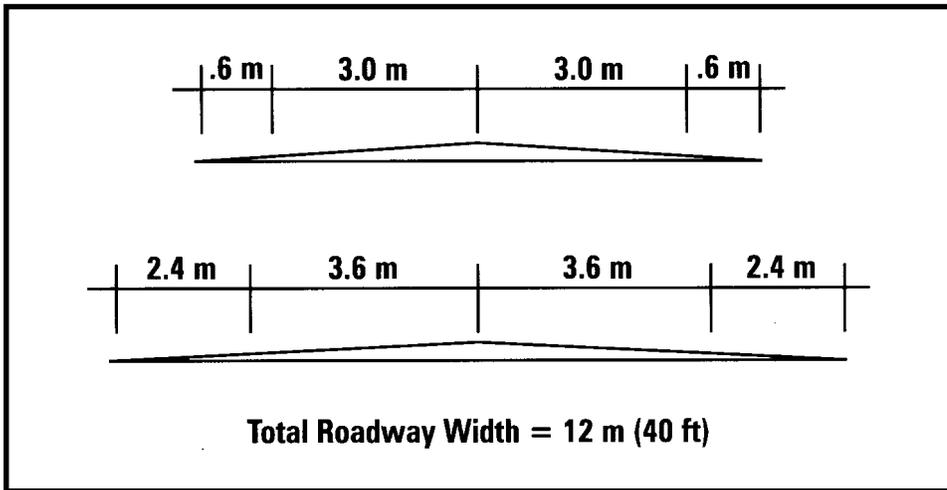


Figure 3.4

The total width of a rural collector can vary from 7.2 m to 12 m, depending on traffic volume.

The Impact of Land Use Changes on Road Functions

Land use is an important determinant of the function of an area's roads. As land use changes because of development, especially at the urban fringe, road functions also change. It is not uncommon for roads that once served as rural local access routes to farmland, and now serve suburban residential subdivisions and commercial land uses, to be reclassified as urban collectors or arterials depending on the intensity of development and the type of traffic generated by the development. Design standards or guidelines must change to meet actual or impending change in traffic character and road function.

Actions taken by a local jurisdiction to control or direct the form and location of growth or to preserve the current physical and scenic characteristics of a highway corridor should also reflect the need for a reexamination of existing functional classification and, perhaps, even a change in jurisdictional responsibility (see Figure 3.5). For example, the construction of a new controlled-access bypass route might allow for a downward reclassification of what had been the existing arterial route through a community to a collector-level facility.

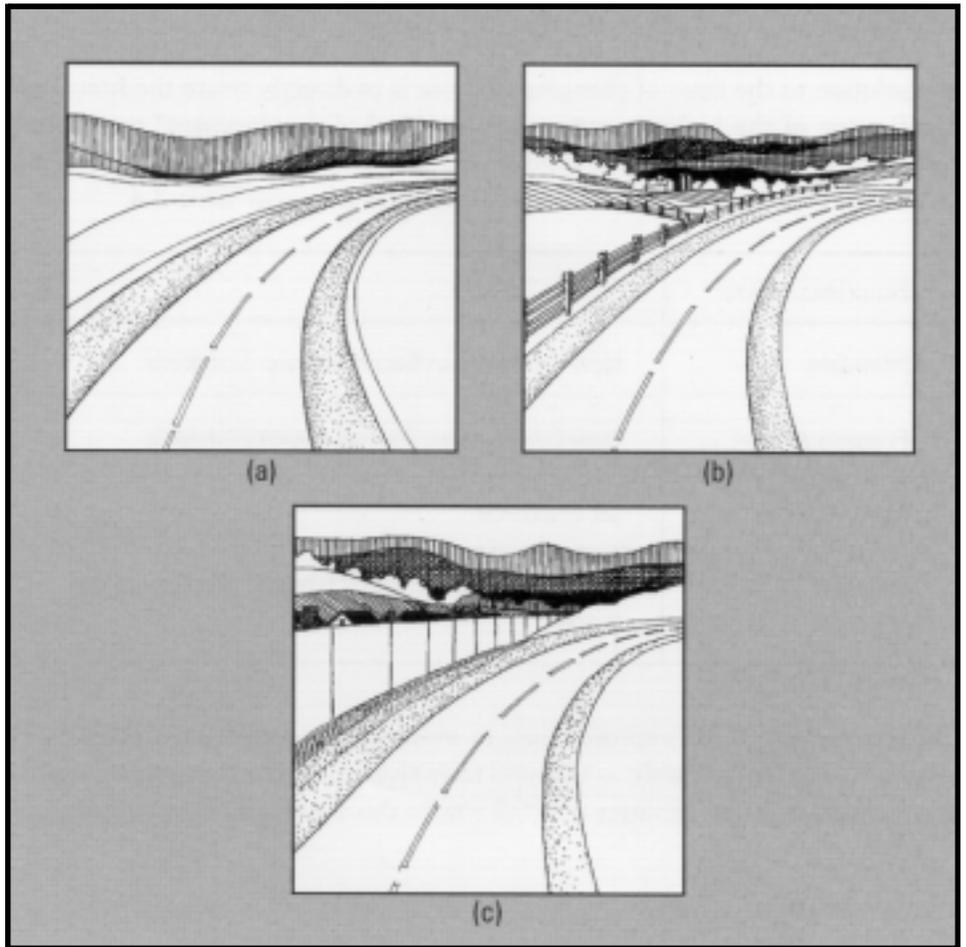


Figure 3.5
Road functions can change over time.
These views show changing land use
along a rural highway. The first view
(a) shows a new road through the
country. The second view (b) shows
the first residences along the road.
The third view (c) shows suburbaniza-
tion and the need for mitigation.

Solution

One solution to the issue of changing land use is to directly relate the functional classification of the highway system to the “level of development” or, in other words, the design criteria that should be applied. The State of Washington is one jurisdiction that has done this. This relationship is shown in Table 3.4.

Functional Class	Design Criteria
Interstate	New Construction/Reconstruction Standards
Principal Arterial	New Construction/Reconstruction Standards
Minor Arterial	3R Standards
Collector	Maintenance of Structural Integrity and Operational Safety

*Table 3.4
Relationship of Functional
Classification and Design Criteria*

This process allows for improvements to even minor arterial-type routes to be designed using 3R standards, as opposed to applying traditional design criteria for new-location highway facilities that fall within this functional classification.

Chapter 4

DESIGN CONTROLS

Refer to Chapter II of the AASHTO Green Book



In addition to functional classification, there are a number of design controls that affect the geometry of a highway. (Rt. 71, IL)

BACKGROUND

In order to design the basic elements of a highway—including its alignment and cross section—the designer must have an understanding of the basic design controls and criteria associated with the highway. One of the most important, highway functional classification, was discussed in Chapter 3. Other important design controls include, but are not limited to the following:

- The design speed of the facility
- The acceptable degree of congestion (i.e., the design-year peak-hour level of service) on the facility
- The physical characteristics of the “design vehicle” (i.e., the largest vehicle that is likely to use the facility with considerable frequency); in virtually all instances, the highway design vehicle is an over-the-road tractor-trailer
- The performance of the design vehicle (particularly important in terms of accommodating heavy trucks in mountainous terrain or buses and recreational vehicles in areas subject to high levels of tourist activity)
- The capabilities of the typical driver along the facility (i.e., local residents using low-speed neighborhood streets versus interstate travelers on rural freeways)
- The existing and design-year traffic demands to be placed on the facility (e.g., daily and peak-hour traffic volumes, the mix of passenger cars and trucks on the facility)

Two of the most important of these factors are design speed and peak-hour level of service. This chapter will focus on these two important criteria. The peak-hour level of service, however, only serves as a controlling factor for a small number of highways. For most highways, after the functional classification and associated design speed for a particular highway facility have been established, the degree of flexibility available to the designer is significantly limited.



Speed limits are not the same as the design speed. They are regulatory limits enforceable by law.

Design Speed

Design speed is defined by the AASHTO Green Book as:

...the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.

Table 4.1
Relationship Between Design Controls and Design Features

Design Features	Design Controls			
	Functional Classification	Traffic Data	Terrain Locale	Design Speed
Lane width, rural	X	X		X
Lane width, urban	X		X	
Rural shoulder width, type	X	X		
Urban shoulder width, type	X		X	
Guiderail offset	X	X		
Degree of curve				X
Grades	X		X	X
Bridge clearances (horizontal & vertical)	X	X		
Stopping sight distance				X
Superelevation				X
Widening on curves				X
Rural design speeds	X	X	X	
Urban design speeds	X		X	

Source: Location and Design Manual, Vol. 1, Roadway Design, Ohio DOT.

All geometric design elements of the highway are affected in some way by the selected design speed. Some roadway design elements are related directly to and vary appreciably with design speed. These include horizontal curvature, superelevation, sight distance, and gradient (see Table 4.1). Other elements are less related to design speed, such as pavement and shoulder width and clearances to walls and traffic barriers. The design of these features can, however, affect vehicle operating speeds significantly. As a result, more stringent criteria for these features are generally recommended for highways with higher design speeds. Conversely, less stringent criteria for these features may be more appropriate on roadways with lower design speeds.

The selection of a particular design speed is influenced by the following:

- The functional classification of the highway
- The character of the terrain
- The density and character of adjacent land uses
- The traffic volumes expected to use the highway
- The economic and environmental considerations.

Typically, an arterial highway warrants a higher design speed than a local road; a highway located in level terrain warrants a higher design speed than one in mountainous terrain; a highway in a rural area warrants a higher design speed than one in an urban area; and a high-volume highway warrants a higher design speed than one carrying low traffic volumes.

(Left) Lower design speeds are appropriate for city streets.



(Right) Higher volume rural highway facilities should use higher design speeds.



As discussed in Chapter 3, most States and localities have adopted a range of acceptable design speeds for each of the major classes of highways and streets (i.e., freeway, other arterial, collector, and local). Table 4.2 illustrates typical minimum design speeds for various types of highways located in level, rolling, and mountainous terrain.

Freeways		
Terrain	Design Speeds	
	Rural	Urban
Flat	70-80	70
Rolling	60-70	60-70
Mountainous	50-60	50-60
Arterial Highways		
Terrain	Design Speeds	
	Rural	Urban
Flat	60-70	30-60
Rolling	40-60	30-50
Mountainous	30-50	30-50
Collector and Local Roads		
Terrain	Design Speeds	
	Rural	Urban
Flat	30-50	30-40
Rolling	20-40	20-40
Mountainous	20-30	20-30

Table 4.2

Typical Minimum Design Speeds for Various Types of Highways (in mph)

Source: Traffic Engineering Handbook (Fourth Edition), Institute of Transportation Engineers, Washington, DC, 1992, p. 156. Note: 1 mile/hr = 1.613 km/hr

The values presented in Table 4.2 are minimum acceptable design speeds for the various conditions of terrain and traffic volumes associated with new or reconstructed highway facilities. Designers need to balance the advantages of a higher vehicle operating speed gained through the use of a higher design speed against the flexibility lost in design. It may be more important to retain the maximum possible flexibility, so that a context-sensitive roadway that is more in tune with the needs of a community is designed using a lower design speed.

As used here, the term “context sensitive” refers primarily to the land use and environmental conditions adjacent to the highway. For example, for any particular highway other than a freeway or major arterial, as land use density increases, the design speed would typically decrease. The design speed of an urban collector street passing through a residential neighborhood should be appreciably lower than that for a rural highway with the same functional classification. This also recognizes the fact that bicycles and pedestrians would be more likely to use a route located in an urban area.

Similarly, in areas that have significant historic interest or visual quality, a lower design speed may be appropriate in recognition of lower average operating speeds and the need to avoid affecting these historic or aesthetic resources.

The Green Book agrees with this philosophy:

Above-minimum design values should be used where feasible, but in view of the numerous constraints often encountered, practical values should be recognized and used.

Along arterial streets, the controlling factor of design speed applies to a lesser degree than on rural highways or high-type urban facilities, such as freeways or expressways. On many of the arterial streets located in large urban areas, maximum vehicle operating speeds for several hours of the day may be limited to those at which the recurring peak period traffic volumes can be accommodated. Thus, speeds may be governed by the presence of other vehicles traveling en masse both in and across the through travel lanes and by traffic control devices, rather than by the physical characteristics of the street.

During off-peak periods of low-to-moderate traffic demand, vehicle operating speeds are governed by such factors as speed limits, mid-block turns, intersection turns, number of driveways and entrances, traffic signal spacing, and signal timing. As a result, when arterial street improvements are being planned, the selection of the appropriate design speed must be balanced against such factors as speed limits, physical and economic constraints, and the probable running speeds that can be attained during off-peak hours.

Although most States have adopted a range of allowable design speeds appropriate for each of the various functional classifications for use in the design of new or reconstructed highway facilities, situations may arise where even the use of the lowest typically acceptable value would result in unacceptably high construction or right-of-way costs or unacceptable impact on adjacent properties. In such instances, the design exception process discussed in Chapter 2 can be employed. For example, the reconstruction of a two-lane rural arterial route through a relatively flat but environmentally sensitive area might need to employ a design speed of 80 km/h (50 mph) rather than the recommended value for this functional classification of 100 km/h (60 mph) shown in Table 4-2.

Peak-Hour Level of Service

Once an appropriate design speed has been selected, the other basic defining elements of the highway (i.e., the number of lines and the basic configuration of junctions with other highway facilities) can be determined through application of the concept of acceptable peakhour level of service. Level of service is a grading system for amount of congestion, using the letter A to represent the least amount of congestion and F to refer to the greatest amount. For a comprehensive treatment of this topic, refer to the Highway Capacity Manual¹. Table 4.3 presents a brief description of the operating characteristics associated with each level of service.



As congestion approaches capacity, speed decreases.

Level of Service	Description
A	Free flow, with low volumes and high speeds.
B	Reasonably free flow, but speeds beginning to be restricted by traffic conditions.
C	In stable flow zone, but most drivers are restricted in the freedom to select their own speeds.
D	Approaching unstable flow; drivers have little freedom to select their own speeds.
E	Unstable flow; may be short stoppages.
F	Unacceptable congestion; stop-and-go; forced flow.

*Table 4.3
Level-of-Service Characteristics*

Source: Adapted from the AASHTO *Green Book*.

¹ 1995 Highway Capacity Manual (Special Report 209), Transportation Research Board, Washington, DC, Third Edition, updated 1994

The appropriate degree of congestion (that is, the level of service) to be used in planning and designing highway improvements is determined by considering a variety of factors. These factors include the desires of the motorists, adjacent land use type and development intensity, environmental factors, and aesthetic and historic values. The factors must be weighed against the financial resources available to satisfy the motorists' desires.

Table 4.4 presents the relationship between highway type and location and the level of service appropriate for design, suggested by the AASHTO Green Book. Taking into consideration specific traffic and environmental conditions, the responsible highway agency should attempt to provide a reasonable and costeffective level of service

Highway Type	Type of Area and Appropriate Level of Service			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C
Arterial	B	B	C	C
Collector	C	C	D	D
Local	D	D	D	D

Table 4.4
Guide for Selection of Design
Levels of Service

Source: Adapted from the AASHTO Green Book

While the *Highway Capacity Manual* provides the analytical basis for design calculations and decisions, judgment must be used in the selection of the appropriate level of service for the facility under study. Once a level of service has been selected, all elements of the roadway should be designed consistently to that level.

For example, along recreational routes subject to widely varying traffic demands according to the time of year or in response to environmental or land use considerations, the designer may conclude that the selection of a level of service that is lower than what is usually recommended may be appropriate. The selection of the desired level of service for a facility must be weighed carefully, because the facility's overall adequacy depends on this decision.

ISSUES

Application of Appropriate Design Speed

For some projects, community residents may perceive an imbalance between the scale of improvement deemed appropriate by the highway designers and that viewed as appropriate by the affected community. Much of this conflict can be traced to the design speed for the subject project.

For example, an older two-lane rural road with a posted speed limit of 45 mph (72.5 km/h) may be adequate to accommodate current and anticipated future traffic demands, except for a short section containing several sharp curves that has a high incidence of accidents. If this facility were classified as a minor arterial, a State's design criteria might suggest that the reconstruction of the deficient section of roadway utilize a minimum design speed in the range of 60 to 70 mph (96.6 to 112.7 km/h).

If these criteria were followed, the reconstructed section would have a significantly higher design speed (and, hence, a higher operating speed and magnitude of physical impact on its surroundings) than the immediately adjacent sections of highway, resulting in a potentially unsafe condition.

Solution

One approach to avoiding this problem would be to apply a lower uniform design speed over the entire length of the route. This would suggest the application of a design speed of 50 mph (80.5 km/h) to the reconstruction project to preserve the design continuity and character of the route.

A similar approach was taken during the design of State Route 9A in New York City to better integrate the project into its surroundings. Although this facility is classified as a principal urban arterial street with an allowable design speed under New York State DOT design criteria as high as 60 mph (96.6 km/h), a design speed of only 40 mph (64.4 km/h) was used. The roadway's capacity remains unchanged and the roadway is functioning safely and efficiently.

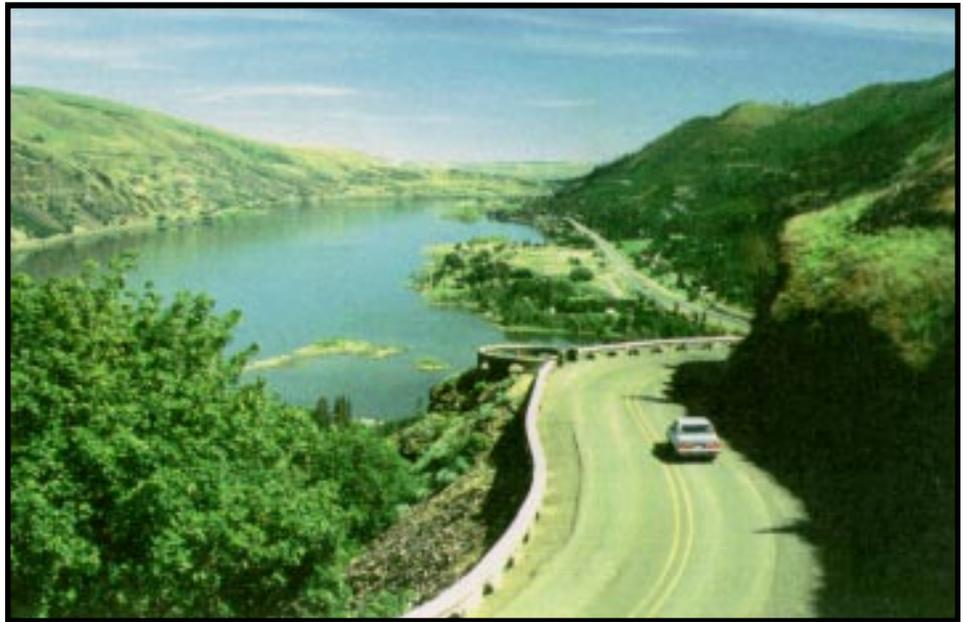
Note that the design speed must be higher than the posted speed and should also be above the operating speed on a facility, regardless of the posted speed.

Chapter 5

HORIZONTAL AND VERTICAL ALINEMENT

Refer to Chapter III of the AASHTO Green Book

One of the best examples of integrating a highway into its surroundings. (Columbia River Highway, Hood Co., OR)



BACKGROUND

One definition of a visually attractive and unobtrusive highway is the degree to which the horizontal and vertical alignments of the route have been integrated into its surrounding natural and human environments. This takes careful planning and design, as noted in the AASHTO Green Book:

Coordination of horizontal alignment and profile should not be left to chance but should begin with preliminary design, during which adjustments can readily be made ... The designer should study long, continuous stretches of highway in both plan and profile and visualize the whole in three dimensions.

This application of a holistic approach to highway design, where the road is integrated into its surroundings, separates the outstanding project from one that merely satisfies basic engineering design criteria (see Figures 5.1 and 5.2). An excellent description of this holistic design process is contained in the publication *Aesthetics in Transportation*, from which the following is excerpted:

A general rule for designers is to achieve a “flowing” line, with a smooth and natural appearance in the land, and a sensuous, rhythmic continuity for the driver. This effect results from following the natural contours of the land, using graceful and gradual horizontal and vertical transitions, and relating the alignment to permanent features such as rivers or mountains.



The alignment of Rt. 8 gracefully follows the Naugatuck River. (Naugatuck, CT)

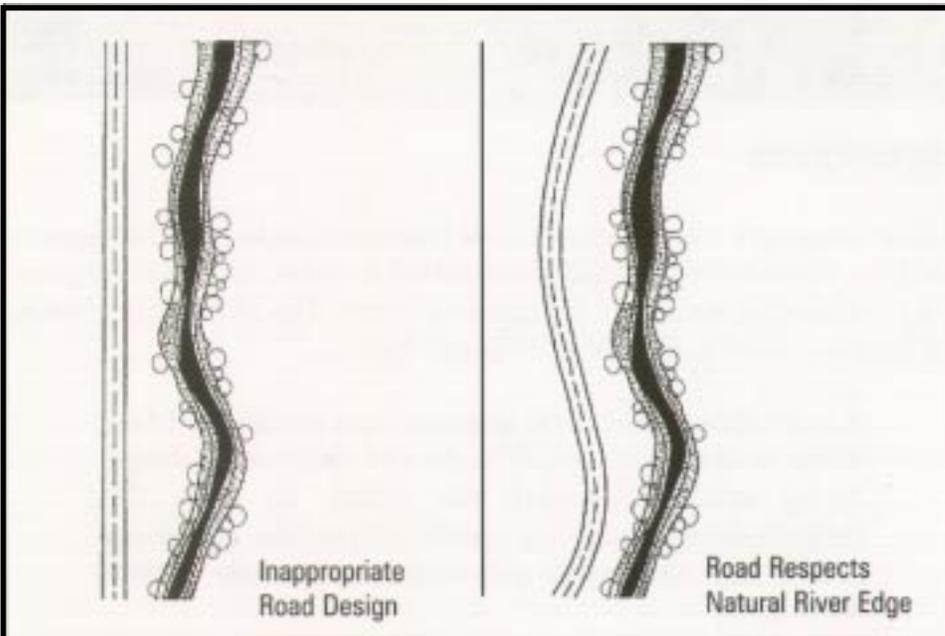


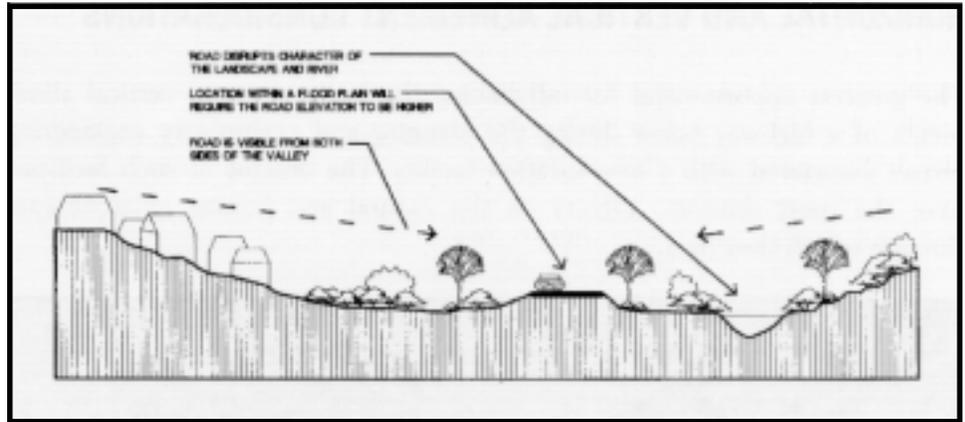
Figure 5.1
Inappropriate road design does not integrate with the natural surroundings.

¹ *Aesthetics in Transportation*, U.S. DOT, November 1980, p. 89.

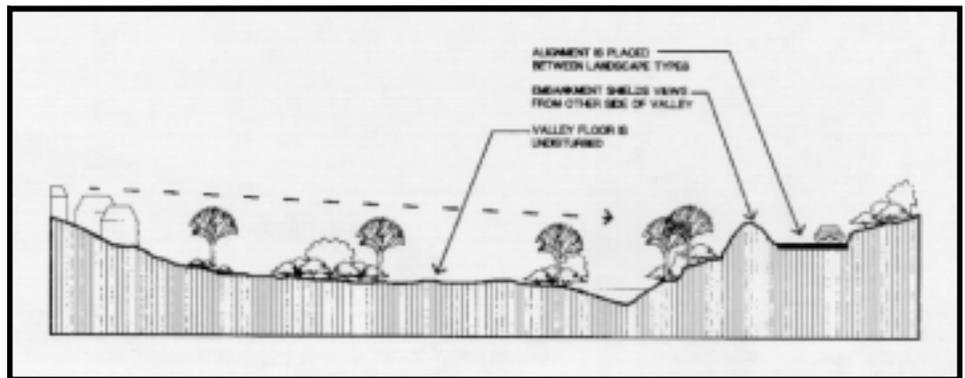
Figure 5.2

The alignment of a new facility plays an important role in minimizing impacts on the surroundings.

In this example, the character of the landscape was disrupted.



In this alternative, the valley is undisturbed and the road is partially shielded from view.



HORIZONTAL AND VERTICAL ALINEMENT CONSIDERATIONS

The greatest opportunities for influencing the horizontal and vertical alignments of a highway occur during the planning and preliminary engineering phases associated with a new-location facility. The designs of such facilities have the most dramatic effects on the natural and human environments through which they pass.



Preservation of unique rock formations enhances the view along this highway. (State Route 313, Moab, UT)

The more typical design problem faced by today's highway engineers is the improvement of an **existing highway or street**. In many instances, the basic alignments may have been established well over 100 years ago. Regardless, the same basic design principles with respect to horizontal and vertical alignments can, however, be applied to both new and existing facilities.

Important points to consider regarding horizontal and vertical alignments are that they should be consistent with the topography, preserve developed properties along the road, and incorporate community values. The superior alignments are ones that follow the natural contours of the land and do not affect aesthetic, scenic, historic, and cultural resources along the way. Construction costs may be reduced in many instances when less earthwork is needed, and resources and development are preserved. It is not always possible, however, to avoid having an impact on both the natural and human environments. That is why the superior alignments incorporate input received by the community through a participatory design process.

When possible, the alignment should be designed to enhance attractive scenic views, such as rivers, rock formations, parks, historic sites, and outstanding buildings. The designation of certain highways as scenic byways recognizes the importance of preserving such features along our Nation's roadways.

Equally important as the consideration of the horizontal alinement is that of the facility's vertical alinement. A number of factors influence the vertical alinement of a highway, including the following:

- Natural terrain
- Minimum stopping sight distance for the selected design speed
- The number of trucks and other heavy vehicles in the traffic stream
- The basic roadway cross-section; i.e., two lanes versus multiple lanes
- Natural environmental factors, such as wetlands and historic, cultural, and community resources

COMBINATION OF HORIZONTAL AND VERTICAL ALINEMENT

The interrelationship of horizontal and vertical alinement is best addressed in the route location and preliminary design phases of a project. At this stage, appropriate tradeoffs and balances between design speed and the character of the road-traffic volume, topography, and existing development-can be made. A mistake often made by inexperienced engineers is designing the horizontal alinement first and then trying to superimpose the design onto a vertical profile. Because they must be complementary, horizontal and vertical geometries must be designed concurrently. Uncoordinated horizontal and vertical geometries can ruin the best parts and accentuate the weak points of each element. Excellence in the combination of their designs increases efficiency, and safety, encourages uniform speed, and improves appearance-almost always without additional cost.

One tool to assist in coordinating horizontal and vertical geometries is the use of computer-aided design (CAD). CAD enables highway designers to quickly assess the interrelationships between horizontal and vertical alinement, particularly in areas of difficult terrain.

Proper consideration of these basic design considerations will help to ensure that both new-location facilities and improvements to existing highways fit harmoniously into their surroundings.



Good integration of horizontal and vertical alinement on a reconstructed two-lane rural highway. (State Route 89 near Lake Tahoe, CA)

ISSUES

There are numerous examples around this country of excellence in integration of the horizontal and vertical alignments of highways into their surroundings. Unfortunately, there are also examples of new or widened highways that have scarred a rural landscape or disrupted an established community. While these past actions cannot easily or inexpensively be rectified, future problems can be avoided by applying the principles outlined above and the creative approaches detailed below.

Avoiding Impact on Adjacent Natural and Human Environments

Particularly during the era of Interstate construction from the 1950's to the 1980's, a number of instances of new highway construction had a devastating impact on communities and areas of environmental sensitivity. It is readily acknowledged that there will be some degree of physical impact on the surroundings associated with the construction of any new location highway or major reconstruction or widening of an existing highway facility. However, from the perspective of horizontal and vertical alignment, much of this impact can and should be alleviated.

Solution

Impact on the surrounding environment can be minimized by careful attention to detail during the route location and preliminary design phases and a willingness of all concerned parties to work together toward a common goal. For example, minor adjustments to the originally proposed horizontal and vertical alignments (combined with the use of short sections of retaining wall) along the Lincoln Beach Parkway (U.S. Route 101) in Oregon eliminated the need to acquire any of the adjacent homes and businesses.



Minor alignment changes can avoid impacts on adjacent properties. (U.S. Route 101, Lincoln Co., OR)

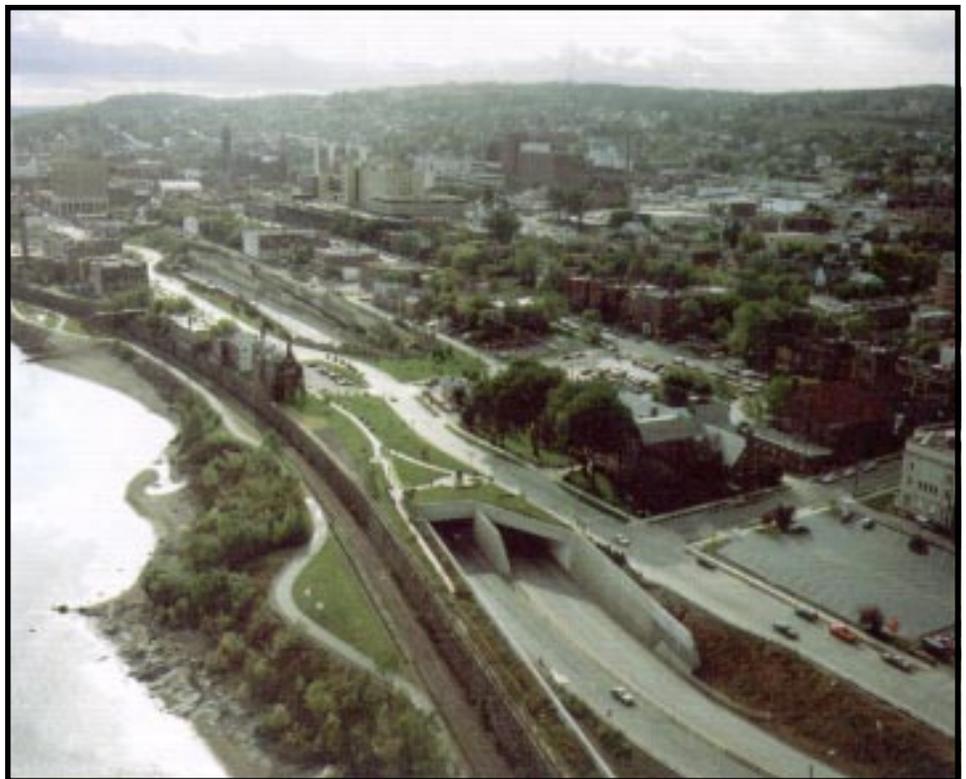
Similarly, a minor horizontal alignment shift at the beginning of the project allowed for the Hollister Bypass (SR 156) in San Benito County, CA, to avoid affecting a number of historic properties.

Impact on the historic Mitchell Fruit Farm was avoided as a result of a minor shift in the horizontal alignment of the Hollister Bypass. (San Benito, CA)



The use of a “cut-and-cover” design, whereby the roadway is placed below the existing ground level and covered over with a park, building, or other public space can help to avoid negative impact. Lake Place Park in Duluth, MN and other public parks were the result of cut-and-cover tunnels that not only saved historic properties but also gave pedestrians improved access to Lake Superior.

Designers employed several cut-and-cover tunnels along I-35 to avoid impacting an historic district and to reconnect the downtown to the waterfront. (Duluth, MN)



In many cases, there is a potential for designing a divided highway with independent horizontal and vertical alignments for each direction of traffic.



*Separate profiles and varied median widths on divided roadways are options for designers to minimize impact on the environment.
(Rt 395, Inyo National Forest, CA)*



*Each side of the highway can have a different alignment to better integrate the roadway into its surroundings.
(I-15, MT)*

Coordination Between Horizontal and Vertical Alinement

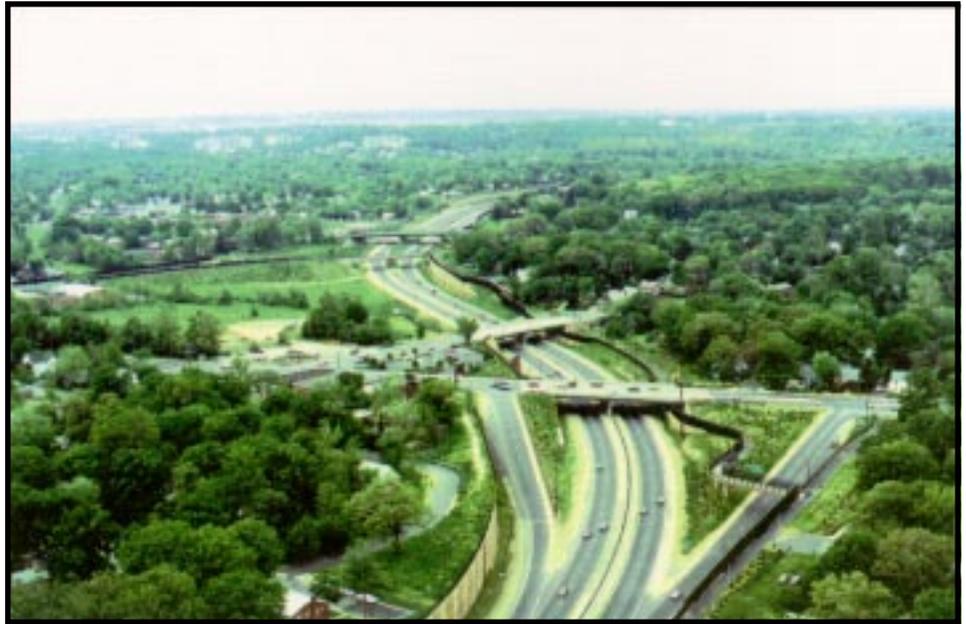
When horizontal and vertical alinements are designed separately from one another, unnecessarily large cuts and fills may be required, resulting in very dramatic and often visually undesirable changes to the natural landscape.

Solution

One of the ways to ensure the most effective coordination of horizontal and vertical alinement is through the use of a multidisciplinary design team during the planning and engineering phases of a project. On such projects as I-66 in Fairfax and Arlington Counties in Virginia, the combined expertise of landscape architects, urban designers, structural engineers, and historic preservationists, in addition to civil engineers and highway designers, has resulted in superior highway improvement projects.

The concept of using a multidisciplinary design team is not new; it was pioneered in the early 1900's during the planning and design of the Bronx River Parkway in Westchester County, NY. After a period of use primarily on large-scale or controversial projects, this approach has come back into more general application as a way to achieve community consensus.

*A multidisciplinary design team can help minimize the impact an urban freeway has on a community.
(I-66, VA)*



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Chapter 6

CROSS-SECTION ELEMENTS

Refer to Chapter IV of the AASHTO Green Book

*A residential street.
(Newport, RI)*



BACKGROUND

The cross section of a road includes some or all of the following elements:

- **Traveled way** (the portion of the roadway provided for the movement of vehicles, exclusive of shoulders)
- **Roadway** (the portion of a highway, including shoulders, provided for vehicular use)
- **Median** area (the physical or painted separation provided on divided highways between two adjacent roadways)
- **Bicycle and pedestrian facilities**
- **Utility and landscape areas**
- **Drainage channels and side slopes**
- **Clear zone width** (i.e., the distance from the edge of the traveled way to either a fixed obstacle or nontraversable slope)

Considered as a single unit, all these cross-section elements define the highway right-of-way. The right-of-way can be described generally as the publicly owned parcel of land that encompasses all the various cross-section elements (see Figures 6.1 and 6.2).

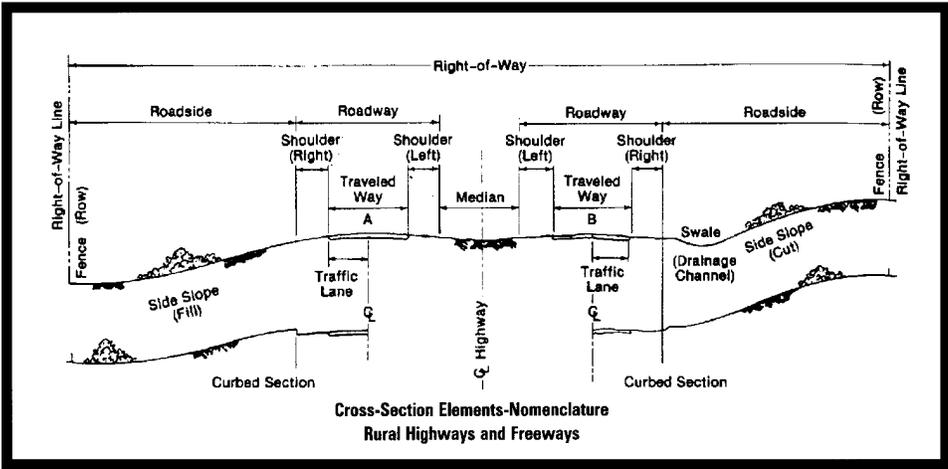


Figure 6.1
Two-lane rural highway cross-section design features and terms.

Some decisions about cross section are made during project development, such as the capacity and number of lanes for the facility. Other decisions, such as functional classification, are made earlier in the process. Within these parameters, the Green Book guidelines recommend a range of values for the dimensions to use for cross-sectional elements. Deciding which of the elements to include and selecting the appropriate dimensions within these ranges is the role of the designer.

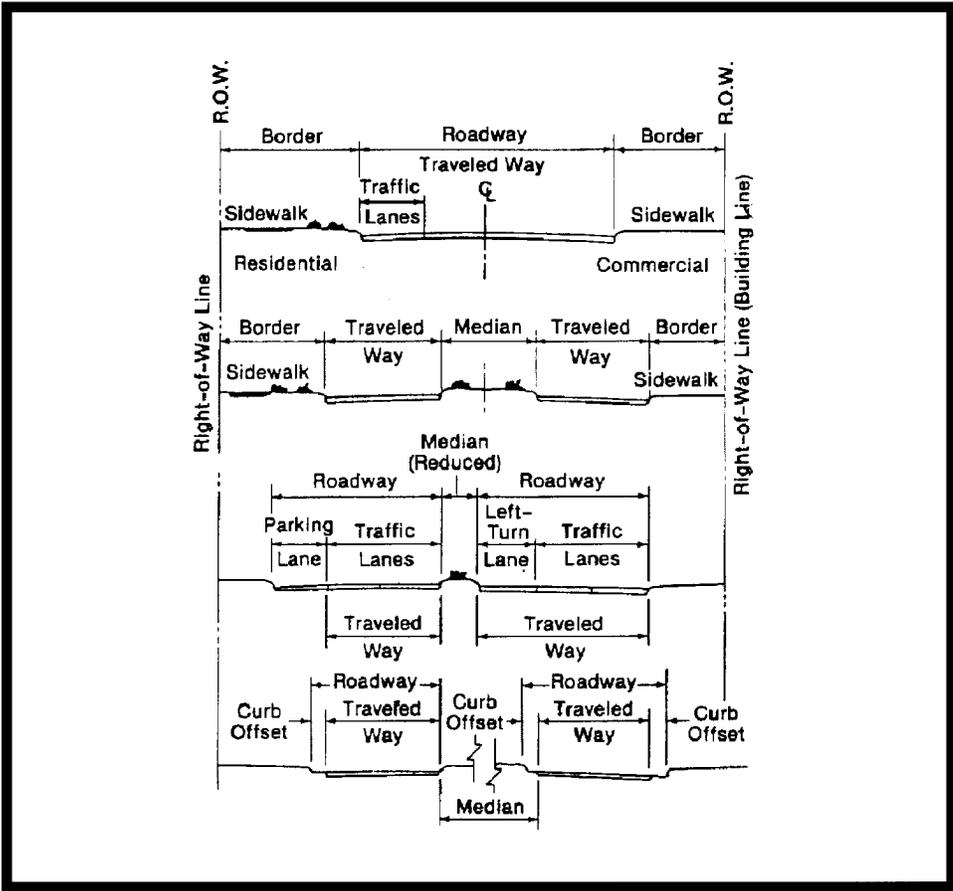


Figure 6.2
Urban highway cross-section design features and terms.

In selecting the appropriate cross-section elements and dimensions, designers need to consider a number of factors, including the following:

- Volume and composition (percent trucks, buses, and recreational vehicles) of the vehicular traffic expected to use the facility
- The likelihood that bicyclists and pedestrians will use the route
- Climatic conditions (e.g., the need to provide storage space for plowed snow)
- The presence of natural or human-made obstructions adjacent to the roadway (e.g., rock cliffs, large trees, wetlands, buildings, power lines)
- Type and intensity of development along the section of the highway facility that is being designed
- Safety of the users

The most appropriate design for a highway improvement is the one that balances the mobility needs of the people using the facility (motorists, pedestrians, or bicyclists) with the physical constraints of the corridor within which the facility is located.

The likelihood of pedestrian and bicycle traffic is one factor to consider when designing the cross section of a facility.



CROSS-SECTION ELEMENTS

Travel Lanes

The number of lanes needed for a facility is usually determined during the concept stage of project development. It is usually the number of lanes necessary to accommodate the expected traffic volumes at a level of service determined to be appropriate for the facility (see Chapter 4 for a discussion of level of service). The number of lanes can only be added in integer units, i.e., a two-lane highway can be widened to three or four lanes. Each additional lane represents an increase in the traffic-carrying capability of the facility.

Knowing future projected travel demands, the designer, using the analysis procedures in the Highway Capacity Manual, can provide input into the decisionmaking process during project development to determine the appropriate number of travel lanes for the level of service desired. Community input also plays a part in this decision. A community may decide through public involvement that a lower level of service is acceptable for the situation than the level of service normally provided for new construction projects.

In urban and suburban areas, signalized intersections are usually the predominant factor controlling the capacity of the highway or street. There may be more latitude in determining the number of lanes for these types of facilities. For example, a two-lane facility approaching an intersection can be expanded to four lanes (one left turn lane, two through lanes, one right-turn lane) at the intersection itself and then returned to two lanes beyond the intersection. The need to distribute traffic safely will determine the need for any expansion of the approach roadway. The added lanes at the intersection can be in a variety of configurations to serve the travel desires of the traffic.

Lane Width

The width of travel lanes is limited by the physical dimensions of automobiles and trucks to a range between 2.7 and 3.6 m (9 and 12 ft). Generally, as the design speed of a highway increases, so must the lane width to allow for the lateral movement of vehicles within the lane. However, constricted right-of-way and other design restrictions can have an impact on this decision. Chapter IV of the Green Book recognizes the need for flexibility in these cases:

Although lane widths of 3.6 m are desirable on both rural and urban facilities, there are circumstances that necessitate the use of lanes less than 3.6 m wide. In urban areas where right-of-way and existing development become stringent controls, the use of 3.3 m lanes is acceptable. Lanes 3.0 m wide are acceptable on low-speed facilities. Lanes 2.7 m wide are appropriate on low-volume roads in rural and residential areas.

*A landscaped median.
(I-35E, St. Paul, MN)*



Medians

An important consideration in the design of any multilane highway is whether to provide a median and, if one is provided, what the dimensions should be. The primary functions of highway medians are to:

- Separate opposing traffic flows
- Provide a recovery area for out-of-control vehicles
- Allow space for speed changes and left-turning and U-turning vehicles
- Minimize headlight glare
- Provide width for future lanes (particularly in suburban areas)
- Provide a space for landscape planting that is in keeping with safety needs and improves the aesthetics of the facility
- Provide a space for barriers.

Depending on agency practice and specific location requirements, medians may be depressed, raised, or flush with the surface of the traveled way. Medians should have a dimension that is in balance with the other elements of the total highway cross section. The general range of median widths is from 1.2 m (4 ft), usually in urban areas, to 24 m (80 ft) or more, in rural areas. An offset of at least a 500 mm (1.5 ft) should be provided between any vertical element located within the median, such as a curb or barrier, and the edge of the adjacent traveled lane.

The design and width of medians again require tradeoffs for designers. In locations where the total available right-of-way is restricted, a wide median may not be desirable if it requires narrowing the areas adjacent to the outside edge of the traveled way. A reasonable border width is required to serve as a buffer between private development along the road and the edge of the traveled way, and space may be needed for sidewalks, highway signs, utilities, parking, drainage channels and structures, proper slopes and clear zones, and any retained native plant material. On the other hand, wider medians provide more space for plant material, offer a refuge for pedestrians at intersections, and help soften the look of the roadway. Including and designing medians requires public input to find the design that meets the needs of the community.



Two-way left-turn lanes improve safety and efficiency for vehicular traffic but do not afford a safe refuge for pedestrians.

The use of two-way left-turn lanes on urban streets in densely developed suburban commercial areas has increased as an alternative to raised medians with left-turn or U-turn bays. Although not as aesthetically pleasing as raised, planted medians, continuous left-turn lanes can improve capacity. Two-way left-turn lanes generally are not recommended in residential areas because they do not afford a safe refuge for pedestrians. Also, the number of driveways can create unsafe vehicle maneuvers.

*Shoulders increase safety and highway capacity and provide a place for pedestrians and bicyclists when no sidewalks are provided.
(Rt. 197, MD)*



Shoulders

Although the physical dimensions of automobiles and trucks limit the basic width of travel lanes, the treatment of that portion of the highway to the right of the actual traveled way, that is, the “roadway edge,” provides the designer with a greater degree of flexibility. This is true in both urban and rural areas, although different design elements are more appropriate in each location.

Shoulder widths typically vary from as little as 0.6 m (2 ft) on minor rural roads, where there is no surfacing, to about 3.6 m (12 ft) on major highways, where the entire shoulder may be stabilized or paved.

The treatment of shoulders is important from a number of perspectives, including safety, the capacity of the highway section, impact on the surrounding environment, and both the initial capital outlay and ongoing maintenance and operating costs. The shoulder design should balance these factors. For example, a designer must consider the impact of the shoulder width and other roadside elements on the surrounding environment and, at the same time, how these dimensions will affect capacity. Even with a maximum lane width of 3.6 m (12 ft), the absence of a shoulder or the presence of an obstruction at the edge of the travel lane can result in a reduction in capacity of as much as 30 percent, compared to an area where shoulder or clear zone exists that is a minimum 1.8 m (6 ft) wide. On the other hand, significant environmental, scenic, or historic resources may be adversely affected by a widened shoulder.

Another consideration is the accommodation of pedestrians and nonmotorized vehicles. In many parts of the country, highway shoulders provide a separate traveled way for pedestrians, bicyclists, and others (when no sidewalks are provided).



(a)



(b)



(c)



(d)

Various shoulder treatments:

(a) Gravel

(b) Paved

(c) Concrete

(d) Grass with sidewalk

In addition to the dimensions of shoulders, designers have choices to make about the materials used. Shoulders may be surfaced for either their full or partial widths. Some of the commonly used materials include gravel, shell, crushed rock, mineral or chemical additives, bituminous surface treatments, and various forms of asphaltic or concrete pavements.

In a number of States, particularly in the southern part of the country where snow removal is not an issue, grass or turf surfaces have been provided on top of compacted earth embankments. The advantages of grass shoulders are that they provide both a natural storm water detention system and are aesthetically pleasing. The disadvantages can be that they are often less safe than paved shoulders and force pedestrians and bicyclists to share the road with motorists, if no off-street facility is provided.

Shoulders represent an important element in roadway drainage systems by carrying surface runoff away from the travel lanes into either open or closed drainage systems. A variety of design treatments have been used to accommodate roadway drainage across shoulder areas. In rural and suburban areas, the most common technique allows surface runoff to cross over the shoulder and go directly into drainage ditches running parallel to the roadway edge.

In rural areas where significant physical and/or environmental constraints exist, more “urban” style solutions have been used. For example, along an older section of Maryland State Route 51, passing through the Green Ridge State Forest in Allegany County, steep, narrow cuts along the existing alignment severely limited the total roadway width. Asphalt curbing and a closed drainage system were constructed in conjunction with a recent pavement rehabilitation project. This allowed for a modest widening of the travelway and elimination of an area of steep and narrow ditches, without the need to engage in major earthwork.

Use of paved shoulder, asphalt curbing, and closed drainage system along a rural minor arterial.



Clear Zones

An important consideration in defining the appropriate cross section for a particular highway facility is the width of the clear zone. As defined in Chapter IV of the AASHTO Green Book, the clear zone is “...*the unobstructed, relatively flat area provided beyond the edge of the traveled way for the recovery of errant vehicles.*”

The width of the clear zone is influenced by several factors, the most important of which are traffic volume, design speed of the highway, and slope of the embankments. The AASHTO Roadside Design Guide¹ is a primary reference for determining clear zone widths for freeways, rural arterials, and high-speed rural collectors based on these factors. For low-speed rural collectors and rural local roads, the AASHTO Green Book suggests providing a minimum clear zone width of 3.0 m (10 ft). For urban arterials, collectors, and local streets with curbs, the space available for clear zones is typically restricted.

¹ Roadside Design Guide, AASHTO, Washington, DC, January 1996.

Curbs

Used primarily in urban and suburban environments, curbs can serve some or all of the following functions:

- Drainage control
- Roadway edge delineation
- Right-of-way reduction
- Aesthetics
- Delineation of pedestrian walkways
- Reduction of maintenance operations
- Assistance in roadside development.

There are basically two types of curbs: barrier and mountable. Flexibility in the use of either type is a handy tool for a highway designer when defining the cross section of an improvement project. Barrier-type curbs are not, however, recommended for projects with design speeds above 65 km/h (40 mph).

Curbs can be constructed from a variety of materials, including concrete, asphalt, and cut stone. Figure 6.3 illustrates a variety of commonly used barrier and mountable curbs.

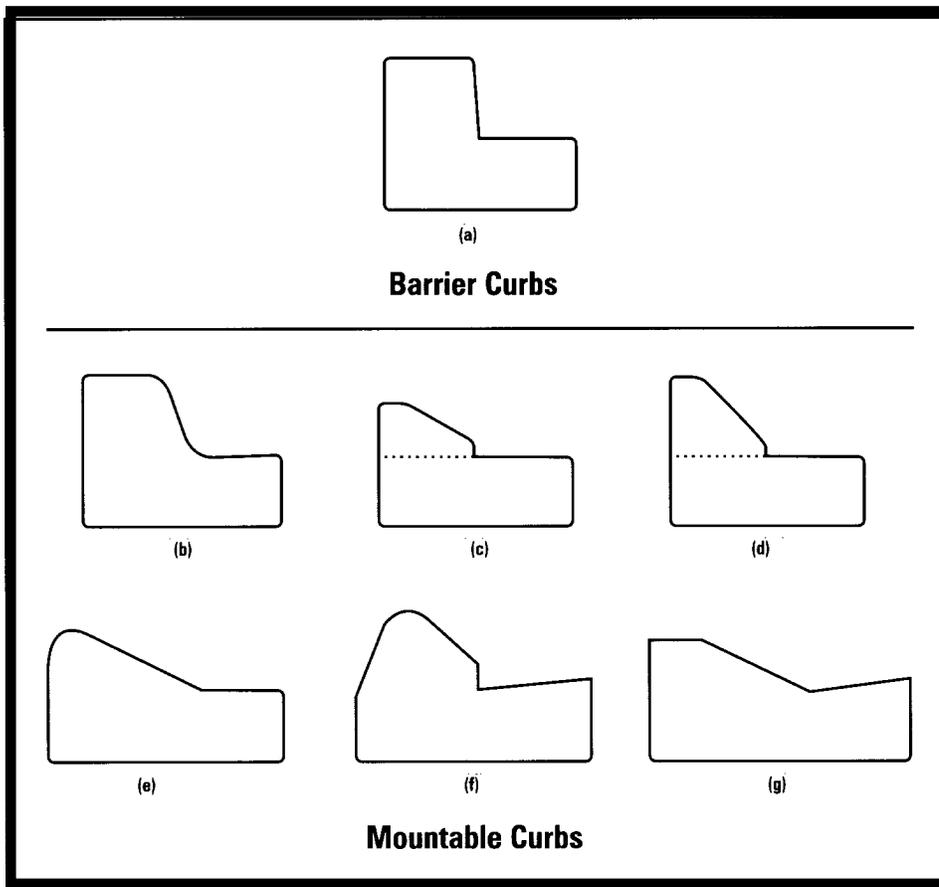
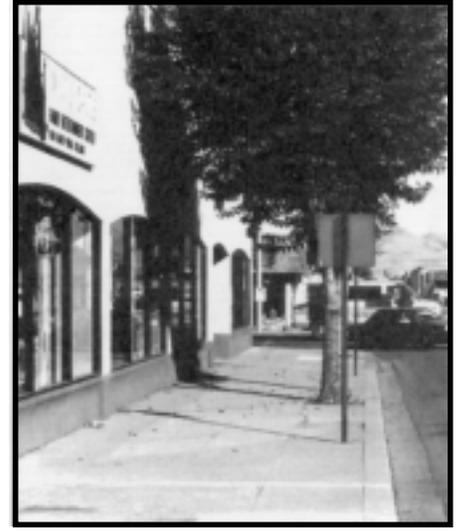


Figure 6.3
Examples of barrier and mountable curbs.

Sidewalks and Pedestrian Paths

The safe and efficient accommodation of pedestrians along the traveled way is equally important as the provisions for vehicles. Too often, pedestrians are a secondary consideration in the design of roadways, particularly in suburban areas. Although sidewalks are an integral part of city streets, they are much more rare in rural areas and provided only sporadically in suburban areas, despite data that suggest that providing sidewalks along highways in rural and suburban areas results in a reduction in pedestrian accidents.

Sidewalks can be located next to a planted strip or flush with the roadside edge.



When considering the placement of sidewalks, designers have several options. The sidewalk can either be placed flush with the roadside edge (if a curb is provided) or next to a buffer area, such as a planted strip (usually of grass or plant material), located between the sidewalk and roadside. The pros and cons of each option should be weighed and considered by the designer, using input from the community. For example, a planted strip has these advantages:

- Pedestrians are kept at a greater distance from moving vehicles and thus are safer (in urban areas with on-street parking, parked cars help to act as a shield for pedestrians from moving traffic, so a buffer space may not be necessary to address that concern).
- Planted strips tends to add to the aesthetics of the facility and help reduce the apparent width of hard surface space.
- Planted strips provide a space for snow storage.

Buffers, or planted strips, may have the disadvantage of requiring additional right-of-way that may negatively affect restricted right-of-way corridors.

Another important consideration, and one in which the designer is given some flexibility, is in the width of the sidewalk and planted strip. Typically, sidewalks in residential or low-density commercial areas vary in width from 1.2 to 2.4 m (4 to 8 ft). The Americans with Disabilities Act Accessibility Guidelines of August 1992 set the minimum passing width on a sidewalk at 1.525 m (5 ft) at least every 61 m (200 ft). If a planted strip is provided between the sidewalk and the curb, it should be at least 0.6 m (2 ft) wide to allow for maintenance activities. This planted strip also provides space for street lights, fire hydrants, street hardware, and landscaping.



The wider the sidewalk, the more room there is for street furniture, trees, utilities, and pedestrians. (Alexandria, VA)

Sidewalks can also provide space for street furniture and necessary traffic poles and signals; however, additional width should be added to sidewalks to accommodate these fixtures. The wider the sidewalk, the greater the number of pedestrians that can be accommodated and the less difficult it is for them to maneuver around these fixed objects. When considering the placement of objects inside sidewalks, it is important not to overlook the need to maintain as unobstructed a pathway as possible. For instance, locating utility poles to the sides and not in the center, of sidewalks is important. This detail facilitates the movements of people with disabilities as well.

Adding sidewalks to a facility where none previously existed can be beneficial to a community. When the Lincoln Beach Parkway section of the Pacific Coast Highway (U.S. Route 101) was reconstructed in the early 1990's, sidewalks were added along both sides of the facility. Not only did this result in a more aesthetically pleasing alternative to the shoulder section for the two travel lanes that previously existed, but the sidewalks made it safer for residents to walk between their homes and local commercial facilities. Residents can now interact with each other much more easily, which has fostered a higher level of community spirit.

Sidewalks can be built with a variety of shapes and materials.
(San Antonio, TX)





Pedestrian barriers can provide safety by separating pedestrian and vehicular traffic. (Annapolis, MD)



Street trees and light fixtures are carefully lined to one side of the sidewalk to provide the widest possible space for pedestrians.

Accommodating Bicycles

Bicycles are recognized by many as a viable mode of transportation in the United States, both for commuting and recreation. Transportation designers should consider the needs of these users in the design of facilities. Basically, there are five types of bicycle facilities:

- **Shared lane**-a “standard-width” travel lane that both bicycles and motor vehicles share
- **Wide outside lane**-an outside travel lane with a width of at least 4.2 m (14 ft) to accommodate both bicyclists and motorized vehicles
- **Bicycle lane**-a portion of the roadway designated by striping, signing, and/or pavement markings for preferential or exclusive use by bicycles and/or other nonmotorized vehicles
- **Shoulder**-a paved portion of the roadway to the right of the traveled way designed to serve bicyclists, pedestrians and others
- **Multiuse path**-a facility that is physically separated from the roadway and intended for use by bicyclists, pedestrians, and others

A multiuse path.



There are three primary factors to consider when designing facilities to accommodate bicycles and other nonmotorized vehicles:

1. What type of bicyclist is the route most likely to serve, i.e., advanced bicyclists, basic bicyclists, or children?

Advanced bicyclists are the experienced riders who make up the majority of the current users of collector and arterial streets, wish to operate at maximum speed with minimum delays, and require sufficient space on the roadway shoulder to be treated as vehicles. Designated bicycle lanes along a roadway give riders an even greater degree of comfort along arterial and collector streets. Basic bicyclists and children generally prefer the most comfortable, although sometimes circuitous, access to destinations, using low-speed, low-traffic-volume streets or a separate, multiuse path.

2. What type of roadway project is involved, i.e., new construction, major reconstruction, or minor rehabilitation?

Recommended design treatments are most easily implemented when new construction or major reconstruction is planned. Although retrofit and/or enhancement projects may be relatively limited in scope, opportunities to make at least minor improvements to better accommodate the needs of pedestrians and bicycles should be investigated. Marginal roadway improvements undertaken as part of 3R projects, such as widening the pavement area 0.3 to 0.6 m (1 to 2 ft) will enhance the roadway for bicycle use.

3. What are the current and future traffic operations and design characteristics of the route that will affect the choice of bicycle design treatments?



The shoulders on SR 313 were specifically designed to accommodate bicycle traffic. (Moab, UT)

Six factors are recognized by transportation planners and engineers as having the greatest effect on bicycle use:

- Traffic volume**-higher traffic volumes represent greater potential risk for bicycles.

- Average motor vehicle operating speed**-operating speed is more important than the posted speed limit; motor vehicle operating speed can negatively affect the bicyclist's comfort unless mitigated by special design treatments.

- Traffic mix**-the presence of trucks, buses, and other large vehicles can increase risk and have a negative impact on the comfort of bicyclists.

- On-street parking**-additional width is needed for bicycle lanes on roads that have on-street parking.

- Sight distance**-this must be sufficient to allow a motor vehicle operator to either change lane position or slow to the bicyclist's speed when overtaking the bicycle, primarily on rural highways.

Number of intersections-the number and frequency of intersections should be considered when assessing the use of bike lanes. Intersections pose special challenges to bicycle and motor vehicle operators and require special treatments.

East Capitol Street accommodates two travel lanes, on-street parking, and a designated bike lane in each direction. (Washington, DC)





*The highway landscape is an important part of its overall appearance.
(Papago Freeway, Phoenix, AZ)*

Landscape Design and Selection of Plant Material

Landscape design is an important element in the design of all highway facilities and should be considered early in the process, so that it is in keeping with the character or theme of the highway and its environment. The AASHTO Green Book mentions three objectives of landscape design:

- To provide vegetation that will be an aid to aesthetics and safety
- To provide vegetation that will aid in lowering construction and maintenance costs
- To provide vegetation that creates interest, usefulness, and beauty for the pleasure and satisfaction of the traveling public

Landscape designs for urban highways and streets plays an additional role in mitigating the many nuisances associated with urban traffic and can help a roadway achieve a better “fit” with its surroundings.



Landscape treatment is most successfully integrated into a project when considered early in the design. (OR)

Trees

An important aspect of roadside landscape design is the treatment of trees. Single-vehicle collisions with trees account for nearly 25 percent of all fixed-object fatal accidents annually and result in the deaths of approximately 3,000 people each year. This problem is most apparent on roads that have existing trees, where designers do not have direct control over placement. For landscape projects, where the type and location of trees and other vegetation can be carefully chosen, the potential risks can be minimized.

Integrating trees into the design of a facility has many advantages. Trees provide a visual “edge” to the roadway that helps guide motorists. Trees also add to the aesthetic quality of a highway. In urban and suburban areas, trees soften the edges of arterial and collector streets. If sight distance is a concern, taller trees with lower branches that are trimmed or low-growing (shorter than 1 m [3 ft]) herbaceous and woody plants can be another option along both the roadway edge and in raised medians.

Trees add to the visual appeal of this urban street and can be placed in both medians and along roadway edges.





Trees make a difference. Compare the left side of this roadway with the right side, where the trees have been removed. (Rt 30, Maui, HI)

It is important to select the appropriate species of tree for the highway environment. In particular, trees need to be chosen that can survive poor air quality, infertile and compacted soils, and extreme temperature fluctuations. Remember that maintenance, particularly during the first year after installation, is essential to the long-term health and viability of trees and other plants. Utilize the skills and knowledge of the city or town urban forester or arborist, the local agricultural extension service, or a landscape architect to identify the plant material that will be best suited for the location.

In addition to selecting a type of tree for its hardiness, the size and placement of trees is another important consideration. Generally, a tree with a trunk diameter greater than 100 mm (4 in) measured 100 mm (4 in) above the ground line is considered a “fixed object” along the roadway. Because most trees grow larger than this, their placement along the roadway needs to be carefully considered. Factors that affect this decision include the design speed, traffic volume, roadway cross section, and placement of guardrail. Trees should not be placed in the clear zone for any new construction or major reconstruction, nor should they be considered safe because they are placed just outside the clear zone. The safe placement of trees to prevent errant drivers from hitting them should be made in conjunction with a highway designer who is knowledgeable about safety. However, the decision to create a clear zone that requires the removal of existing trees is an issue that should be presented to the public and addressed by the multidisciplinary team early on.

Trees are an important aspect of community identity and carry a great deal of emotional ties with the residents. If communities consider existing trees a valuable resource, alternatives to complete eradication should be pursued. These include installation of traffic barriers, lowering of the design speed, or even complete redesign of the facility to incorporate the trees. It is not unusual for a community to value one specific tree and desire to preserve it. In general, transportation designers must balance safety with other community values when considering facility design and tree preservation.

Utilities

One element of cross-section design that is often overlooked is the accommodation of public utilities. Overhead utilities typically include electric, telephone, and cable television. For new construction in urban areas, electric, telephone, and other telecommunication lines are now often placed underground.

Motor vehicle collisions with utility poles result in approximately 10 percent of all fixed-object fatal crashes in the United States annually. Utility poles also have a negative affect on the aesthetics of a roadway. It is important, therefore, whether designing in rural or urban locations, to consider accommodating utilities early in the design process.

The most desirable design solution, in terms of safety for overhead utilities, is to locate the utility poles where they are least likely to be struck by a vehicle. (The same is true for sign and luminaire supports.) The 1996 AASHTO *Roadside Design Guide* notes the following options for the location and design of utilities:

- Bury power and telephone lines underground
- Increase lateral pole offset
- Increase pole spacing
- Combine pole usage with multiple utilities
- Use a breakaway pole design
- Use traffic barriers to shield poles

Burying power and telephone lines, although the safest and most aesthetically pleasing option, is also the most expensive. For example, during the reconstruction of 1.66 km (1.03 miles) of Carson Street in the city of Torrance, CA, all the existing overhead utilities were placed underground at a cost of about \$2.3 million, or approximately 37 percent of the total project cost. Because of these tradeoffs, the design and location of utilities requires public input and should be considered early in the design of each project.

Traffic Barriers

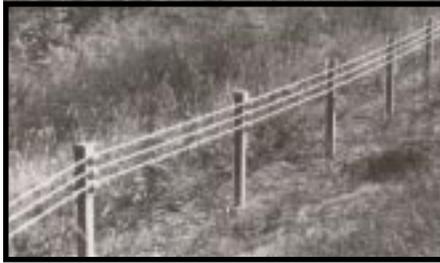
The options available to designers for traffic barriers include deciding whether or not to include them in the design and, if they are included, deciding which type to choose. The purpose of the barrier, as stated in the AASHTO Green Book, is to *“minimize the severity of potential accidents involving vehicles leaving the traveled way where the consequences of errant vehicles striking a barrier are less than leaving the roadway.”* In addition to preventing collisions with fixed objects along the roadside, traffic barriers are themselves obstacles and have some degree of accident potential. The use of traffic barriers should consider these tradeoffs.

A wide variety of traffic barriers is available for installation along highways and streets, including both longitudinal barriers and crash cushions. Longitudinal barriers (such as guardrails and median barriers) are designed primarily to redirect errant vehicles and keep them from going beyond the edge of the roadway. Crash cushions primarily serve to decelerate errant vehicles to a complete stop (such as impact attenuators at freeway exit gore areas).

The design of the traffic barrier is an important detail that contributes to the overall look or theme of roadway design; therefore, in addition to safety, the selection of an appropriate barrier design should include aesthetic considerations. In addition, all traffic barriers should meet crash-testing guidelines for the type of roadway being designed. Crash-testing guidelines have different levels, depending on the facility and the type of vehicles that will use the facility. For example, on parkways with restricted truck traffic, many aesthetic barriers have been designed and crash tested. The criteria used for these types of barriers are less stringent than the criteria for facilities with truck traffic. Because aesthetic considerations are usually a factor on parkways, many of these barriers are designed to add to the visual quality of the road. Even for roads that are not parkways, however, there are still many barrier designs that meet the criteria for facilities with truck traffic. Given these options, designers must balance their decisions based on safety, cost, and aesthetics.



Weathering steel is a low-cost option for designers who are trying to “blend” a barrier into the surrounding environment. (NM 65, Montezuma, NM)



(a)



(b)



(c)



(d)

A sample of available traffic barrier designs includes:

- (a) A three-strand cable barrier system allowing deflections on impact of up to 4.6 m (15 ft)
- (b) Various steel beam barriers allowing deflections on impact of up to 1.2 m (4 ft)
- (c) Steel-backed timber barriers that allow deflections on impact of up to 2.4 m (8 ft)
- (d) New Jersey shaped concrete barriers
- (e) Stone masonry walls consisting of a reinforced concrete core faced with stone masonry.



(e)

An in-depth discussion of the factors associated with the decision to install traffic barriers and guidance on the selection of a particular barrier design is presented in the AASHTO *Roadside Design Guide*.

A concern among some States when selecting a barrier design is cost. Aesthetic barriers might have a higher upfront cost than standard steel barriers and may be more expensive to maintain. One solution to this concern is to be consistent in the type of aesthetic barrier used throughout a State. For instance, a State might want to limit the type of barriers used to only two, an inexpensive barrier for highways where aesthetics are not a major concern and an aesthetic type for highways where visual quality is important. In this way, States can cut back on the cost to maintain multiple barrier designs.

Weathering steel guardrails are an example of an inexpensive barrier that may be considered acceptable in certain surroundings. For many States, weathering steel has been a good solution, because its rustic color helps the guardrail blend into the environment. Weathering steel has, however, had durability problems in a few areas.



These HOV lanes are restricted to buses, vanpools, and carpools carrying three or more occupants. (I-84, CT)

Accommodating Transit

Highways operate as truly multimodal transportation facilities, particularly in large urban areas. Accommodating public transit and other high-occupancy vehicles (HOVs) is an important consideration. On one end of the scale, this may involve including sidewalks to allow local residents to walk to and from bus stops. As higher levels of vehicle traffic and transit usage are expected, bus turnouts may need to be considered. At the higher end of the scale, such as on major urban freeways, dedicated bus lanes and/or HOV lanes may need to be incorporated into the design. The management of the local public transit operator should be consulted during the planning stage, if possible, so that these facilities can be incorporated into the design from the beginning.

ISSUES

Some of the challenging aspects of highway design have to do with cross-section elements. Decisions that designers need to make may include the number of lanes proposed for the improvement, the width of travel lanes and shoulder areas, the type of drainage proposed, or the desirability of including sidewalks or bicycle/pedestrian paths as part of the project.

Restricted Right-of-Way

Many roads currently exist that were not built to today's standards. These roads may be located in restricted right-of-way corridors that have scenic or historic resources adjacent to the roadway. It is necessary to try to avoid impacting these resources when considering highway improvements.

Solution

One option, as has been discussed previously, is to reconsider the functional classification and design speed of a particular section of highway, because these decisions go a long way toward defining the basic design parameters that can be used in connection with an improvement of the facility. Lowering the design speed or changing the functional classification results in a lowering of the minimum width dimensions for the cross-sectional elements.

Another option is to maintain the road as is or as a 3R project. Design criteria established by States are generally lower for 3R projects than for reconstruction projects. A third option is to seek design exceptions. Whichever alternative is chosen, the designer should try to maintain consistency in the roadway cross section. If only a small stretch of highway is located within restricted right-of-way, it would be unsafe to narrow that stretch while maintaining a much higher roadway width before and after it.

A successful resolution of the design of a highway cross section was found during the planning and design for the State Route 9A project along the Hudson River in Manhattan. The existing at-grade "interim" facility had two 3.6-m (12ft) lanes in each direction, separated by a 4.6-m (15-ft) flush median with a Jersey barrier.

The preferred alternative, which is now under construction, replaces a rather unattractive urban street, with a six- to eight-lane divided urban boulevard that has a landscaped median. The new design incorporates extensive landscaping and separate bikeways and pedestrian walkways. The width of the travel lanes was reduced from 3.6 m (12 ft) on the existing surface street to 3.4 meters (11 ft) on the new urban boulevard. This cross section accommodates traffic demands and dramatically enhances the physical environment of the project area. More information about this project is in the case study section of this Guide.

The Design of Cross-Section Details

Some highway facilities may be designed with the greatest concern to fit into their surrounding environments, but if the details are not carefully thought out, they can still leave the impression of an unappealing roadway.

Solution

The design of all elements of the highway cross section adds greatly to its appearance. Design details include the design and width of the median and traffic barriers and the selection of plant material. All these elements contribute to the theme of the roadway and should be considered as a unit. The best method for achieving a unified look is to work with a multidisciplinary design team from the beginning of the project development process through the last detail of the design.

Details are some of the first elements users of a facility will notice. For example, designers may go through a lot of trouble to preserve vegetation along the roadway because of its importance to the community and its scenic qualities, but if designers use concrete barriers as shields in front of this vegetation, that one element may catch the users' attention.

Another option that aids designers in the details of cross-section elements is the use of computer-imaging technology. The series of figures on the following page illustrates the application of various combinations of basic design elements to define a number of widening options for a portion of State Highway 23 in Rockville, MN. These options include the use of different median types and widths and incorporate different levels of right-of-way acquisition.

The Minnesota DOT has found the use of such computer-imaging techniques to be particularly useful in illustrating the impact of alternative design concepts on existing facilities for project area residents and businesses. Minnesota DOT has made this approach a standard element in all major project planning and preliminary engineering assignments.

With the increasing need to ensure meaningful and continuous public involvement on all such projects, the use of computer imaging to illustrate design alternatives to communities will help to alleviate potential conflicts and misunderstandings and lead to the best design decisions.

Computer visualization showing proposed design concepts of SH 23 in Rockville, MN.

Existing conditions.



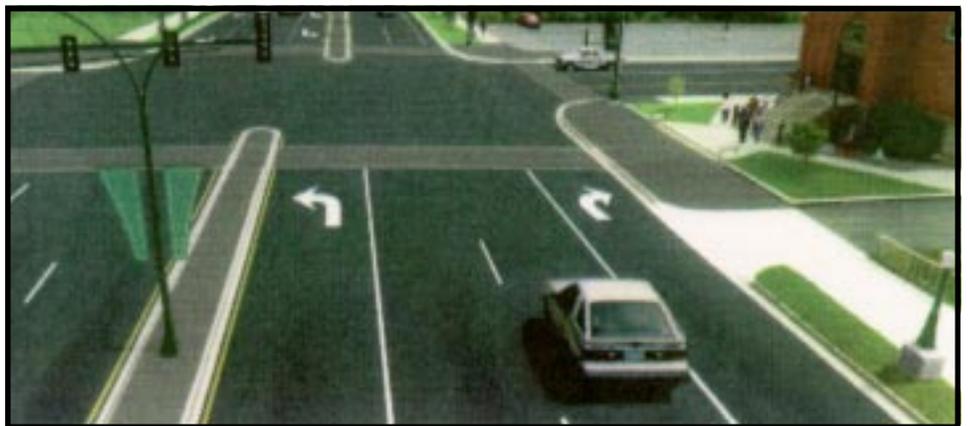
Proposed continuous left turn lane design.



Proposed continuous left- and right-turn lane design.



Proposed channelized and raised median design.



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Chapter 7

BRIDGES AND OTHER MAJOR STRUCTURES

Refer to Chapter V, VI, VII and X of the AASHTO Green Book

This historic wrought iron camel back truss is one of the few remaining in the country. It has been preserved by moving it to a new location, where it now serves as a footbridge. (Baraboo, WI)



BACKGROUND

Bridges and other related major structures play an important role in defining the manner in which a highway affects the aesthetic, scenic, historic, and cultural resources of the corridor within which it is located. Indeed, some of the distinguishing features of a number of major cities are their bridges. When one thinks of San Francisco, one of the first images that comes to mind is the Golden Gate Bridge. Smaller structures have a visual impact as well, such as the Manchester Street Bridge in Baraboo, WI, shown above.



Architectural treatment enhances the visual quality of these concrete piers. (Wabasha, MN)



Careful attention to details helped create this overpass that is not only visually appealing but also pedestrian friendly. (CA)

GENERAL GUIDELINES FOR THE GEOMETRICS OF BRIDGE DESIGN

The geometric criteria in the AASHTO Green Book for new or replacement bridges deal primarily with the width of the bridge deck and its relationship to approach roads. Early design coordination is important when establishing the width of a new or replacement bridge and in determining its horizontal and vertical alignment. Road engineers, architects, and landscape architects, as well as members of the community, can provide input to help the bridge designer determine the appropriate geometric dimensions and overall appearance of the bridge. The AASHTO Green Book presents a range of options for traveled-way widths for bridges with a span of less than 30 m, depending on functional classification and average daily traffic, as illustrated in the following tables.

Table 7.1
Minimum Roadway Widths for
Bridges on Local Roads

Current Average Daily Traffic	Minimum Clear Roadway Width of Bridge
400 and under	Traveled way + 0.6 m each side
400-2,000	Traveled way + 1.0 m each side
over 2,000	Approach roadway width

Source: Adapted from the AASHTO Green Book, p. 423.

Table 7.2
Minimum Roadway Widths for
Bridges on Collectors

Current Average Daily Traffic	Minimum Clear Roadway Width of Bridge
under 400	Width of traveled way + 0.6 m each side
400-1,500	Width of traveled way + 1.0 m each side
1,500-2,000	Width of traveled way + 1.2 m each side
over 2,000	Approach roadway width

Source: The AASHTO Green Book, p. 467.

On urban collectors and arterials, the AASHTO Green Book recommends that the minimum clear width for new bridges be the same as the curb-to-curb width of the approach street.

In addition to determining the width of the travelway, a bridge designer must consider the need for pedestrian and nonvehicular traffic over the bridge and the most appropriate method for accommodating it. This could include a wide shoulder, a raised sidewalk, or both. If sidewalks are on the approach road, continuity of the sidewalk over the bridge is important.

For existing bridges that do not meet the criteria for travelway width, the AASHTO Green Book recognizes that those that tolerably meet the criteria may be retained. It identifies some of the factors in considering the retention of existing bridges, including *“the aesthetic value and the historical significance attached to famous structures, covered bridges, and stone arches”* (p. 423). Because of this, AASHTO has criteria for minimum roadway widths and minimum structural capacities for bridges that are to remain in place. It is important to consider this option for each aesthetically and historically significant bridge on a case-by-case basis, before deciding to demolish and replace it.

BRIDGE DESIGN ELEMENTS

In addition to determining the geometrics of a bridge, designers must consider many design elements. Basically, bridges are viewed from two perspectives. Traveling over the bridge deck, the driver of a vehicle sees the travelway, bridge railings, and the view to either side. If the bridge crosses over another roadway, water or land both on its side and underneath can also be viewed from this perspective. It is important for bridge designers to keep in mind that these two perspectives may require consideration of additional aesthetic treatments for the bridge.

For the design of the bridge deck, the major components include the width of the travelway and shoulders and pedestrian and other nonvehicular accommodations, as mentioned above. Other components include railings, lighting fixtures, and other design details. For the side of the bridge, the major components include the piers, the side fascia, abutments, and wing walls. In addition, the bridge railings and other fixtures selected for the top of the bridge will also play a design role for the side, because they can be seen from below.



*Cape Creek Bridge
(Oregon Coast Highway, OR)*

A view of the bridge deck.



A view of the bridge side.

Bridge Railings

When designing a bridge, designers can either choose to use a bridge railing that has already been designed and crash tested, or they can design a new one and have it crash tested. If designing a new railing, designers can use two AASHTO publications as guidance:

Standard Specifications for Highway Bridges (current edition) and

LRFD [Load and Resistance Factor Design] Bridge Design Specifications (current edition).

FHWA requires that the railings of all bridges on the NHS be crash-tested and recommends following the crash testing procedures in National Cooperative Highway Research Program (NCHRP) Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, 1993. This report identifies six test levels for bridge railings which are intended to match the type of traffic and design speeds on the bridges.

Currently, there are approximately 60 crash-tested railing designs. These include steel bridge railings, solid concrete barriers, aluminum bridge railings, aesthetic steel pipe bridge railings, aesthetic stone masonry-faced concrete, and wood railings. Typically, each State has its own standard railings. The New Jersey and F-shape concrete safety shape bridge railings are the most commonly used for new-construction projects. Because of the desire for aesthetic barriers, however, other types have been developed.

Aesthetic treatment on a solid concrete barrier. (OR)



Steel pipe bridge railings. (Blue Ridge Parkway, NC)



Bridges with lower traffic volumes, little truck traffic, and lower design speeds have the most options in terms of the types of bridge railings that have been crash tested. For instance, timber bridge railings have been developed for both longitudinal and transversely laminated wood bridge decks. In some cases, guardrail-to-bridge rail transition designs have been crash tested; in other cases, they have not.

Often there is concern over designing bridge railings that prevent drivers from seeing through to the water or landscape below as they drive over the bridge. Solid concrete barriers may block the view, which many times is quite scenic. For this reason, bridge designers should consult the community when considering the type of railing to be used. There are metal railings that have been crash tested and approved by FHWA that allow the view to be maintained. State DOTs vary in their uses of these types of railings.



*Metal bridge railings provide a view of scenic rivers for motorists.
(Fairbanks Bridge, Farmington, ME)*



*Solid concrete barriers separate vehicular traffic and nonvehicular traffic, while ornate pedestrian railings and light fixtures enhance the visual quality of this bridge.
(PA 45 Lewisburg River Bridge, Lewisburg, PA)*

ISSUES

The conflicts in design of highway bridges relating to aesthetic, scenic, historic, and cultural resources commonly boil down to one of two issues:

- Should an existing structure be rehabilitated or should a new bridge be constructed?
- Is a new structure out of scale with its surroundings or is its design incompatible with its environment?

Reconstruction Versus Rehabilitation

In many instances, particularly for bridges of historic or aesthetic value, the rehabilitation of the bridge is the preferred solution, rather than total replacement. This option is not always feasible, but should be pursued as much as possible.

Solution

As stated above, the AASHTO Green Book recognizes that existing bridges that tolerably meet geometric criteria can be retained. Each bridge needs to be examined on an individual basis, considering the design factors unique to that structure. Only after careful analysis and consultation with the community, should a determination be made.

This historic bridge was restored by building a new bridge within the existing trusses. The new bridge carries its own weight, as well as the weight of all traffic crossing it. (Greenwich, CT)





*Overlapping highway and railroad bridges.
(Rt. 70, CA)*

This was the experience of the California Department of Transportation (Caltrans) with the rehabilitation of several steel truss structures along State Route 70 in Butte and Plumas Counties. The route has several unique features, including the bridges, all of which are of riveted steel construction in various truss and arch configurations.

A 1985 project scoping report recommended demolishing the existing structures and replacing them with more modern style steel or concrete structures designed to satisfy current seismic design criteria. Caltrans held a series of meetings with FHWA, the State Historic Preservation Officer, and other State and local agencies in an attempt to develop alternatives other than full bridge replacement.

While it had been originally assumed that the structural capacity of the bridges was limited with regard to vehicle weight, further investigations determined that the actual limiting feature was the size of the vehicles that could pass through the highway tunnels located on either side of the bridges. The bridges were determined to have very few problems with vehicle height or width restrictions. Rather, it was the tunnels that had been cut through the solid granite of the Sierra Nevada Mountains that established the maximum height and width of the vehicles that could use this section of Route 70.

As a result of this finding, Caltrans staff developed several rehabilitation schemes designed to increase the structural capacity and seismic stability of the structures without changing their basic designs or appearances. These rehabilitation alternatives were presented at a public information meeting in April 1992 and met with great support. All the rehabilitation activities are being conducted in accordance with the Secretary of the Interior's Standards for Rehabilitation.

*Detail of railing on a typical
Rt. 70 bridge*



Another option that preserves structurally or functionally deficient bridges is to move them. This has been done successfully in many States. Often, the historic structure is moved to a location where it can serve as a bridge for a pedestrian or nonmotorized vehicle path.

Compatible Design Scale

When rehabilitation of existing bridges is not feasible, a common concern of local residents is whether the proposed new structure will visually “fit into” the community.

Solution

The solution for designing a visually attractive and context-sensitive new bridge is to be flexible and to work with the community from the beginning to obtain public input. Professionals from other disciplines, such as architects, can also assist, especially if engaged early in the design of the structure. It is important to consider how the use of the geometric criteria will affect the overall scale of the bridge and to consider how that scale will relate the bridge to its surroundings.



*The Oyster River Bridge before.
(Durham, NH)*

The New Hampshire Department of Transportation (NHDOT) proposed to demolish the historic two-lane Oyster River Bridge, because of structural deficiencies and replace it with a four-lane structure on a higher elevation. When the original four-lane replacement concept was presented to the community, significant opposition arose, not only to the greatly enlarged scale of the proposed improvement, but also to the impact this option would have on adjacent 18th century houses, a community park, and a small cemetery. In a collaborative effort with the town of Durham and local residents, NHDOT staff undertook a reassessment of the project’s scope to develop a design that was more compatible with its surroundings. The result of this effort was an award-winning facility.



New replacement bridge and downstream pedestrian/bicycle bridge.

The newly reconstructed crossing provides two 3.6-m (12-ft) travel lanes and two 2.4-m (8-ft) shoulders and incorporates a lower vertical profile very close to that of its 1800's vintage predecessor. Much of the original stonework was used for facing of the abutments. While a number of bicyclists use the new bridge, a parallel bicycle/pedestrian crossing was constructed a short distance downstream to allow for better access to and from a riverside park.

Although rehabilitation of historic bridges may be the preferred option, it is not always possible. The Oyster River Bridge is an excellent example of a new structure designed to be compatible with the scale of its surrounding environment.

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Chapter 8

INTERSECTIONS

Refer to Chapter XI of the AASHTO Green Book

A good intersection design: a blend of safety and aesthetics.



BACKGROUND

At-grade intersections are one of the most critical and most complicated elements in highway design. The efficiency, safety, speed, cost of operation, and capacity of the highway system depend on the design of its intersections. Design criteria that are used to create the most efficient roadways are easily thwarted when that roadway meets up with intersecting traffic vying for the same limited roadway space. In urban and suburban areas in particular, the capacity of signalized intersections can effectively define the capacity of the highway system. Add the need safely to accommodate bicyclists and pedestrians with varying degrees of mobility, and the need to handle left and right turns, and the challenge faced by designers becomes even more complicated.

The Basics of Intersection Design

As stated in the AASHTO Green Book, the main objective of intersection design is to:

...reduce the severity of potential conflicts between motor vehicles, buses, trucks, bicycles, pedestrians, and facilities, while facilitating the convenience, ease, and comfort of people traversing the intersections. (p. 627)



*A "T" intersection.
(Wethersfield, CT)*

Intersection design can vary widely in terms of size, shape, number of travel lanes, and number of turn lanes. Basically, there are three types of at-grade intersections, determined by the number of intersecting legs, topography, traffic patterns, and the desired type of operation. Each roadway radiating from an intersection is called a "leg." Most intersections have four legs, which is generally accepted as the maximum recommended number for safety and capacity reasons. The three basic intersection types are:

- "T"-intersection (three approach legs)
- Four-leg intersection
- Multi-leg intersection (five or more approach legs).

INTERSECTION DESIGN ELEMENTS

As is the case with other aspects of the highway design process, designers can use a wide range of intersection design elements in combination to provide both operational quality and safety. These include:

- Traffic islands to separate conflicting vehicle movements
- Street closures or realignments to simplify the number and orientation of traffic movements through an intersection
- Separate left- and right-turn lanes to remove slow-moving or stopped vehicles from through traffic lanes
- Medians and channelized islands to provide refuge for pedestrians and bicyclists out of the vehicular traveled way.

The following paragraphs summarize of primary intersection design guidelines.

Angle of Intersection

Crossing roadways should intersect at 90 degrees, if possible, and at no less than 75 degrees. Skew angles of 60 degrees or less may need geometric countermeasures, such as reconstruction, or traffic control, such as signalization.

Horizontal and Vertical Alinement

The alinement before and through an intersection must promote driver awareness, operate well under frequent braking, and be easy to drive, so that the navigational task is not too difficult. The Green Book has recommended values for the minimum stopping sight distance needed based on the design speed of the approach roads. The design of intersections should also incorporate provisions for intersection sight distance.



Plant materials in medians enhance an intersection's appearance.

Medians

Medians, either raised or painted, provide a physical separation between opposing traffic flows. They also provide a refuge area for pedestrians to wait at crossing locations. Medians are a standard form of channelization at rural roadways and urban street intersections carrying four or more lanes. There are two principal functions of medians specifically located at intersections:

- Separating opposing traffic flows
- Providing storage for vehicles making left- and U-turns and vehicles crossing traffic and shielding pedestrians

Another important benefit of a median in an urban area is that it offers a green space for trees and low-growing plant material. Careful consideration is needed, however, to select the proper location and type of plantings. Particularly in narrow medians, plantings can create maintenance problems, and trees can cause visual obstructions if not carefully located.

Field studies and accident analysis provide similar findings on the operational and safety effects of the median width at intersections.¹ At rural unsignalized intersections, accidents and undesirable driving behavior decrease as the median width increases. In contrast, at suburban signalized and unsignalized intersections, accidents and undesirable driving behavior increase as the median width increases.

¹ *Median Intersection Design*, NCHRP Report 375, Transportation Research Board, National Research Council, National Academy Press, Washington, DC, 1995.

In other words, at rural unsignalized intersections, wider medians are preferable to narrower medians, unless signalization or suburban development is anticipated. At suburban intersections, the median should not be wider than necessary to accommodate the median left-turn treatment needed to serve current and future traffic volumes.

Example of a median landscape treatment.



Left Turn Lane Warrants and Design

Left-turn lanes may provide added safety and efficiency at both unsignalized and signalized intersections. At signalized intersections, left-turn lane warrants are based on the magnitude of turning movements, accident experience, and general capacity relationships. The design values for left-turn approach tapers, turn bay tapers, and storage lane lengths are based on deceleration in the lane, storage in the lane, or a combination of both. At signalized intersections, the required length of storage bay is a function of signal cycle length.

An example of a simple safety improvement is the addition of a painted left-turn lane at a rural intersection. This action not only reduces the potential for year-end accidents, but also provides drivers with a comfortable way to make a left turn. However, as is discussed in the Issues section of this chapter, the addition of a left turn lane can also affect resources along the side of the road or change the character of the road corridor. These are tradeoffs for designers to consider.



Left-turn lanes can improve safety and capacity.

Right-Turn Lane Warrants and Design

Depending on right-turn traffic volumes, accident history, highway speed, and availability of right-of-way, right-turn lanes may be appropriate for some intersections. As with left-turn lanes, the taper and storage length design is based on deceleration, storage requirements, or both.

Corner Radius Design

The design for an intersection corner radius is based on the selection of a reasonable design vehicle for the specific location. Design vehicles can range from large (tractor-trailer combinations) to small (private autos). There are a number of tradeoffs involved in this decision. Designing the corner radius for large vehicles requires more open intersections, and increases cost, and such intersections are more difficult to mark, signalize, and operate. In addition, the larger the dimensions of the radius, the greater the distance across the intersection from one side of the street to the other. This can make crossing the intersection much more difficult for pedestrians, particularly people who are elderly or have mobility impairments. Conversely, designing the corner radius for small vehicles can create operational problems should a significant number of larger vehicles have to use the intersection. Table 8.1 presents some general guidelines to assist in the selection of the appropriate design vehicle for various highway types.

Table 8.1
*Guidelines for the Selection of
Intersection Design Vehicles*

Highway Type	Design Vehicle
Rural Highways	
Interstate/freeway ramp terminals	WB-50
Primary arterials	WB-50
Minor arterials	WB-50 or WB-40
Collectors	SU-30
Local Streets	SU-30
Urban Streets	
Freeway ramp terminals	WB-50
Primary arterials	WB-50 or WB-40
Minor arterials	WB-40 or B-40
Collectors	B-40 or SU-30
Residential/local streets	SU-30 or P

Source: *Intersection Channelization Design Guide*, NCHRP Report 279, 1985. Note: WB-50 =semi-trailer combination, large; WB-40 =semi-trailer, intermediate; SU-30 =single unit truck; B-40=single unit bus; P=passenger car.

The actual radius or curb return design can be accomplished in one of four ways. Simple circular radius designs are the most commonly encountered design on lowspeed collector and local streets and in downtown areas. Alternative design methodologies include the use of symmetrical three-centered compound curves, asymmetrical three-centered compound curves, or simple radius curves with tapers. These designs better fit the paths of turning vehicles, thereby providing more efficient operations.

Table 8.2 illustrates some of the operational characteristics associated with a range of intersection corner radius dimensions for simple radius curves. This can be used as a guide in determining the appropriate radius design.

Corner Radius	Operational Characteristics
<5	Not appropriate for even P-design vehicles
10	Crawl-speed turn for P vehicles
20-30	Low speed turn for P vehicles; crawl-speed turn for SU vehicles with minor lane encroachment
40	Moderate speed turn for P vehicles; low-speed turn for SU vehicles with minor lane encroachment
50	Moderate-speed turns for all vehicles up to WB-50

*Table 8.2
Operating Characteristics of
Intersection Corner Radii*

Source: *Intersection Channelization Design Guide*, NCHRP Report 279, 1985.

Note: P=passenger car; SU=single unit truck; WB-50=semi-trailer combination large

Designers made use of two traffic islands for right-turning vehicles at this "T" intersection. (Bloomfield and Windsor, CT)



Traffic Islands

Traffic islands, or channelization, represent one of the most important tools in the design of intersections. Islands can either be painted directly on the roadway surface or they may be raised. Painted or “flush” channelization may be used on high-speed highways to delineate turning lanes, in constrained locations, or where snow removal is a concern. Raised islands, with appropriate channels or curb ramps to accommodate users of wheelchairs or other related devices, should be used where the primary function of the island is to shield pedestrians, locate traffic control devices, or prohibit undesirable traffic movements.

There are two basic types of traffic islands—corner islands that separate rightturning vehicles and median or divisional islands that separate opposing traffic flows on an intersection approach. Although islands in general provide a safe refuge for pedestrians, corner islands that separate right-turning vehicles in particular may make crossing intersections more difficult for pedestrians. These islands tend to widen the crossing distance. They can also make it more difficult for pedestrians to maneuver through the intersection, see oncoming traffic making right turns, and know where to cross, if the islands are not clearly delineated.

Traffic Control Devices

Traffic control devices are installed to designate right-of-way at intersections and to provide for the safest and most efficient movement of all traffic, including pedestrians and bicyclists. The standards established in the latest edition of the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), published by the FHWA, must be followed to determine proper intersection control.



A multiway stop installation is useful as a safety measure at some locations.

NEW INTERSECTION DESIGN CONCEPTS

In recent years, a new intersection design concept has evolved to provide an alternative to the traditional T, four-leg, and multi-leg intersections. This design concept is called a roundabout.

Modern roundabouts are increasingly being recognized as design alternatives to the use of traditional traffic signals for intersections for arterials. They improve both safety and efficiency for pedestrians and bicyclists, as well as motor vehicles. So far, roundabouts have been built in such States as California, Colorado, Maryland, Nevada, Florida, and Vermont. These roundabouts are different from rotary or traffic circles that have been used in the United States for a number of years to give entering traffic the right-of-way and encourage higher design speeds.

The modern roundabout is designed to slow entering traffic and allow all the traffic to flow through the junction freely and safely. Unlike the older rotary design, entering vehicles must yield the right-of-way to vehicles already in the circle. A deflection at the entrance forces vehicles to slow down. Traffic signals are not used, and pedestrians cross the streets at marked crosswalks.



*Modern roundabouts can reduce delay and increase safety.
(Cecil Co., MD)*



All vehicles, including bicycles, are forced to slow down and pay attention when entering a modern roundabout. (Cecil Co., MD)

The average delay at a roundabout is estimated to be less than half of that at a typical signalized intersection. Decreased delay may mean that fewer lanes are needed. Signalized intersections often require multiple approach lanes and multiple receiving lanes, which leads to a wider road.

Perhaps the greatest advantages of roundabouts are their urban design and aesthetic aspects. Roundabouts eliminate the clutter of overhead wires and signal poles and allow signage to be reduced. They can be distinctive entry points into a community or mark a special place. The central island offers an opportunity for a variety of landscape designs, as well.

ISSUES

Each of the various components of intersection design can cause conflicts between the need for a safe and adequate design, on the one hand, and the need to minimize impact to the surrounding physical and human environments, on the other. In addition, the need to accommodate pedestrians and bicyclists can sometimes cause conflicts with the need to provide an efficient operating environment for vehicular traffic.

Accommodating Pedestrians

The safe and efficient accommodation of pedestrians at intersections is equally important as the provisions made for vehicles. Pedestrian movements should be provided for and their locations controlled to maximize safety and minimize conflicts with other traffic flows. Too often, pedestrians are a secondary consideration in the design of roadways, particularly at intersections in suburban areas.

Solution

For all but a few exceptions, pedestrian crosswalks should be located at intersections, should have appropriate curb ramps for accessibility, and should be clearly marked. Two parallel painted lines generally are not enough of a distinguishing marking. Often motorists confuse these lines with the stopping line and pull right up to the edge of the crosswalk. At a minimum, some type of striping or painting inside the crosswalk area is recommended to improve safety. Many cities and suburban areas have gone beyond this and added aesthetic treatments to their crosswalk designs, including use of the following:

- Distinguishing materials for crosswalks, such as brick, patterned concrete, and cobblestone
- Granite edging
- Colored pavement or solid painting of crosswalks.

*A well-designed
pedestrian crosswalk.
(Annapolis, MD)*





A clearly delineated and elevated crosswalk, signage, and appropriate turning radius design contribute to this pedestrian-friendly intersection.



Pedestrian signals integrated with a combination traffic signal support and street light pole.

Pedestrian signals should be used in conjunction with vehicular traffic signals at all signalized intersections where pedestrians are likely to be present. Push buttons can be used at isolated intersections or where vehicular demand warrants maximizing the time for vehicular movement through the intersection. Fixed-time traffic signals with relatively short cycle lengths are more appropriate in urban or downtown areas.

*A raised pedestrian crosswalk and narrow corner radius design discourage nonlocal traffic and high speeds in this residential neighborhood.
(Carbondale, IL)*



Painted diagonal pavement markings.



Appropriate Corner Radius Design

As mentioned earlier, there are many tradeoffs involved in the selection of the appropriate type and dimension of radius designs. Issues arise when all of the factors involved in the design decision are not considered. For example, if the primary intent of the intersection design is to move traffic through as quickly as possible, a higher corner radius would be selected. The dimensions of the corner radius send a message to drivers entering residential neighborhoods regarding the speed they can drive and should be designed with this in mind. Encouraging fast speeds around intersection corners into residential areas will undermine efforts to lower operating speeds within the neighborhoods themselves. In addition, faster speeds create an unsafe environment for pedestrians.



Pedestrians rely on intersection locations to cross roadways. At the same time, by adding left- and right-turn lanes and large turning radii, intersections can be and often are the widest parts of roadways. The distance pedestrians must cross is an important consideration in design.

Addition of Left-Turn Lanes

A common conflict arising from the use of channelization, or separation of traffic into definite paths of travel by traffic islands, medians, or pavement markings, is the addition of left-turn lanes. While there is no doubt that this can create a smoother flowing intersection, especially on two-lane roads, the addition of a left-turn lane can significantly widen the width of the roadway, unless there is a median. This can change the character of an area, affect adjacent development or resources, and cause the road to be out of scale with its surroundings.

Solution

In cases where a left-turn lane is truly needed to improve safety and operational efficiency in a constricted right-of-way, there may not be an easy solution to this issue. Sometimes the addition of left-turn lanes depends on new growth and development along the corridor. If the scenic, historic, or cultural resources are such that any additional widening would affect these resources, it may be that decisions made at the land use stage of planning should be reconsidered. Limiting development along the corridor will limit traffic volumes and the need for additional left-turn lanes. Another option is to lower traffic volumes on the roadway through other means, including creating or widening alternative routes.

Painted turn lanes improve traffic safety and capacity at intersections but may be a tradeoff for communities that do not want a widened roadway.



The most important point is that the necessity of the left-turn lane must be carefully determined. If it is truly needed, designers can use the flexibility available to them in the applicable geometric design standards to try to minimize any additional widening of the traveled way and limit the impact on adjacent resources to the fullest extent possible.

Aesthetics of Traffic Signals and Sign Hardware Supports

Traffic control devices are beneficial in improving the safety and efficiency of intersections. In addition, there are many alternative design treatments that meet MUTCD and crashworthy standards and can be used to fit the design into the surrounding context.

Solution

Traffic control device supports should be designed to be safe and compatible with their surroundings. This may be a particular concern for designers in scenic or historic settings. Options for the designer include:

- Span wire installations for traffic signals that allow the poles to be set back, out of the direct line of sight
- Combination poles that carry street lights and traffic signals
- Decorative traffic signal poles
- Tapered mast arm traffic signal designs in lieu of span wire.

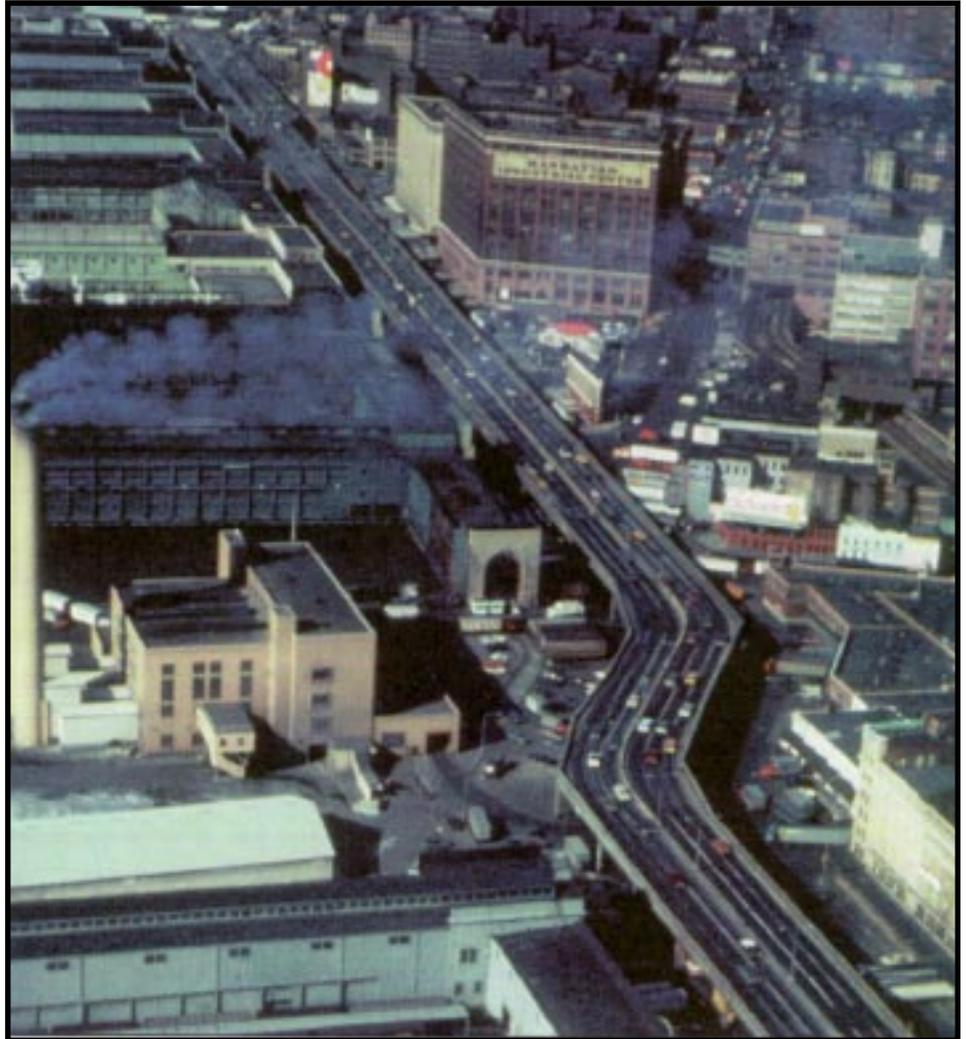


Combination poles carry traffic signals, signs, and street lights. This type of design can be very appropriate in certain settings. (Falls Church, VA)

Case Studies

ROUTE 9 RECONSTRUCTION

Borough of Manhattan, New York, NY



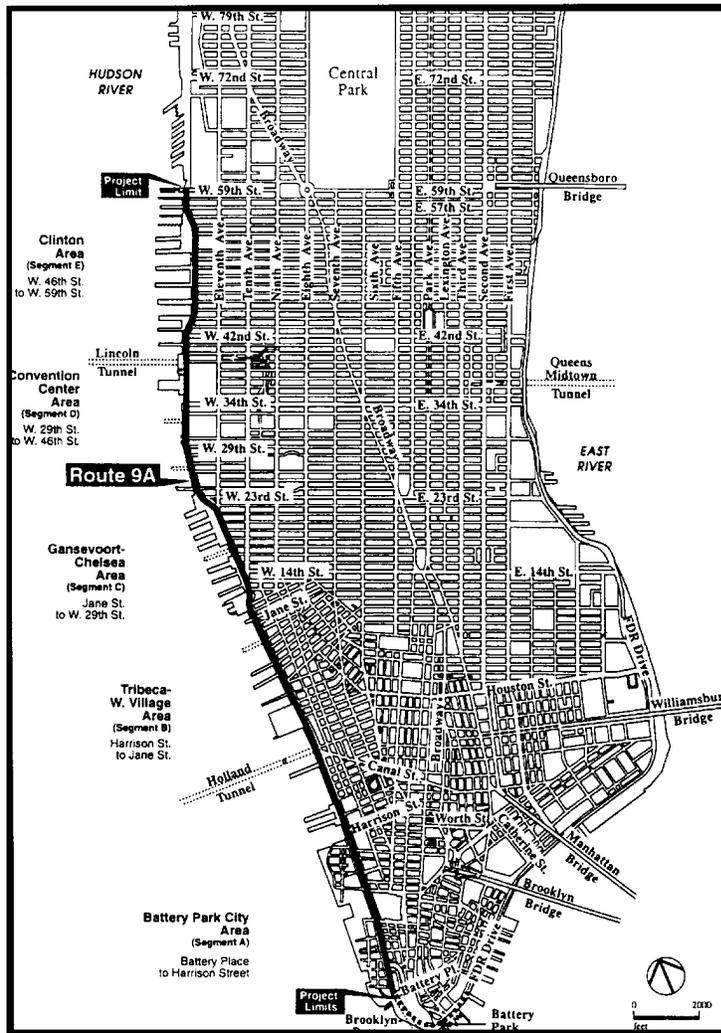
*Aerial view of West Side Highway
(looking South), circa 1970.*

BACKGROUND/PURPOSE

After more than 20 years of planning and design efforts, the reconstruction of what was formerly known as the West Side Highway has now begun. The project proposes to reconstruct State Route 9A from Battery Place to 59th Street along the western edge of Manhattan. This 5-mile section of roadway lies at the southern end of New York State Route 9A, which begins at the Brooklyn-Battery Tunnel and extends northward for approximately 76 km (47.5 miles), until it merges with U.S. Route 9 in Peekskill, NY in northern Westchester County. Commonly known as West Street, Eleventh Avenue, Twelfth Avenue, the West Side Highway, or the Miller Highway, this portion of State Route 9A plays a vital role in the regional transportation system of the New York metropolitan area.



Borough of Manhattan, NY, NY.



Location site map

Previously, this portion of Route 9A comprised the West Side Highway, an elevated limited-access roadway originally constructed in the 1930's between the Battery and 72nd Street, and a service road and local service street beneath the elevated roadway terminating at 59th Street. After the collapse of a portion of the elevated roadway in the early 1970's, and in recognition of its overall deteriorated condition, the entire section of highway from the Battery to 59th Street was closed to traffic in 1974. The elevated structure was subsequently demolished in the late 1970's, and the existing at-grade roadway was repaved to serve as an interim roadway until a permanent replacement for the West Side Highway could be constructed.

A proposal originally conceived in the early 1970's for the construction of a six to eight-lane interstate freeway facility known as Westway, which would have been partly elevated and partly depressed below grade, was withdrawn in 1985. The Westway funds were redistributed to several transportation projects in the

Section of collapsed West Side Highway in 1972.



city of New York, one of which was for the reconstruction of the interim roadway and its improvement into a permanent facility. The primary purpose of the Route 9A reconstruction project is to address the numerous problems and deficiencies associated with the continued use of the interim roadway and to accommodate some of the traffic that was diverted to other streets in the area when the elevated roadway closed.

The Route 9A facility serves a variety of regional, arterial, and local transportation activities and needs. It is an important interconnection between the Brooklyn Battery Tunnel, the Franklin D. Roosevelt (FDR) Drive and the East River Bridges via the Battery Park underpass, the Holland Tunnel, the Lincoln Tunnel, and the West Side Highway/Henry Hudson Parkway, which provides access to the George Washington Bridge, the Cross-Bronx Expressway, and points north.

The roadway is a major north-south artery in Manhattan's street grid that serves through movements to and from the borough. It is also a local street that provides vehicular and pedestrian access to the activities, businesses, and residences that line its right-of-way. The roadway also serves important intermodal functions by providing access to three Hudson River ferries, passenger liner terminals, excursion ships, and a heliport, and by serving as the terminus point for five crosstown bus lines.

The existing traffic volumes on the roadway reflect Route 9A's importance in the region's transportation system. Route 9A serves regional, arterial, local, and intermodal transportation functions. Average daily two-way traffic volumes range from 69,000 to 81,000 vehicles. With the closure and demolition of the elevated West Side Highway, the New York City DOT estimates that as many as 10,000 vehicles per day have diverted to Manhattan's other north-south routes, further taxing the capacity of these already congested roadways.

At a number of the key intersections along existing Route 9A during peak travel hours, traffic volumes approach or exceed theoretical roadway capacity. At these times, vehicular travel speeds on several segments of the existing roadway have been observed to drop to less than 3 mph (normal walking speed). Clearly, the existing “interim” facility is in need of substantial improvement.

ENVIRONMENTAL AND DESIGN ISSUES AND CONSTRAINTS

In 1987, the city of New York and New York State established a joint West Side Task Force in an attempt to reach a consensus on what action should be taken to replace the deficient interim highway. The task force ultimately developed the concept of creating an at-grade six-lane urban boulevard as the most appropriate solution to the identified problems. The primary goals, objectives, and design principles developed by the Task Force formed the basis for the subsequent Environmental Impact Statement (EIS) and project planning and design phases of the Route 9A project.

The project encompassed the full gamut of issues and concerns associated with providing major improvements to an existing transportation facility in an established urban area. In addition to issues that are typically encountered in major improvement projects, such as potential impact on adjacent land uses (including parks and historic structures) and air quality and noise effects, a number of other considerations were addressed during the project planning and design process. These included the following:

- The degree to which traffic using the facility would intrude into adjacent residential and commercial neighborhoods.
- The appropriate size of the median area.
- The accommodation of pedestrian movements across the highway from the existing developments on the east side to the planned linear park along the Hudson River waterfront.
- Separation of bicycle and pedestrian traffic.
- Access to commercial activities.
- The design of street light standards.

Functional Classification	Principal urban arterial street
Design Traffic Volumes	20-year projection from completion of project construction
Design Speed	40 mph
Level of Service	D (desirable)
Sight Distance	Crest - 275-ft Sag - Riding comfort controls
Grades	7% maximum 5% desirable
Alignment	573-ft minimum radius
Cross Slope	2% (planar)
Superelevation	4% maximum
Vertical Clearance	14.5-ft minimum
Lane Width	11-ft through lane 11-ft left-turn lane 1-ft offsets to curb or barrier
Number of Lanes	6 to 8 with turning and acceleration lanes as necessary
Medians	19-ft for mainline at-grade sections (face of curb to face of curb) 4.5-ft minimum for depressed, elevated, and constricted sections
Curbs	East side - 7-in curb Median - 7-in curb and/or 20-in to 34-in barrier West side - 7-in curb and/or 20-in to 34-in barrier Pedestrian ramps at all crosswalks
Shoulders	None, except 2-ft left and 6-ft right on structure at Canal Street and in depressed section at 34th and 42nd Streets Parking lane east side
Drainage	10-year storm - surface and closed system 50-year storm - depressed roadway
Border and Sidewalks	15-ft - east side sidewalk, 8-ft where constricted 15-ft - west side walkway, 8-ft where constricted 9-ft - buffer area west side of roadway
Parking Lanes	10-ft east side, commercial areas; 8-ft residential areas
Bikeway	12-ft mainline; 8-ft min. where constricted
Street Lighting	Roadway - 1.0 fc (see note) Depressed - 5.0 fc Tunnels - 50/5 fc, day; 5.0 fc, night
Horizontal Clearance	2-ft from face of curb to fixed objects

Note: fc = footcandle

General design criteria employed on the Route 9A reconstruction project.

The facility will have 3.3-m (11-ft) travel lanes with .30-m (1-ft) offsets from the .50-m to .85-m (20-in to 34-in) barrier curb. The high barrier curb has been crash tested by FHWA Region 15 staff to a speed of 70 kph (45 mph) and is similar to that used on the Washington, DC area parkway system. The curb was selected as an alternative to the use of shoulders, which are preferred in the AASHTO Green Book for a facility of this functional classification and design speed.

The new facility uses a design speed of 65 kph (40 mph) and will have a posted speed limit of 55 kph (35 mph), even though the project's functional classification as a principal urban arterial street would have allowed for a much higher design speed to be used.

Detailed Traffic Analysis

The traffic analysis performed as part of the EIS process was very detailed, and ultimately covered almost all of Manhattan. This analysis determined that virtually none of the users of the highway were traveling over its complete length, but rather using it to gain access to the east-west street system on the island. The road thus operates, both today and in the future, as essentially a collector-distributor system between the Brooklyn-Battery Tunnel on the south and the elevated Henry Hudson Parkway on the north.

To prevent the intrusion of through traffic into adjacent residential areas, a number of the originally proposed median openings will be closed, allowing only right-turn in and right-turn out movements between the northbound boulevard travel lanes and the east-west street system.

Pedestrian Movements

Pedestrian movements back and forth across the highway were examined extensively. Indeed, one of the major design elements of the project is the integration of the highway improvements with the pedestrian crossings to the planned Hudson River Waterfront Park. In addition, a small existing city park at 23rd Street will be greatly expanded (ultimately to encompass more than a full city block) both as a new urban amenity and to provide improved traffic operations in this area.

An associated feature is the use of a “bulb-out” design along the east side of the highway at all intersections to better delineate the curb parking areas and to help minimize the pedestrian crossing distances across the travel lanes. These designs will be closely coordinated with the pedestrian crossing points on the landscaped median.



Computer-generated illustration of separated pedestrian promenade and bicycle pathway along the river side of reconstructed Route 9A.

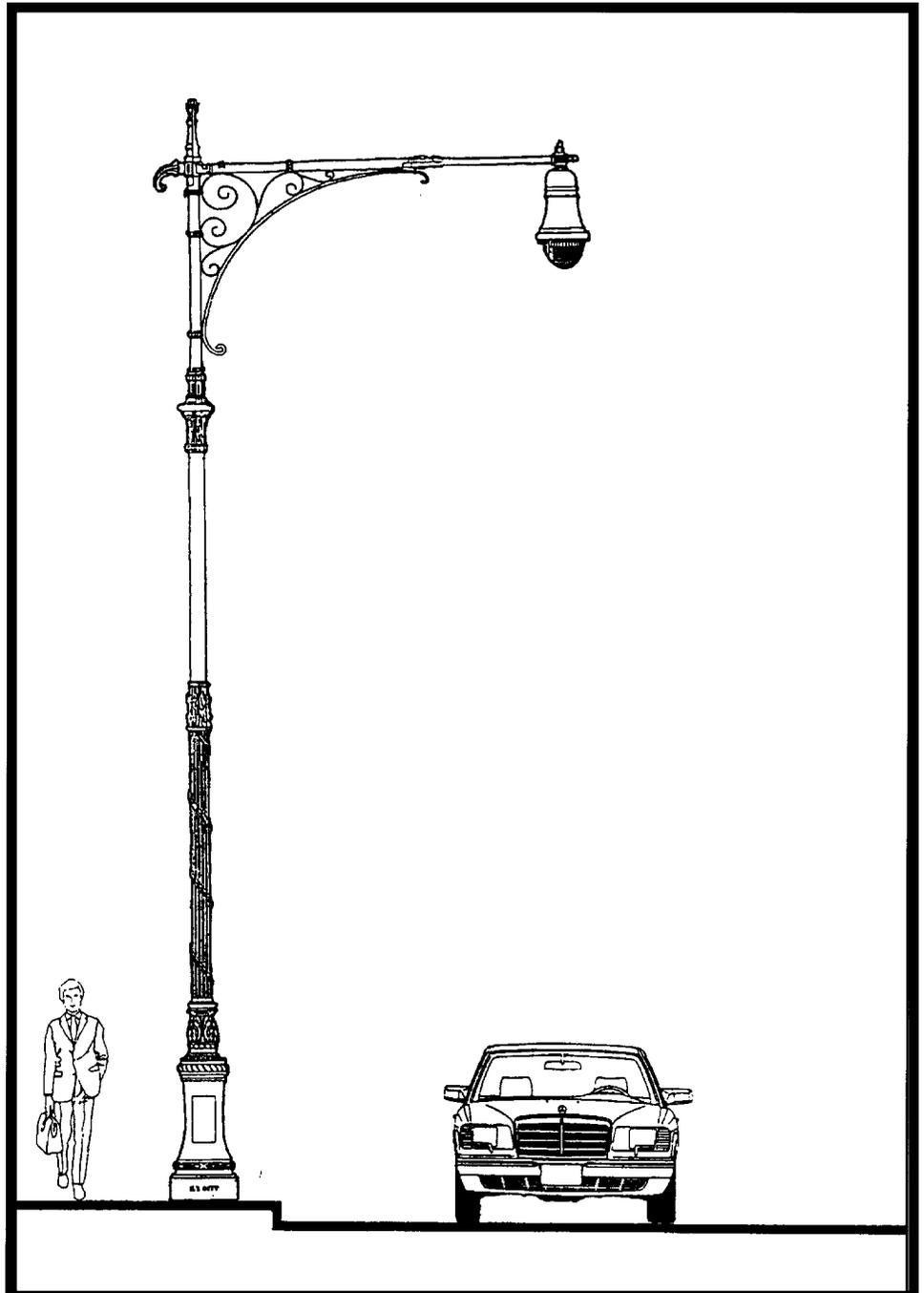
Separation of Pedestrian and Bicycle Traffic

In this part of Manhattan, as in many urban areas, there are significant conflicts between pedestrians and bicyclists. A design element incorporated to alleviate this conflict along the river side of the boulevard is the provision of a separate 4.9-m-wide (16-ft) bikeway for use by bicyclists and roller-bladers (both recreational and commuter) and a parallel 4.6-m-wide (15-ft) pedestrian pathway-promenade.

The Street Light Design Issue

As the design concept moved into the formal preliminary and final design phases, a major issue that was successfully resolved concerned the design of the street lights along the project. The design of the standard New York State Department of Transportation (NYSDOT)/city of New York steel street light pole was deemed by community representatives to be out of keeping with the overall urban boulevard concept.

After some additional research, it was discovered that the light poles that were being used in the privately developed Battery Park West (a mixed-use office/retail/residential development) were replicas of a design originally found throughout the city of New York in the early part of this century. This replica design is being incorporated along the length of the project.



Unique street light design enhances aesthetics.

Other Notable Design Elements

No formal design exceptions were requested for this project by the New York State DOT. All the design elements are within AASHTO allowable ranges. Some of the special elements that have been incorporated into the final design of the project include the following:

- Compatibility with the Hudson River Park Conservancy in terms of paving materials, dimensions of paving and planting strips, plant materials, and other elements.
- Reuse of existing granite paving blocks found along the waterfront area as edge treatments between the separate bicycle and pedestrian paths.
- Use of mixed plant materials (grass, shrubs, and trees) in the median area, as opposed to use of all trees or all grass, to better reflect the character of the adjacent land uses along each segment of the highway.

LESSONS LEARNED

This project has the potential for widespread application across the Nation as an illustration of the manner in which a collaborative, multidisciplinary planning and design process, incorporating a high level of continuous public involvement, can result in the creation of a world-class street design.

It also illustrates how detailed investigations of travel demand and traffic movement patterns can result in a dramatic change in the scale of the proposed improvement, from a six- to eight-lane elevated urban freeway to a six-lane urban boulevard with a design speed of 65 kph (40 mph).

STATE ROUTE 9A AT A GLANCE

Setting: Midtown Manhattan, New York, NY

Length: 8.2 km (5.1 miles)

Traffic Volume: At 59th Street - northern project limits
3,600 vehicles per hour
(1988 AM peak hour, peak direction)
3,750 vehicles per hour
(1998 AM peak hour, peak direction)
3,900 vehicles per hour
(2018 AM peak hour, peak direction)

Design Speed: 65 kph (40 mph)

Type of Road: 6- to 8-lane, median-divided urban principal arterial street

Design Cost: \$18 million (1994 estimate)

Construction Cost: \$380 million (1994 estimate), including engineering design, construction supervision, right-of-way, and inflation

Key Design Features: Use of lowered design speed to mitigate right-of-way impact and to reflect urban character of surrounding development; use of high barrier curbs along both sides of center-landscaped median and along roadway edge with riverside linear park; treatment of pedestrian crossing areas; provision of separate pathways for bicyclists and pedestrians

Debits: None reported

Similar Projects: West Main Street, Westminster, MD
Carson Street, Torrance, CA

Contacts for: Mr. Douglas A. Curry, P.E.
Additional Information: Director, Route 9A Reconstruction Project

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New York State DOT
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Streetscape improvements include sidewalks, walls, and landscape.



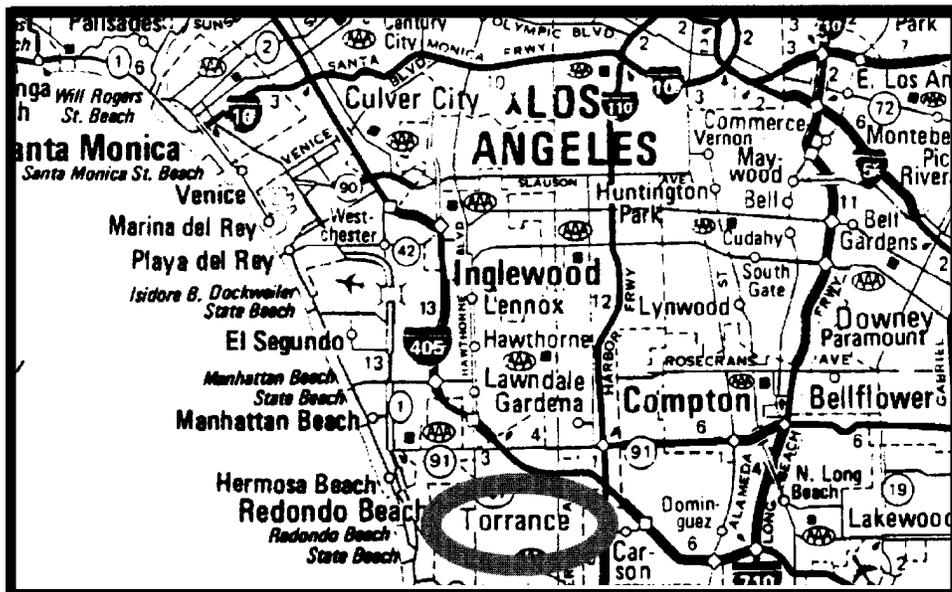
CARSON STREET RECONSTRUCTION

City of Torrance, CA

BACKGROUND/PURPOSE

Carson Street is a major east-west arterial street running through the middle of the city of Torrance. Torrance is located near Los Angeles in southern California. This reconstruction project was 1.66 km (1.03 miles) long, and its limits are Madrona Avenue to the west and Crenshaw Avenue to the east.

The street is predominately residential in character; 75 percent of the frontage is single-family homes and the remainder is multifamily garden-style apartments. Some commercial developments are located at the intersection of Carson Street and Crenshaw Avenue and in the vicinity of the Del Amo Fashion Mall, near the intersection of Carson Street and Madrona Avenue.



City of Torrance, CA.

Location site map.

Improve Traffic Flow Along Corridor

A driving issue behind the project was to relieve congestion and increase roadway capacity to improve traffic flow to and from the expanding Del Amo Fashion Mall area, which has over 18.6 ha (2.0 million ft²) of retail commercial activity. The 1988 base-year average daily traffic (ADT) volume was 28,000, which was anticipated to increase to 31,000 by 1992. As a result of the recession experienced in the region during the late 1980's and early 1990's, the projected volume increases did not occur. The current (1995) ADT is at about the preconstruction level of 28,000 vehicles per day.

Improve Safety Conditions

High levels of traffic congestion on the original four-lane undivided cross sections and the absence of left-turn lanes were responsible for a high rate of accidents, primarily rear-end collisions. Travel speeds at about 10 mph above the posted 56.5kph (35-mph) limit and poor pavement conditions contributed to further safety concerns.

General Improvements to Street and Streetscape

Before the project, the street had no curb, gutter, or sidewalks and residential access was over dirt or gravel driveways. The street had little landscape material or aesthetic features. Utilities, such as electrical power, cable TV, and telephone, were all on overhead lines.

ENVIRONMENTAL AND DESIGN ISSUES AND CONSTRAINTS

Moving utilities underground was a major consideration of the project. The estimated cost for relocating utility lines underground, including power (Southern California Edison), cable TV (Paragon Cable Television), and telephone (Pacific Bell), was \$2.3 million, which raised the issue of funding. Another major design issue was the maintenance and improvement of existing residential driveways. Little or no driveway consolidation was desired. The presence of residential development along both sides of the roadway precluded consideration of any significant right-of-way acquisition.



Typical five-lane urban cross section.

ACTIONS TAKEN TO RESOLVE ISSUES AND CONSTRAINTS

Capacity and Safety Improvements

To improve roadway capacity and safety, a five-lane urban cross section with a two-way median left-turn lane was implemented. A seven-lane section was used at the west end of the project, where there was an existing five-lane section with curb parking. The new pavement was composed of 150 mm (6 in) of asphalt concrete pavement on top of 180 mm (7 in) of Class A base material. The preproject ADT was about 28,000 to 29,000. The proposed pavement was designed to accommodate an ADT of 30,000 with 1 to 2 percent trucks.



Plant materials and retaining wall.

General Street Improvements

Curb, gutter, and sidewalks were added along both sides of the entire project to provide improved roadway drainage and to accommodate pedestrians and bicyclists. Driveway consolidation was held to a minimum, and access was maintained by adjusting curb lines to hold a distance of 5.5 m to 6.1 m (18 ft to 20 ft) between the curb edge and garage doors.



Concrete interlocking pavers at bus stop.

Improvement to the general aesthetics of the street was a major distinguishing feature of the project. Flowering plants, shrubs, and ground cover were placed at the west end of the project on a thin median between the main street and a north side service road. Turf and eucalyptus trees were planted along the entire project in the space between the back of the curb and the new sidewalk. Concrete interlocking pavers were placed in these strips at the end-of-block locations. An underground irrigation system was installed in landscaped areas with pipes running toward adjacent properties. Landowners were asked to connect to these pipes and maintain the green spaces in front of their homes. Approximately 75 percent of the landowners complied.

Utility Undergrounding

Another major aesthetic improvement was the relocation of all the overhead power, cable TV, and telephone lines underground. The \$2.3 million price tag for this project element was paid for through the application of set-asides mandated by the State Public Utility Commission (PUC). These set-asides are collected by the public utilities in the region as part of their basic rate structure plans and made available by the PUC to such cities as Torrance for major improvement projects. Work from the edge of public right-of-way to electric meters on adjacent properties was paid for by the city of Torrance. The meter connections at individual houses were paid for by landowners at an average cost of \$150 to \$500 per unit, depending on site requirements.

Public Involvement

An extensive public involvement program was conducted throughout the entire project. Several meetings were held with both the general public and individual homeowners and businesses. Some of these meetings were held during the concept development phase of the project. The project had support from homeowners, businesses, and the city council. Almost everyone wanted the proposed improvements, but some residents were concerned with specific property issues. Such issues as accidents, congestion, noise, and traffic speed were raised by citizens early in the project. During construction, mailings and hand-delivered notices were distributed to keep the public informed of changes in traffic patterns and other milestones.

Design Exception

General urban street standards prescribed by the AASHTO Green Book and the MUTCD were used on this project. The only formal design exception associated with the project was the use of a 10.1-m-wide (33-ft) travelway for midblock U-turn movements, as opposed to the Caltrans 17.7-m (45-ft) standard.

Project Timeline

This project was conceptualized in the late 1970's. Underground Utility District #12 was established in October 1987. Utility undergrounding work was completed and overhead wires and poles were removed in January 1991. Roadway and drainage design was completed and the project was advertised for construction in March 1991. The project was awarded to Sully/Miller Construction for \$2.5 million in April 1991 and construction began in July 1991.

In order to accommodate access to the Del Amo Fashion Mall during the 1991 holiday shopping season, a temporary four-lane undivided roadway using one side of the ultimate project was constructed and opened to traffic from November 1991 through mid-January 1992. The whole project was completed and open to traffic in October 1992. The total cost of the Carson Street improvement project was \$6.2 million, including \$2.3 million for utility undergrounding and \$1.0 million for right-of-way acquisition.

LESSONS LEARNED

This was the largest single street improvement project undertaken in the city of Torrance in the last 20 years. An early and extensive public involvement program aided this project and its acceptance by the community. The program was considered very effective in minimizing public opposition and concern. Issues raised by the public, such as congestion, safety, and noise, were substantially alleviated. Noise levels have dropped since the completion of the project, which serves the pre-construction level of ADT. The drop in noise level is attributed to better pavement conditions and less traffic congestion (particularly, less starting and stopping, especially by trucks).

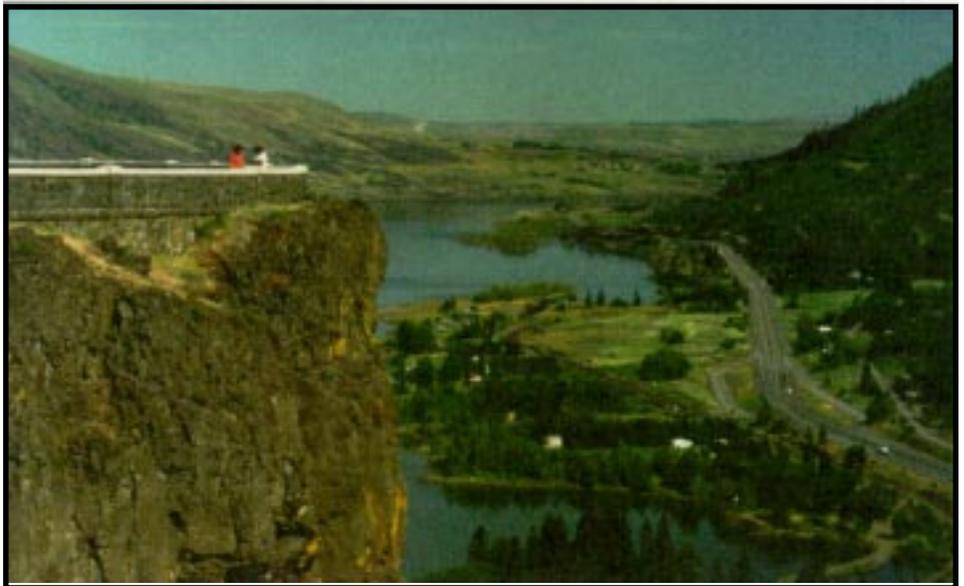
Following its completion, the project received an award for highway engineering design excellence from the California DOT in 1993 and was nominated for an FHWA Biennial Highway Design Excellence Award in 1994. Since the completion of the project, many landowners along the street have made significant improvements to their properties. Conditions of many of the residences along the corridor had deteriorated during the years before construction. Since the project's completion, some older homes have been demolished and replaced with newer structures. In general, the project had a very positive impact on the corridor and the community.

CARSON STREET RECONSTRUCTION AT A GLANCE

Setting:	Southern California; urban/suburban, primarily residential with some commercial areas
Length:	1.66 km (1.03 miles)
Traffic Volume:	28,000 ADT (1995 count)
Design Speed:	56 kph (35 mph)
Type of Road:	Urban major arterial; seven- or five-lane cross section with two-way median left-turn lane
Design Cost:	Some design was done in-house, but the majority was done by ASL Consulting Engineers for a total fee of \$253,000
Construction Cost:	\$6.2 million (including \$2.3 million for utility undergrounding, and \$1.0 million for right-of-way acquisition)
Key Design Features:	Use of concrete interlocking pavers, extensive plant material, and utility undergrounding in an effort to improve general aesthetics
Debts:	Incomplete participation by adjacent landowners with landscape maintenance
Similar Projects:	Lincoln Beach Parkway, Lincoln County, OR One-Way Couplet, Carbondale, IL West Broad Street, Falls Church, VA
Contacts for Additional Information:	Mr. Brooks Bell, P.E. Senior Division Engineer City of Torrance Engineering Department 3031 Torrance Boulevard Torrance, CA 90509-2970 Tel: 213-618-2820

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The Columbia River Gorge.

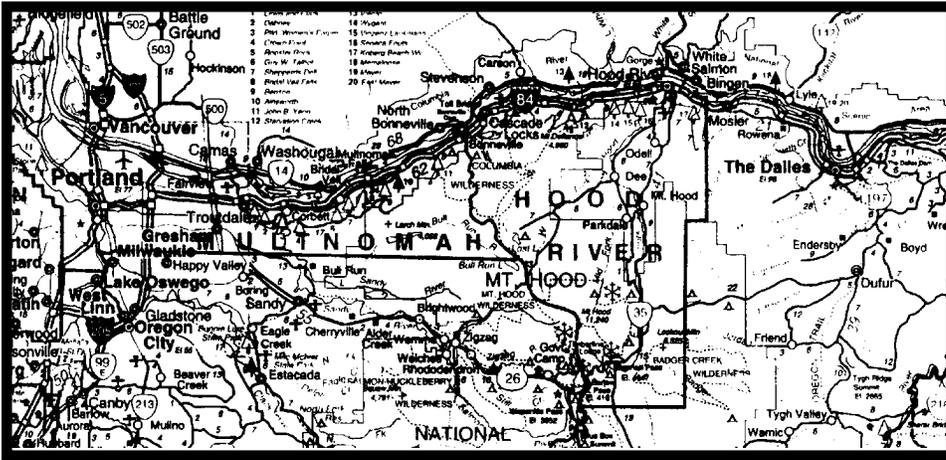


HISTORIC COLUMBIA RIVER HIGHWAY

Multnomah, Hood River, and Wasco Counties, OR

BACKGROUND/PURPOSE

When the 121-km-long (75-mile) Columbia River Highway between Troutdale and The Danes was officially completed on June 27, 1922, it was hailed as one of the engineering marvels of its age. The first paved highway in the Northwestern United States, the Columbia River Highway was conceived, designed, and constructed as both a scenic attraction and as a means of facilitating economic development along the Columbia River corridor between the Pacific Ocean and the areas to the east of the Cascade Mountains. It was heralded as one of the greatest engineering feats of its day, not only for its technological accomplishments but also for its sensitivity to one of the most dramatic and diverse landscapes on the North American Continent.

Multnomah, Hood River,
and Wasco Counties, OR.

Location site map

The history of the development, decline, and continuing rebirth of the Columbia River Highway is particularly instructive to the highway engineering community as we approach the beginning of a new century and a future of increasing reliance on the rehabilitation and restoration of existing infrastructure instead of the construction of new highways. This study also illustrates the manner in which state and local governments can preserve and enhance existing highways that possess unique scenic and historic qualities within the framework of modern design criteria. Much of the discussion of the background and history of the highway has been excerpted from the Historic Preservation League of Oregon's publication *Oregon Routes of Exploration-Discover the Historic Columbia River Highway* and *A Traveler's Guide to the Historic Columbia River Highway*.

Creation of the Columbia River Highway

Samuel C. Lancaster was the designer of the Columbia River Highway. His romantic and deeply spiritual attitudes toward the environment and mankind's relationship to nature framed subsequent discussions of the Historic Columbia River Highway for all time. Looking back from the vantage point of 80 years after its dedication, one cannot help but marvel at how well Sam Lancaster accomplished his task. Highway building in the United States was in its infancy. The automobile had not yet become the dominant mode of transportation that it is today. The human foot, the horse and wagon, the riverboat, and the railroads were the means of popular transportation. Travel conditions before the highway was built were grim. What roads existed were crude and unstable dirt wagon trails. Pioneers trying to get to the Willamette Valley from The Dalles during the early 1800's had essentially three choices: (1) build a raft and risk the dangers of the rapids near Cascade Locks, (2) pick their way along the Columbia River Gorge, where they encountered mudflows, rockslides, canyons, and sheer rock walls, or (3) follow the Barlow Trail over the southern flank of Mt. Hood. Each of these routes was hazardous and slow.

By the late 1800's, steamboats and railroads served some locations along the Columbia Gorge, but a good road was needed for general traffic. Early roadbuilding efforts, such as the Wagon Road from the Sandy River to The Danes of the 1870's, were largely unsuccessful. Serious attention to building a road through the Columbia Gorge grew with the advent of the automobile. In 1908, Samuel C. Hill, often referred to as the "Father of the Columbia River Highway" and a Good Roads Advocate in Washington and Oregon, invited Sam Lancaster, already known for his pioneering road-building efforts in Tennessee, to the Pacific Northwest to share in Hill's vision of creating a highway through the Columbia Gorge. In 1908, Hill, Lancaster, and Major H.L. Bowlby (who was soon to become the Oregon State Highway Department's first State Highway Engineer) traveled to Europe to attend the First International Roads Conference. They traveled extensively in Germany, Italy, and Switzerland to view and study European road-building techniques and designs



Typical overlook area along the highway.



One of the many waterfalls along the route.

The Vision Becomes a Reality

Upon their return from Europe, Hill and Lancaster began designing and building a prototype paved road system on the grounds of Hill's 28.3-km (7,000-acre) estate at Maryhill, WA. In February 1913, the Oregon State Legislature viewed the results of this effort and went away sufficiently impressed to create the Oregon State Highway Department and Commission the next month. Major H.L. Bowlby was subsequently appointed the first State Highway Engineer; later Sam Lancaster was named Assistant State Highway Engineer and Charles Purcell was named State Bridge Engineer.

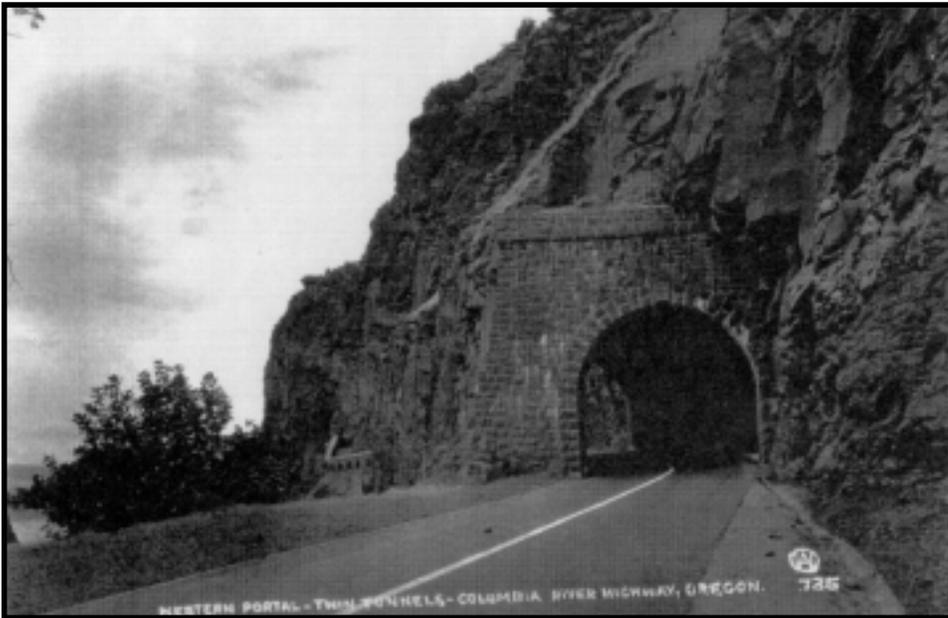
On August 27, 1913, the Multnomah County Commissioners met with Hill and the backers of the highway project at the Chanticleer Inn overlooking the western end of the Gorge. The next day, Sam Lancaster, attending as a guest of Hill's, was appointed Multnomah County Engineer for the highway. (One year later the Columbia River Highway was designated a State highway, setting the stage for future State involvement.) Lancaster went to work immediately, beginning the survey and route location from Chanticleer Point to Multnomah Falls in September 1913.



Typical curvilinear alignment

From the very beginning, this was to be both a scenic and a modern highway. The challenging requirements set by Lancaster were to locate the road in such a way that it would be at least 7.3 m (24 ft) wide, have grades no steeper than 5 percent, and have curve radii no less than 30.5 m (100 ft). At the same time, the roadway was to be located so as to provide maximum scenic opportunities, yet do as little damage to the natural environment as possible. Amazingly, Lancaster was able to achieve all these goals, even over the first segment of the highway, which required accomplishing an elevation change of nearly 183 m (600 ft) in a distance of less than 1.6 km (1 mile).

The construction of the highway incorporated a number of features then found only in Europe such as miles of dry masonry walls (built by Italian stone masons) and rock rubble guard walls with arched openings. At Mitchell Point, John Elliott, the location engineer who worked with Lancaster on the eastern segment of the highway, exceeded the achievements of the legendary Axenstrasse around Lake Lucerne, Switzerland. Elliott directed the construction of a tunnel bored through solid rock into which were cut five openings instead of the three on the Axenstrasse, to allow travelers to view the magnificent scenery. An original design element was the construction of stone observation areas with benches for weary travelers. Extensive use was made of the then new construction material reinforced concrete for bridges and viaducts, over the length of the highway. Many of these structures are still in use today.



Early days of the Columbia River Highway.

The highway, although only partially paved, was officially opened on July 6, 1915, between Portland and Hood River. Paving began in June 1915, making the Columbia River Highway the first major paved road in the Northwest. On June 7, 1916, the highway was officially dedicated with ceremonies at Crown Point and Multnomah Falls. At 5:00 p.m. that day, President Woodrow Wilson touched a button in the White House that “electronically unfurled the flag of freedom to the breezes” at Crown Point.

Construction continued eastward from Hood River along the alignment established by John Elliot in 1915 to The Dalles. This final section of the highway included two tunnels bored through the bluffs near Mosier. Finally, on June 27, 1922, Simon Benson, who was an ardent supporter and benefactor of the project, ceremoniously spread pavement mixture on the final segment at Rowena Point near The Dalles. After almost 9 years of work on the Columbia River Gorge Highway, the final segment linking Astoria to The Dalles was complete. From The Dalles to Troutdale, workers had built an amazing 119 km (73.8 miles) of roadway, including 3 tunnels, 18 bridges (some of world-class quality for their time), 7 viaducts, and 2 footbridges.

Early Economic Benefits of the Highway

The Columbia River Highway proved to be much more than just an engineering marvel and a scenic attraction. It stimulated tremendous economic growth in every community it touched. Restaurants served up salmon and chicken dinners to hungry travelers. Automobile dealers and service stations sprang up to fix tires and replenish fuel. Before long, motor parks, auto camps, and the grand Columbia Gorge Hotel in Hood River made it possible for travelers to experience a variety of overnight accommodations. Retail stores flourished in the towns along the route, and summer homes appeared on the forested slopes above the river and the highway.

Decline and Disuse

Within a decade after its completion, technological advances in transportation began to make the Columbia River Highway obsolete. Trucks and cars became larger and faster, making travel on the narrow, winding roadbed increasingly difficult and dangerous. By 1931, plans were underway to make another road, but this one would be straighter and closer to river level. Public enthusiasm for this replacement highway was tempered by a lack of funds and, aside from a new tunnel constructed through Tooth Rock near Bonneville Dam in 1935, little more was done. Nevertheless, interest in the new highway remained high, and a portion of it was constructed from Troutdale to Dodson in the summer of 1949.

By 1954, the new “water-level” freeway (originally designated as U.S. Route 30 but now I-84) finally reached The Dalles, but not without significant damage to the original Columbia River Highway. Nearly 4.2 km (26 miles) of the old road between Dodson and Hood River had been either destroyed or abandoned. In 1966, the world-famous Mitchell Tunnel was dynamited to allow for the completion of the adjacent section of I-84. Many of the original bridges, stone guardrails, and observatories fell into disrepair. Towns and businesses bypassed by the freeway suffered declines as new economic opportunities were created at the freeway interchanges.

The only segments of the original route that remained usable were the sections from Mosier to The Dalles and from Dodson to Troutdale. The Historic Columbia River Highway began to deteriorate badly.

Renewal and Rebirth

Fortunately, the 1980’s marked the reversal of this trend. Heightened environmental awareness led to the creation of the Friends of the Gorge, which spearheaded the successful effort to create the Columbia River Gorge National Scenic Area. The preservation and interpretation of the historic highway is specifically mandated in the Federal enabling legislation, which also created the Bistate Columbia River Gorge Commission.

A parallel historic preservation movement led to a survey and inventory of the historic highway by the National Park Service. In 1983, the Oregon DOT successfully nominated the surviving sections of the Historic Columbia River Highway to the National Register of Historic Places. The Historic Preservation League of Oregon led the successful effort to create the Historic Columbia River Highway Advisory Committee to monitor changes, alterations, and improvements to the highway.

Early days of the Columbia River Highway.



After restoration.

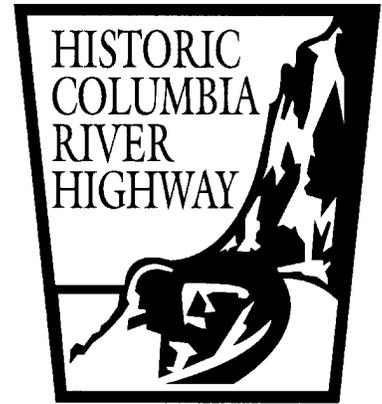


Signs of the rebirth of the great road are everywhere. The Oregon DOT is doing an excellent job of rebuilding stone guardrails and concrete caps, recasting and installing delicate concrete arches along the viaducts, and signing the highway with an appropriate logo. The Highway Division of the Oregon DOT is also in the process of developing a long-term master plan for the restoration and reuse of the highway. The Friends of Vista House, in cooperation with the Oregon State Parks and Recreation Department, have restored the Vista House as an interpretive center. Today, millions of visitors each year drive, hike, and bicycle along portions of the highway.

ENVIRONMENTAL AND DESIGN ISSUES AND CONSTRAINTS

Perhaps the single most distinguishing feature of the ongoing efforts to rehabilitate the Historic Columbia River Highway is that the designs are intended to replicate the original configuration of the facility as it existed at the time of its completion in 1922. This is analogous to the historic preservation process applied to buildings to return them to their original conditions. Current Oregon DOT plans call for the restoration of as much as possible of the entire 119 km (74 miles) from Troutdale to The Dalles as either a scenic highway or a hiker/biker trail.

The location of the highway in a National Scenic Area prevents the construction of any projects that would have an adverse impact on the defined historic resource, which in this instance is the highway itself.



ACTIONS TAKEN TO RESOLVE ISSUES

Crash-Tested Historic Guardrails

One of the more impressive ongoing restoration projects involves the replacement of existing steel guardrails installed over the past several decades with a “new” crash-tested two-beam timber guardrail backed by wood and steel that closely replicates the original 1915-vintage guardrail design, of which no sections remain today. The “new” guardrail has been crash tested at 80 kph (50 mph) and approved for use by the FHWA nationwide. Interestingly, evidence in the archives of the Oregon DOT indicates that the original 1915 guardrail design was adopted by the U.S. Bureau of Public Roads and several States in the 1920’s and 1930’s as the “standard” guardrail for use in similar rural environments.

Oregon DOT staff noted that, if current AASHTO guidelines were to be fully adhered to, the historically accurate replacement guardrail would need to be installed at many more locations than where it previously existed and it is currently being reinstalled.

Hiker/Biker Multiuse Design Elements

In places where it would not be economically feasible to recreate the historic road in its original location, a representative hiker/biker trail is planned for construction. In such areas as the now-closed Mosier Tunnels, which are too narrow to accommodate two travel lanes wide enough for modern vehicles, the rubble-filled tunnels will be rehabilitated to their original conditions and will provide access limited to bicycles and pedestrians. Wherever possible, the “new” sections of facility needed to accommodate the current “missing links” in the original 1920’s vintage alignment will utilize the same historical design criteria of maximum 5 percent grades and 30.5-m-minimum (100-ft) radius curves, although a slightly narrower pavement width may have to be provided in certain locations. The new hiker/biker trails are being designed in accordance with current ADA provisions in order to allow use of these facilities by individuals with disabilities.

Newly installed steel-backed wooden guardrail.

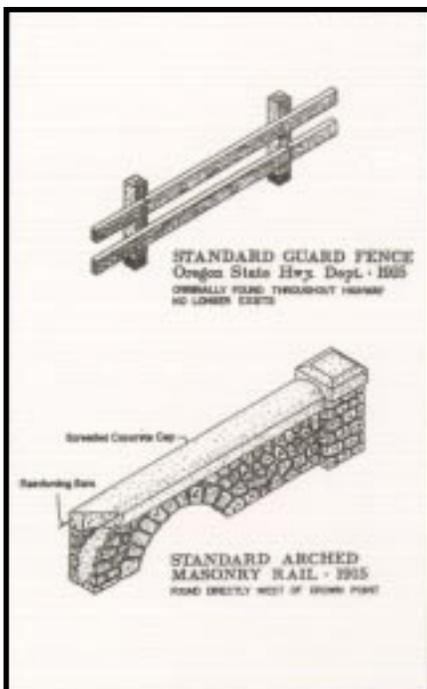


Aesthetic Considerations of Enhancement Projects

Throughout the design of the current enhancement/rehabilitation projects, Oregon DOT staff members have been particularly cognizant of the need to consider the aesthetic qualities of the Columbia River Gorge. An example of this concern is the manner in which the remediation of a continuing rock fall area was addressed as part of the rehabilitation project encompassing Tanners Creek to Eagle Creek. Because it was not possible to use Oregon DOT's standard steelcolumn-supported, metal rock-fall fencing, the decision was made to shift the roadway alignment slightly to provide a greater separation between the rock face and the edge of the travelway. The resulting lateral separation space is able to accommodate falling rocks.

Moreover, because virtually the entire length of the Historic Columbia River Highway is on the National Register of Historic Places and the highway is located in a designated National Scenic Area, no roadway widenings are permitted. The result is that the "new" roadways are identical in cross section to the existing highway.

In the Tanners Creek area, the planned improvements will involve the removal and relocation of existing overhead electrical utility lines and poles and the removal of some trees to reopen some of the historic vistas of the gorge. One issue to be addressed here is determining exactly which of the trees should be removed.



Cost Considerations of Historic Enhancement Projects

The costs of the ongoing rehabilitation and enhancement projects for the Historic Columbia River Highway are considerable. For example, the initial installation of 886 m (2,906 linear ft) of two-rail steel-backed timber guardrail had a total bid price of \$119,146 or about \$41.00 per linear ft (\$134.50 / m). If standard Oregon DOT steel guardrail had been installed, the estimated cost would have been approximately \$32,000 or about \$11.00/linear ft (\$36.09/m). The historically accurate timber guardrail costs about 3-1/2 times as much to install as traditional steel guardrail. Since the installation of the initial sections of the two-rail steelbacked timber guardrail in 1992, however, no maintenance of the guardrail has been necessary. It is anticipated that the guardrail will eventually need to be repainted about once every 5 years. The estimated cost of this activity (in 1994 dollars) is approximately \$3.20/linear ft (\$10.50/m).

Similarly, the requirement for the use of hand labor in association with the reconstruction of stone guard walls has resulted in substantially higher costs for this activity than if standard steel guardrails or concrete barrier walls had been installed. However, the Oregon DOT understands the need for an appropriate balance to be maintained between enhancement, maintenance, rehabilitation, and new construction projects and remains committed to the Historic Columbia River Highway projects.

LESSONS LEARNED

The experience of the Oregon DOT with the design and construction of improvements to the Historic Columbia River Highway has the potential for widespread application across much of the United States. In particular, many of the generally low-volume rural highways that have been, or are proposed to be, designated as “scenic highways” date from the general era of the original Columbia River Highway and thus share similar geometric constraints. Now that regional through traffic that once used these older highways has shifted to more modern parallel freeway routes, opportunities may exist for the enhancement and rehabilitation of these older routes to a configuration similar to that at the time of their original construction.

The existence of an FHWA-approved two-rail steel-backed timber guardrail that has been crash tested to 80 kph (50 mph) provides an alternative to the use of current steel guardrail designs, especially on those routes where the timber guardrail would help to provide a more aesthetically pleasing vista. Finally, the experience of the Oregon DOT with the construction and maintenance of such “nontraditional” roadway design features as timber guardrails and stone guard walls should prove to be of use to a number of other States facing similar requests from historic preservation groups.

*Young's Creek (Shepards Dell)
Bridge after restoration.*



*Spindle railing after restoration on
the Young's Creek Bridge.*



HISTORIC COLUMBIA RIVER HIGHWAY AT A GLANCE

Setting:	World-class designated National Scenic Area; rural highway passing through small communities.
Length:	Approximately 119 km (74 miles) (from Troutdale to The Dalles)
Traffic Volume:	Widely variable, from approximately 4,200 vehicles per day in most heavily traveled western sections (with peak summer weekend volumes of approximately 7,500 vehicles per day) to about 500 vehicles per day in the most lightly traveled eastern sections
Design Speed:	Not applicable; rehabilitation of existing historic roadway; estimated design speed of 56 to 73 kph (35 to 45 mph)
Type of Road:	Historic, scenic highway (owned and maintained by Oregon DOT); functional classification - collector
Design Cost:	Current enhancement/rehabilitation projects only— Not available (in-house by Oregon DOT staff)
Construction Costs:	Current enhancement/rehabilitation projects only— \$120,000 for initial installation of 886 m (2,906 linear ft) two-rail steel-backed timber guardrail; \$35,000 for initial rock guard wall reconstruction; other projects totaling approximately \$4.0 million are planned for the next 3 to 5 years
Key Design Features:	Restoration/rehabilitation of existing historic highway to original condition at time of completion in 1922; installation of two-rail steel-backed timber guardrail very similar in design to original; reconstruction of rock guard walls; reconstruction of original concrete bridges
Debits:	Design limits operating speeds to 48 to 65 kph (30 to 40 mph) in most areas
Similar Projects:	Paris-Lexington Road, KY Oyster River Bridge, Durham, NH SR 89, Emerald Bay, Lake Tahoe, CA SR 92, Lebanon Road, New Castle County, DE

(Continued on next page)

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*View from top of slope
beyond to Lake Tahoe*



STATE ROUTE 89-EMERALD BAY SOUTH LAKE TAHOE

El Dorado County, CA

BACKGROUND/PURPOSE

This project is located on the east side of the Sierra Nevada mountain range in northwestern California very close to the Nevada State line. Construction involved a 1.1-km (.7-mile) stretch of State Route 89 along Emerald Bay near Cascade Lake and Eagle Falls on the southwestern shore of Lake Tahoe.

The purpose of this project was to upgrade a stretch of the existing narrow two-lane section of Route 89 to a more modern two-lane cross section. The primary goal of the proposed design was to address slope stabilization and erosion control issues to reduce rock slides that frequently closed this section of the highway,

which is the only all-weather route around the west side of Lake Tahoe. Secondary goals of the project were to improve safety, enhance roadway drainage, and minimize potential negative impact on the water quality of Lake Tahoe.

This portion of Route 89 was originally constructed in 1930-31 to provide a link along the west side of Lake Tahoe between the two major east-west routes in the region: State Route 70 on the north and U.S. Route 50 on the south. With the construction methods available at that time, the road closely followed the lay of the land, following ridge lines and older wagon trails along the edge of the lake. This resulted in a number of very dramatic vistas from the route, particularly in the area around Emerald Bay.



Typical area along highway that is subject to rock slides.

ENVIRONMENTAL AND DESIGN ISSUES AND CONSTRAINTS

The physical location of the project, combined with the climatic conditions of the region, presented a number of unusual issues and constraints that had to be addressed during the design and construction phases of the improvement.

Unstable Geology

The area adjacent to the western side of Lake Tahoe is subject to relatively frequent earthquake-induced landslides and rock falls. The basic geological structure of the area is fractured granite with steep slopes and little ground cover. Indeed, the primary rationale for the project was the desire to alleviate continuing slope instability problems.

Typical area along highway that is subject to rock slides.



Limited Construction Season

This section of State Route 89 is closed during the winter months (typically from mid-November through the end of February) because of continuing major snowfall accumulations that make plowing impractical. Moreover, with several sections of the route lacking shoulders or guardrails, allowing motorists to use the facility, even if adequate snow removal could be provided, would not be advisable. The route is, however, subject to heavy tourist use in the summer and early fall months, and a significant percentage of the traffic is motor homes and buses. These factors combined to limit the available construction period to the spring and late fall months of the year. Additional time constraint problems arose, because the road had to be totally closed for a period of approximately 6 weeks for blasting, boulder removal, and major earthwork.

The Tahoe Regional Planning Agency

A major issue associated with the project was the requirement to maintain the unique visual characteristics of the project area. This task is, in part, the responsibility of the Tahoe Regional Planning Agency (TRPA), a congressionally mandated bistate (Nevada/California) agency that is organized to maintain and enhance the scenic and aesthetic qualities of the Lake Tahoe region.

Some areas within the project limits were identified as TRPA Stream Environment Zones that drained directly into Lake Tahoe. About 0.09 ha (.22 acres) of these zones would be disturbed during the project.

ACTIONS TAKEN TO RESOLVE ISSUES

Roadway Design Elements

In order to relieve the rock slide problems that had necessitated the project, the back slope angles were reduced and a number of the largest granite boulders were removed. Slope netting was used in some locations to provide stability until vegetation could be established. Double-thickness retaining walls, terraced rock catchment walls, and trenches were used over the length of the project to provide additional protection areas between the problem slopes and the improved roadway.

In locations with the most significant rock slide potential, side-hill viaduct roadway sections were constructed to carry one lane of traffic and a narrow shoulder. The use of these viaducts essentially shifted the horizontal alinement of the travelway by a distance of one travel lane eastward toward the lake shore and away from the problem slopes. The final “as-built” section includes two 3.6m (12-ft) travel lanes and two 0.6-m (2-ft) shoulders.

The only design exception required was for allowance of the 0.6-m-wide (2-ft) shoulders. FHWA and AASHTO generally consider a 1.2-m-wide (4-ft) shoulder as the minimum acceptable width for a two-lane major collector/minor arterial roadway, such as this portion of State Route 89.

The high level of water quality in Lake Tahoe (estimated to be in excess of 99.5 percent pure water) was ensured by implementing slope stabilization measures along Route 89 in the project area. These measures reduced the occurrence of rock slides, thus reducing the potential of debris entering the lake. Roadway underdrains, as well as sand traps at culvert inlet locations, were used to further reduce the potential for sediment transport into Lake Tahoe. During the actual construction period, any groundwater that was encountered was diverted to on-site sediment basins before to release into the lake.

Safety along the route was improved with the addition of the two 0.6-m (2-ft) shoulders and the 3.6-m (12-ft) travel lanes. This resulted in a total travelway width of 8.5 m (28 ft), which was in context to the previous 6.7-m (22-ft) travelway that lacked any effective shoulder area. In an effort to achieve a 65 kph (40 mph) stopping sight distance and improve an existing “blind” curve, a compound curve with a radius of 152 m to 305 m (500 ft to 1,000 ft) was replaced with a single 457 m (1,500 ft).

Road Closure Disincentives

In order to keep the period of road closure to a minimum, the contractor was provided with an incentive/disincentive clause in the contract of \$50,000 per day. The contractor closed the road for 6 weeks starting May 1, 1992, and through the use of 24-hour construction during that time, earned a \$400,000 bonus. After the 6week period of total closure, alternating one-way traffic was used to keep the road open.

Construction on the project began on April 12, 1992, and was completed 18 months later. The bid was awarded for \$7.6 million, although the final construction cost rose to approximately \$9.2 million as a result of unforeseen difficulties with rock excavation and slope stabilization.

Aesthetic and Environmental Improvements

When the project was originally constructed in 1930-31, extensive use was made of stone masonry walls. Several sections of these walls needed to be replaced during the new project. In an effort to maintain the high level of aesthetic quality in the region, the new side-hill viaduct retaining walls were constructed with textured forms to replicate the surface of the original stone walls. The textured wall forms were constructed in 3.7-m by 3.7-m (12-ft by 12-ft) sections to minimize the number of splice locations. It is anticipated that some of the structures will eventually be hidden by vegetation.

The TRPA initially determined that the color selected for the textured wall forms of the side-hill viaduct retaining walls was too dark and needed to be lightened to better match the existing granite of the region. The original wall stones that were removed were reused to construct walls in a parking area at the Eagle Falls overlook area.

One of the more interesting changes made to the original Caltrans design was the replacement of the standard solid concrete lakeside parapet barrier with a more aesthetically pleasing two-beam guardrail mounted on a low concrete barrier. The new barrier design allows for a better view of the lake from both lanes of traffic and is essentially invisible from the lake and its shoreline.

Although the original barrier design proposed by Caltrans was the generally accepted statewide standard for such applications, it was considered to be unacceptable by the TRPA. The two-beam guardrail which was finally installed had been crash tested by FHWA some years earlier but had not, at the time of this project, been adopted by Caltrans as an acceptable guardrail type. Subsequent to this project, the two-beam guardrail design was accepted by Caltrans as a standard design, particularly in areas with similar aesthetic considerations.



View of finished project.

Some 1,800 trees and shrubs were planted between the terraced upper slope walls and behind the rock catchment walls to blend the slope stabilization treatment into the existing natural environment. The contractor maintained a 1-year plant establishment period, which was supplemented by a Caltrans care and replacement program for four growing seasons.

The 0.09 ha (.22 acres) of Stream Environment Zone that were disturbed by the project were revegetated with the same type of plant species. The species were identified on a joint field review by the Caltrans Resident Engineer and representatives from the United States Forest Service and the California Department of Parks and Recreation. Stream patterns within the Stream Environment Zone were not altered.

LESSONS LEARNED

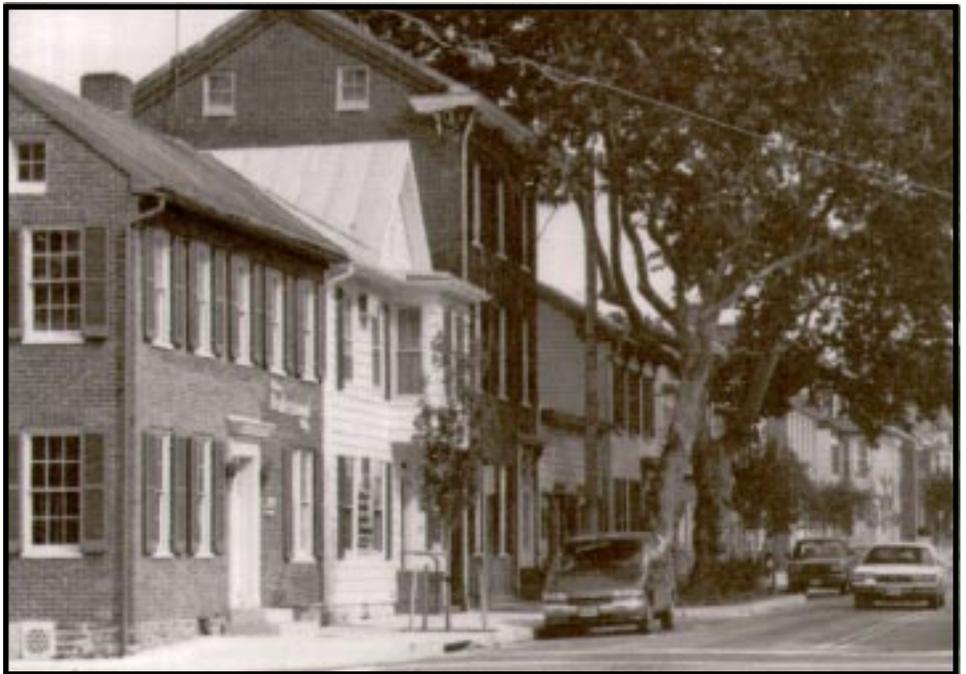
The Emerald Bay project is an example of a road improvement project with potential widespread applicability across the Nation. This is particularly true, because the work involved the reconstruction of an existing two-lane facility dating from the 1930's. The roadway is also located in an area where accommodating environmental and aesthetic considerations was viewed as a primary goal of the project, on an equal footing with improving traveler safety. The result was an improved road with a very scenic character. However, this result was achieved at a relatively high cost of \$9.2 million for 1.1 km (.7 miles) of roadway.

A somewhat nontraditional review agency, the TRPA, played a major role in defining the final design features of this project. During the project planning and design phase, it became clear that the TRPA was primarily concerned with the aesthetics of the improvement (both the view from the road and the view of the road) and not as much with such factors as cost or driver safety. The TRPA also required that a focused environmental impact statement be prepared to assess the potential impact on the scenery and water quality of this relatively modestscale project on Lake Tahoe. This is considerably beyond the normal NEPA requirements for projects of this scale and may establish a precedent for future Caltrans projects in the Lake Tahoe region. The project also required that a TRPA permit be issued before construction could proceed.

Caltrans staff noted that a high level of local agency and community input was received concerning the aesthetic qualities of the project and that the project was considered a "win-win" situation by all parties involved. Indeed, the final product was nominated for an FHWA Design Excellence Award in 1994.

STATE ROUTE 89 - EMERALD BAY AT A GLANCE

Setting:	Northwestern California; Lake Tahoe region of the Sierra Nevada Mountain Range
Length:	1.1 km (0.7 miles)
Traffic Volume:	Not available
Design Speed:	65 kph (40 mph)
Type of Road:	Two-lane rural highway; rural collector functional classification
Design Cost:	Not available; in-house design by Caltrans staff
Construction Cost:	\$9.18 million
Key Design Features:	Reduction of back slope angles; use of catchment walls, slope netting, and side-hill viaducts to reduce the adverse effects of rock slides; application of new (for California) two-beam guardrail to preserve views
Debits:	None
Similar Projects:	State Route 70 - Feather River Canyon, CA Hollister Bypass, SanBenito, CA SR 92 - Lebanon Church Road, DE Historic Columbia River Highway, OR
Contacts for Additional Information:	Mr. Alan P. Glen, P.E. Chief, Geometric Design and Standards Branch State and Local Project Development Program Office of Project Planning and Design California Department of Transportation 1120 "N" Street Mail: P.O. Box 942874 Sacramento, CA 94274-0001 Tel: 916-653-1776 Fax: 916)-654-5881



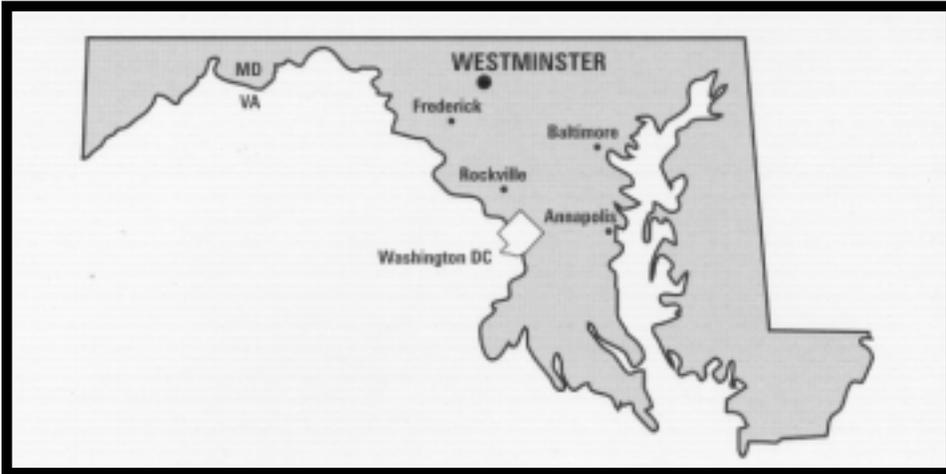
EAST MAIN STREET RECONSTRUCTION

Westminster, MD

BACKGROUND/PURPOSE

East Main Street has changed little since Jeb Stuart's cavalry pursued the 1st Delaware down its dusty way on June 29, 1863, in a prelude to Gettysburg.

Pavement has covered the dust, sidewalks have replaced boardwalks, and utility lines have taken the measure of the maturing trees. In 1990, Westminster had more than doubled its population, to 13,582. At the perimeters, shopping malls beckoned.



Location site map.

The very age that had made downtown Westminster a National Register Historic District was slowly eroding its attractions. Rains lingered in puddles, because there was no storm drainage. Countless repavings had raised the street's center, resulting in slanted parking spaces that caught car doors on curbs. Porches, stoops, and utility poles encroached onto narrow, cracked, and caved-in sidewalks. Vacant stores and office spaces attested to the decline.

After more than a year of planning and design, the Maryland State Highway Administration's consultants completed their drawings for East Main Street's revitalization in October 1990. In May 1991, the city had three new city council members, and the administration and public balked at a 12.2 m-wide (40-ft) roadway of two 3.6-m (12-ft) travel lanes and two 2.4-m (8-ft) parking lanes. That scheme would have removed 42 trees, some dating back to the last century. The old roadway was 10.4 m to 11.9 m (34 ft to 39 ft) wide. The new sidewalks would have an average width of 1.5 m (5 ft), as cramped as the old ones.



One of the existing trees along Main Street.

ACTIONS TAKEN TO RESOLVE ISSUES

In March 1991, the Maryland DOT appointed a 10-member committee to come up with ideas, and the State sent designers to help this task force realize their ideas. By December 1992, after numerous sessions and hearings, the new plan was complete. The State paid for the extra design work, which amounted to \$199,523. Construction began in April 1993 and, in December 1994, the 1.5-km-long (.93-mile) project was open to traffic.

The desire to avoid removing 42 trees had been foremost, thus the total pavement width was reduced from 12.2 m (40 ft) to 11.0 m to 11.6 m (36 ft to 38 ft). In addition, to give trees breathing room, sections of curbing were extended 1.8 m (6 ft) into the parking lane of the roadway. In all, 34 of the 42 mature trees were saved, and 104 trees were added. Metal grates around each tree space keep the soil porous. The city paid the \$36,000 planting and landscaping costs.

Sidewalks were widened from 1.5 m to 3.0 m (5 ft to 10 ft), and in some areas where there had been no sidewalks, there were now 1.2-m to 1.5-m (4 ft to 5 ft) walkways. There are 11 pedestrian-friendly areas with landscaping. Existing telephones and mailboxes remained. Concrete pavers that look like brick add variety to these areas and crosswalks; they also echo the brick of the many historic buildings. Concrete curbstone provides a continuity of texture.

Brick-like concrete pavers, textured pedestrian crossings, trees, and low plantings provide a park-like flavor. Metal tree grates keep soil soft and porous, enhancing growth.



Traffic lanes were reduced in width from 3.6 m (12 ft) to 3.4 m and 3.0 m (11 ft and 10 ft), and transportation staffers feel they could have been as narrow as 2.9 m (9.5 ft), because traffic moves slowly. Often, inches are crucial to tree growth. The speed limit is 40 kph (25 mph), designed for 48 kph (30 mph). Parking lanes remain 2.4 m (8 ft) wide, and each space is marked with a “T” to make more efficient use of the space available. The designated spaces make up for an 11-percent loss of parking space, the equivalent of 19 on-street spaces, used for existing and proposed tree planting. The original design, however, would have required the loss of 35 spaces, a 20-percent loss.



“T” markings clearly define each parking space.



An area of extended curbing interlocks-an extensive area of low plantings with concrete pavers shaped like brick

Important to Westminster's heritage, "street furniture," such as boot scrapers, hitching posts, and entranceways, was conserved. Archaeological digs during the construction phase unearthed a boundary marker, vault, coal chute, and well, items which can be preserved.

LESSONS LEARNED

Not all goals were accomplished. Utility lines did not go underground, because the cost would have been \$3 million plus added costs for new individual connections. Another route would have been the placement of utility lines aboveground, although in the rear of buildings. Utility poles are now fewer but lamer.

A trio of the 34 large trees saved, with some of the 104 new trees planted. A feeling of lush foliage permeates the street sides.



The cost of removing overhead utilities for 1.5 km (.93 miles) would have matched the \$3 million road reconstruction cost. Utility poles were moved to avoid tree canopies, and thus the trimming of limbs.



In all, the city and State learned that citizen involvement at the beginning saves time and that the dollar cost for improved design was \$199,523-in a project that totaled \$3,150,828. Realtors estimate that, because of the increased demand for downtown retail and office space, the added cost of the project will be made up in 4 years' revenues to the city. Current and future streetimprovement projects will involve residents and designers at initial stages and, as the construction takes place, flyers will tell people what is going to be done, when, and where.



A crosswalk's well-defined rectangle contrasts with circular pavement-level corners. At left, the sidewalk has been widened to meet the outer pedestrian walkway border.



Extended curbings take on a variety of patterns, here highlighting a projecting entrance bay and awning. Note how the concrete curbing and building border form continuous lines into the distance.

EAST MAIN STREET RECONSTRUCTION AT A GLANCE

Setting:	Historic downtown in a small city
Length:	1.5 km (.93 miles)
Daily Traffic Volume:	14,100 (1990); 15,000 (1996 est.); 22,000 (2010 est.) Trucks: 6%
Type of Road:	Urban collector
Design Cost:	\$199,523
Total Cost:	\$3,150,828
Key Design Features:	Staggered curbing, textured walkways, and pedestrian-friendly areas
Debit:	Utilities Above Ground
Similar Projects:	Carbondale, IL Frederick, MD West Memphis, AR Falls Church, VA
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*Reconstructed U.S. Route 101
shortly after project completion.*



U.S. ROUTE 101- LINCOLN BEACH PARKWAY

Lincoln County, OR

BACKGROUND/PURPOSE

What has come to be called the “Lincoln Beach Parkway” is, in reality, a section of the Oregon Coast Highway (U.S. Route 101). Construction of the highway began in 1919 to ensure military preparedness. At that time, it was called the Theodore Roosevelt Coast Military Highway. The current name was adopted in 1931.

Running adjacent to the Pacific Coast for nearly 565 km (50 miles), this route is one of the most scenic highways in the United States. Its elevation varies from near sea level to cliffs 305 m (1,000 ft) above the ocean. The road passes through a variety of urban, suburban, and rural landscapes.

Major Traffic Growth Expected

U.S. 101 serves local, regional, and tourist travel demands. Existing ADT volumes within the central coastal region through Lincoln County range from a low of approximately 5,000 vehicles per day at the southern county line to approximately 17,500 vehicles per day in the Lincoln City area. Year 2015 traffic projections forecast these volumes to increase to approximately 11,700 vehicles per day and 32,000 vehicles per day, respectively.

Improved Access vs. Community Impacts

A major conflict facing the entire Route 101 corridor is the need to provide better access to resort-oriented communities to enhance economic development opportunities while balancing the impact of capacity improvements. This issue was particularly acute in Lincoln Beach, a city of 10,000, where new residential and resort developments, and access to them, contributed to increased congestion levels and a high accident rate.

Initial Options

This project was initiated by the Oregon Department of Transportation (ODOT) at the request of the Lincoln County Commissioners in early 1989. Initially, only three actions were considered: (1) the do-nothing/no-build option of retaining the existing two-lane undivided roadway with no access control, (2) a three-lane cross section with a continuous two-way median left-turn lane, and (3) a five-lane cross section with a continuous two-way median left-turn lane. When these three options were presented to the local community at public meetings in connection with the environmental assessment process, each option received an equal amount of support and opposition. The result was that no consensus was reached on the appropriate action.



View of Pacific Ocean beyond.

In 1992, jurisdictions along the highway approved the concept of a Pacific Coast Scenic Parkway to “increase the aesthetic experience, assist in access control, and develop community identity.” These parkways were to deviate from typical ODOT design concepts by providing a raised center median and limited median breaks, while keeping direct access along both sides of the road.

Land Use Control: A Paramount Factor

An important point raised by the Lincoln County Council was the relationship of the project’s design features to the County’s Master Plan, which was designed to control strip development. The Lincoln Beach area is a lightly developed 3.2-km (2-mile) section of homes and small businesses that is in the path of urban growth.



Before improvements.

Parkway Concept Adopted

Following the initial ODOT presentations of the parkway design concept, in 1988, the Lincoln County Commissioners sponsored a second public information meeting. The meeting was well attended by corridor residents and local business owners. As a result, the County Commissioners formally requested that the parkway design concept be implemented.

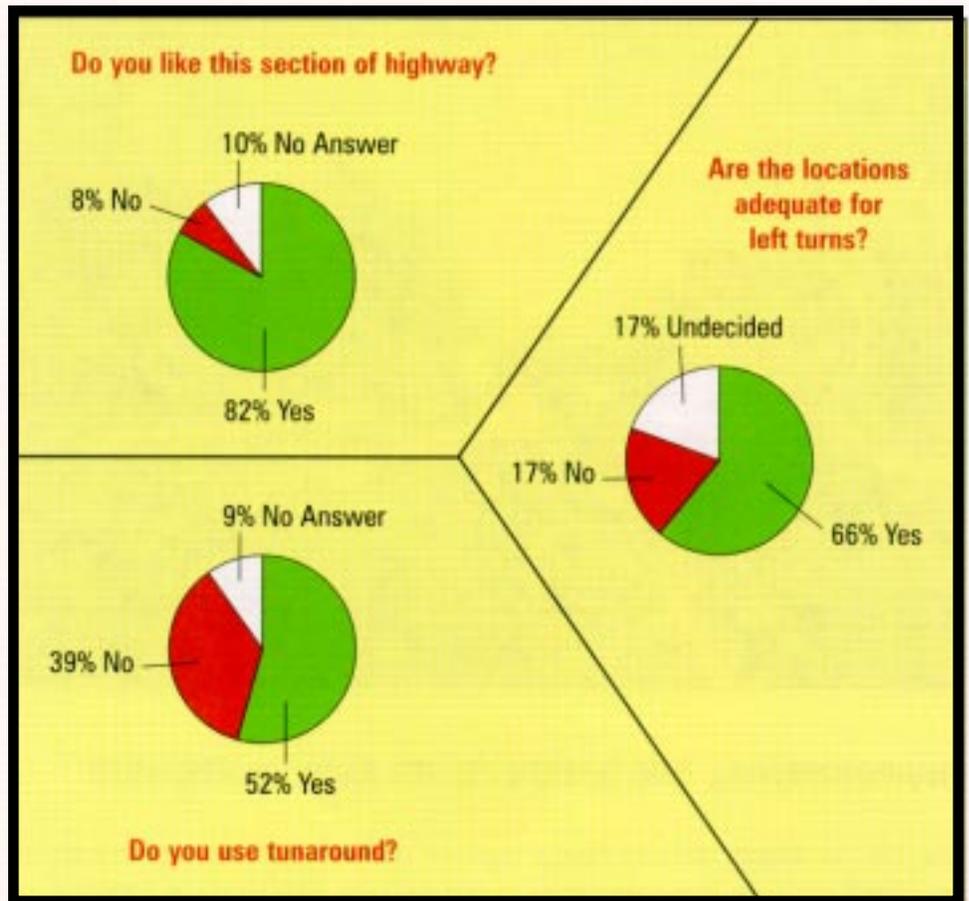
Design was initiated shortly thereafter by ODOT staff, with final plans completed in May 1990. Construction began in August 1990. Construction was complete and the 3.2-km (2-mile) section was opened to traffic in July 1992.

As finally constructed, the Lincoln Beach Parkway has a basic four-lane mediandivided cross section, with a curb-and-gutter closed drainage system and 1.2-m (4-ft) sidewalks along both sides. The cross section consists of two, 3.6-m (12ft) travel lanes on either side of a typical 4.3-m (14-ft) raised, landscaped median. To accommodate bicyclists, the pavement on either side of the median was originally designed to include a 0.6-m (2-ft) left shoulder and a 1.8-m to 2.4m (6-ft to 8-ft) right shoulder. However, the left shoulder is currently striped as 1.2 m (4 ft) wide and the right shoulder is typically 1.2 m to 1.8 m (4 ft to 6 ft) wide.



Widened paved shoulders were provided for bicyclists.

Motorist Survey
(1,535 Interviews)



Favorable Public Reaction

The reaction to the project by both local businesses and residents has been favorable, except for several of the business owners who complain about restricted access. Surveys of users of the facility conducted by Portland State University for ODOT should an 82 percent favorable rating by auto drivers and a 78 percent favorable rating by drivers of delivery and large trucks. Moreover, 77 percent of auto drivers and 79 percent of truck drivers expressed the view that the parkway is much safer than the previous two-lane highway. Recent accident records verify this attitude survey. The records show that the accident rate along this section of parkway has been halved and is lower than on other three-lane or five-lane sections of U.S. Route 101 that have similar traffic volumes and development density.



Turn lane improvements.

ENVIRONMENTAL AND DESIGN ISSUES AND CONSTRAINTS

The Lincoln Beach Parkway design required resolution of the types of issues associated with the implementation of any highway improvement project in a developing suburban area. Residences and businesses with direct access from both directions along the old two-lane highway now have access from only one side of a four-lane divided highway. At one point, a concrete soundwall was built to reduce the noise impact on residents of a trailer park, but the barrier also partially obscures the view of the entrance to a craft shop.

ACTIONS TAKEN TO RESOLVE ISSUES

Access Controls

A complex issue addressed during design was the manner in which to ensure adequate access to adjacent properties. Where possible, median breaks were provided at existing public street intersections and these streets were repaved or reconstructed. In a few instances, closely spaced streets were consolidated into a single crossing point through the use of short sections of parallel connector street. The design of median breaks was tailored to allow for easy movement by oversize recreational vehicles and tour buses.

Emergency Vehicle Access

At street intersections where a median break could not be safely provided, special access-crossing concrete pavers were installed in the landscaped median to allow for fire and emergency vehicles to reach the areas. Raised pavement markers along the mountable median curb identify these locations.

Special Turnaround Design

In recognition of the large number of recreational vehicles and tour buses using the Route 101 corridor during the summer peak season, special turnarounds designed to accommodate full-size buses were provided at the center and at both the northern and southern ends of this project.

Postal Service Provisions

An unanticipated benefit of the median construction resulted from the installation of mailboxes on both sides of the highway. Previously, all mailboxes were located on the northbound or east side of the two-lane highway. Residents are now able to walk or bicycle to get their mail. Many residents believe this action, combined with sidewalks along both sides of the highway, has resulted in a more closely knit community than formerly existed.

Community Enhancements

The extensive use of native low-level plantings in the parkway median and along the perimeters of the roadway and sidewalks has led adjacent property owners to invest in site landscaping and related improvements. Landscaping also helps define the road edges in this area of frequent fog and 2.0 m (80 in) of annual rainfall.

Lessening Noise Impact

Techniques to lessen physical and noise impact on adjacent properties were important. These techniques involved constructing short sections of retaining walls along the roadway edges to avoid side slope impacts on homes. In addition, a soundwall that is 3.7 m (12 ft) high was constructed for a distance of approximately 163 m (600 ft) adjacent to a mobile-home park. Vine-like vegetation enhances the soundwalls.



The Issue of Overhead vs. Underground Utilities

Because this was a demonstration project, ODOT attempted to have overhead utilities placed underground during highway construction. However, the local public utility district declined to support such an option, citing an estimated cost of approximately \$1.2 million. ODOT subsequently obtained \$600,000 in State funds to pay for one-half of the utility undergrounding but still obtained no interest in participation by the public utility district. As a result, half the project has underground utilities and half has overhead lines. An unusual illustration of differing visual effects exists over the relatively short length of the project.

Shoulder Width Exception

The only formal design exception requested from FHWA by ODOT was a reduction in the outside shoulder width from 3.0 m (10 ft) (the 1990 AASHTO Green Book minimum requirement for such rural arterial highways) to 2.4 m (8 ft). The 1994 edition of the Green Book now allows for use of shoulders that are 2.4 m (8 ft) wide on such facilities.

Although not a formal design exception per se, this project does represent a major variance from typical ODOT highway planning and design practice by providing a raised median along a non-access-controlled rural/suburban highway. Generally in Oregon, medians are found only along full access-controlled freeway or expressway facilities and urban boulevards.

LESSONS LEARNED

ODOT views the planning and design of the Lincoln Beach Parkway as a prototype for similar highway improvements that can be implemented along the U.S. Route 101 corridor. The early involvement of residents and businesses, in addition to local elected officials and traditional public agency representatives, is now viewed as standard departmental procedure to better involve all affected stakeholders. Documentation of the safety benefits associated with mediandivided arterial facilities, in contrast to the traditional ODOT three-lane and five-lane urban cross-section design solutions, is an important result of this planning and design effort.

The design treatments associated with the Lincoln Beach Parkway are viewed as a model for resolving future traffic management problems throughout Oregon, especially on U.S. 101. ODOT is now engaged in the second phase of the Coast Highway Corridor Master Plan development, which is concerned with the definition of more detailed access management plans and subarea planning and design studies, including the consideration of a number of through-traffic bypasses around congested urban areas.

LINCOLN BEACH PARKWAY AT A GLANCE

Setting: Pacific Coast resort community, rural transition to suburban

Length: 3.29 km (2.04 miles)

Traffic Volume: 11,500 ADT (1992 count)

Design Speed: 73 kph (45 mph)

Type of Road: Rural principal arterial; four-lane, median divided (part of an Oregon Scenic Byway)

Design Cost: Not available (in-house by Oregon DOT staff)

Construction Cost: \$4.8 million (including \$600,000 for 1 mile [1.6 km] of underground utilities)

Key Design Features: Raised, landscaped median area (first use on a non-limited-access rural highway in Oregon); emergency vehicle median crossover points; special turnarounds provided for buses and large RVs

Debits: Utilities placed underground on one-half of project; limited separation of some existing homes and businesses from edge of travelway due to restricted right-of-way availability

Similar Projects: Carson Street, Torrance, CA
One-Way Couplet, Carbondale, IL
West Broad Street, Falls Church, VA

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