INTRODUCTION

Since 1976 when the U.S. Congress first authorized federal aid for resurfacing, restoration, and rehabilitation (RRR) work, questions about geometric design standards have persisted:

- What improvements to existing highways yield the greatest safety gains in relation to cost?
- How can the overall process of selecting, designing, and constructing RRR projects take advantage of these opportunities for safety improvements?
- How much federal aid should be used for resurfacing and other pavement repairs that preserve and extend the service life of existing highways?

Many state highway organizations have viewed the federal RRR program primarily as a means of addressing critical pavement repair needs. During the 1970s these needs mounted as construction costs escalated and state highway revenues leveled off or declined. As a result, flexible geometric design standards were preferred for RRR projects because stringent standards such as those required for new construction or full reconstruction would, if followed rigorously, dramatically increase project costs. State highway organizations believed that such increases would inevitably lead to the concentration of
available funds on a small number of projects, leaving unattended many federal-aid highways in need of pavement repair and meeting neither preservation nor safety objectives.

Safety organizations, on the other hand, have viewed the federal RRR program as an opportunity to make long-needed safety improvements to older highways at the same time as pavement repairs are made. These organizations have viewed the flexible RRR standards proposed by some highway agencies as too lenient and have favored a more rigorous, safety-oriented design process.

RRR projects may include resurfacing, pavement structural and joint repairs, widening of lanes and shoulders, selected alterations to vertical and horizontal alignment, bridge repairs, and removal of roadside hazards. The federal government considers more extensive improvements reconstruction; lesser repairs are viewed as maintenance and therefore ineligible for federal aid.

Nearly $5 billion, about 10 percent of highway expenditures by all levels of government, are spent annually on non-Interstate RRR repairs, a share that will likely increase as highway programs continue to shift emphasis from construction to preservation. Federal-aid highways account for approximately one-half of the $5 billion spent. From a safety standpoint, about 30,000 persons are killed each year on non-Interstate federal-aid highways, which amounts to two-thirds of all U.S. traffic fatalities, and almost 2 million persons are injured each year.

Until 1976, state and local governments were responsible for undertaking and financing RRR work, and they made their own judgments about the priorities of pavement repair and geometric improvements. Reacting to widespread concern over the deteriorating condition of the nation’s highway system in 1976, Congress authorized the use of federal-aid construction funds for RRR projects. Because no other standards existed, the Federal Highway Administration (FHWA), which oversees the federal highway program, initially applied new construction standards, expecting to later adopt special RRR standards for older nonfreeway highways. Design exceptions were permitted on a case-by-case basis to accommodate difficult situations such as widening roads in urban areas or straightening roads in mountainous regions. Because many of the roads involved were built many years ago to different standards, geometric features such as shoulder widths or curve radii are not uniform. Imposing new construction standards on a nationwide basis resulted in a large number of design exceptions in cases in which upgrading to these standards would have been extraordinarily expensive.

Because of the divergent views on standards and the controversy that arose, FHWA never adopted a set of special RRR standards for nationwide use. Instead it adopted a flexible approach that permits states to develop and apply
their own RRR standards subject to federal approval, or to continue to use new
construction standards. This action failed to silence the debate over RRR
standards as evidenced by the congressional mandate for this study, as well as
the restated program objectives contained in the same legislation “...to
preserve and extend the service life of highways and enhance highway
safety.”

The background and origins of this controversy are discussed in greater
detail in the remainder of this chapter. First, the evolution of federal involve-
ment in funding highway construction is described, and the resulting federal-
aid highway program is discussed. Discussed next is the division of respon-
sibility between federal and state governments for setting highway design
standards and the specific federal rulemaking efforts directed toward mini-
num geometric standards for RRR projects. Finally, a number of key issues
related to the development and application of nationwide standards for RRR
projects are summarized.

In Chapter 2 the following procedures are discussed: use of federal aid for
RRR work by state and local highway agencies, project selection, type of
projects undertaken, design standards and practices used, and the overall role
of safety. Identified in Chapters 3 and 4 are the relationships between key
gEometric features and safety and those between key geometric features and
cost. These relationships are identified as a preliminary step to the evaluation
of the safety cost-effectiveness of geometric design standards. Wherever
reliable quantitative relationships are identified, the safety and cost trade-offs
of alternative standards are evaluated in Chapter 5, with an examination of
project-level effects, as well as the implications for systemwide effects on
safety, highway condition, and funding. The tort liability implications of
geometric design standards and other RRR design practices are examined in
Chapter 6. Finally, the study committee’s key findings and recommendations
for improved highway design practices are given in Chapter 7.

EVOLUTION OF FEDERAL HIGHWAY POLICY

Most highways in the United States are constructed, administered, and main-
tained by state and local governments. These tasks were accomplished with
little federal assistance or involvement until the passage of the Federal-Aid
Road Act of 1916. This act provided substantial financial assistance for
highways, and in doing so, established the following key principles of federal
highway policy:

• State highway agencies: specified that state highway departments would
be the usual coordinator and contact point for all federal assistance;
• Federal-state relationship: affirmed the responsibility of state and local governments to construct, own, and maintain highways while committing the federal government to share in the financing of highway construction;

• Federal-aid apportionment: prescribed distribution of federal highway funds through a formula, which initially considered area, population, and rural postal route mileage;

• Project cost sharing: on federal-aid projects, required that federal funds be matched with state (or local) funds initially, with a maximum federal share of 50 percent;

• Federal oversight: specified that the federal government, originally through the Secretary of Agriculture, approve the plans, specifications, and estimates used for federal-aid highway projects (1-3).

In succeeding legislation over the next 40 years, Congress continued to shape the federal-aid highway program, adding other major principles of federal policy.

• Designated federal-aid highways: In 1921 Congress directed that federal aid be limited to a designated system of interconnected highways. The system designated at the time was the forerunner of today’s federal-aid primary system. Later, other legislation established additional designated federal-aid systems—the secondary system and urban primary extensions in 1934, the Interstate system in 1947, and the urban system in 1970.

• User fee financing: In 1932 the first federal excise tax on motor fuels was enacted. Although tax revenues were directed into the general fund, Congress in its deliberations began to link the tax rate to the level of federal highway expenditures.

• Special categorical programs: Through various highway and economic recovery legislation in the 1930s, Congress began to supplement federal aid for highway construction (regular federal aid) with categorical funds earmarked for specific purposes. The initial programs focused on eliminating the problems of railroad at-grade crossings, a federally funded activity that continues today.

By 1956 the basic principles of the federal-aid highway program were in place, but widespread concern existed over adequacy of U.S. highways, particularly in view of dramatic postwar increases in automobile and truck traffic. Through landmark legislation (the Federal Aid and Highway Revenue Acts of 1956), the federal government responded to this concern, providing new funding to accelerate construction of the Interstate system and increased funding for other federal-aid systems. To finance this greatly expanded federal-aid program, the federal government increased existing highway-
related excise taxes and established additional taxes whose revenues were totally or partly funneled into the Highway Trust Fund. (The trust fund was established as a holding mechanism for tax revenues earmarked for highway purposes.) The legislation required that the trust fund be used on a pay-as-you-go basis—effectively prohibiting federal deficit spending for highway construction.

From the outset financial assistance for the federal highway program (except for special categorical programs) was confined to relatively large, nonroutine projects—projects referred to in the Federal-Aid Road Act of 1916 as “substantial in character.” In practice, this meant that federal aid was available only for constructing new roads or fully reconstructing existing roads to higher design standards. Lesser improvements to existing roads, including costly resurfacing or minor widening of roads constructed earlier with federal aid, were considered maintenance, and therefore were ineligible for federal aid until 1976.

Congress changed the distinction between construction and maintenance when it enacted the Federal-Aid Highway Act of 1976. In response to mounting concern over the condition of the nation’s highway system and the need to shift emphasis from constructing new facilities to preserving existing ones, this act amended the U.S. Code to include resurfacing, restoration, and rehabilitation within the definition of “construction” as the term was used in the federal-aid highway program. The 1976 act authorized, for the first time, the use of federal funds for major repair work on the federal-aid highway system.

The act required that at least 20 percent of the regular federal aid for the primary and secondary systems be spent on RRR work. Later in the Surface Transportation Assistance Act of 1982, Congress modified this provision so that at least 40 percent of the primary, secondary, and urban system funds could be used on the combination of RRR work and reconstruction.

**FEDERAL-AID HIGHWAY PROGRAM**

The federal-aid highway program focuses on a designated system of highways and provides financial aid earmarked for particular components of this system or specific types of highway improvements. Congress authorized federal aid for RRR work within the context of the existing system of federal-aid highways and established funding categories.

**Federal-Aid System**

The designated federal-aid highway system accounts for 22 percent of the nation’s total highway mileage but carries 81 percent of all traffic and accounts
for 77 percent of all traffic fatalities (Table 1-1). It contains high proportions of
the more heavily traveled expressways and arterial highways and few local
roads and streets. For example, about 95 percent of all rural arterial and major
collector highways are included in the federal-aid system.

The federal-aid highway system comprises four components:

- **Interstate system**: Consists of about 44,000 mi of multilane expressways
  with fully controlled access traffic. The Interstate system is part of the federal-
  aid primary system but receives separate funding.
- **Primary system**: Excluding Interstates, consists of 257,000 mi of highways,
  of which 198,000 (77 percent) are two-lane rural roads.
- **Secondary system**: Initially designated in 1944, consists of 398,000 mi of
  highways classified as major collector roads in rural areas, nearly all of which
  (99 percent) are two-lane roads.
- **Urban system**: Includes 144,000 mi of urban arterial and collector roads,
  about 75 percent of which are two-lane roads.

This study is concerned with improvements to all systems except the
Interstate, which in total account for about 95 percent of all federal-aid
mileage, 60 percent of the nation's highway traffic, and two-thirds of its traffic
fatalities. Two-lane rural highways alone account for about 75 percent of all
nonfreeway federal-aid mileage and serve approximately one-fourth of vehicle
miles traveled in the United States (4).

The Federal Highway Administration maintains the Highway Performance
Monitoring System (HPMS) that keeps track of the design characteristics and

### TABLE 1-1  U.S. Highway Fatalities, Road Mileage, and Travel, 1985

<table>
<thead>
<tr>
<th>Federal-aid systems</th>
<th>1985 Fatalities (thousands)</th>
<th>Mileage (thousands)</th>
<th>Vehicle-Miles Traveled (billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Miles</td>
</tr>
<tr>
<td>Interstate</td>
<td>4.2</td>
<td>10</td>
<td>44</td>
</tr>
<tr>
<td>Primary</td>
<td>14.2</td>
<td>32</td>
<td>257</td>
</tr>
<tr>
<td>Secondary</td>
<td>6.3</td>
<td>15</td>
<td>398</td>
</tr>
<tr>
<td>Urban</td>
<td>8.9</td>
<td>20</td>
<td>144</td>
</tr>
<tr>
<td>Subtotal</td>
<td>33.8</td>
<td>77</td>
<td>843</td>
</tr>
<tr>
<td>Off-federal systems</td>
<td>10.0</td>
<td>23</td>
<td>3,019</td>
</tr>
<tr>
<td>Total</td>
<td>43.8</td>
<td>100</td>
<td>3,862</td>
</tr>
</tbody>
</table>

*Source: FHWA, *Highway Statistics 1985* (4) and *Highway Safety Performance, 1985* (5).*

*Includes off-system local travel.*
conditions of the U.S. highway system, including the federal-aid systems, based on a nationwide sample of highway segments. Using this system, FHWA (6) reported to Congress that approximately one-half of the federal-aid primary and secondary mileage has some type of significant geometric design deficiency related to either cross section (e.g., lane and shoulder widths) or alignment (e.g., curves, grades, and sight distance) (Table 1-2). About 16 percent of the mileage on these systems contains pavement deficiencies. In estimating these deficiencies, FHWA assumed “minimum tolerable conditions” that varied by functional classification, terrain, and traffic level.

### Table 1-2 Estimated Deficiencies in Federal-Aid Systems (6)

<table>
<thead>
<tr>
<th></th>
<th>Interstate</th>
<th>Primary</th>
<th>Secondary</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>10.4</td>
<td>16.1</td>
<td>16.2</td>
<td>15.0</td>
</tr>
<tr>
<td>Horizontal and vertical alignment</td>
<td>1.2</td>
<td>14.4</td>
<td>39.6</td>
<td>0</td>
</tr>
<tr>
<td>Cross section</td>
<td>4.6</td>
<td>45.9</td>
<td>38.5</td>
<td>34.2</td>
</tr>
<tr>
<td>Operational</td>
<td>11.0</td>
<td>19.2</td>
<td>3.7</td>
<td>14.3</td>
</tr>
<tr>
<td>Access control</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Miles with single deficiency</td>
<td>17.8</td>
<td>41.5</td>
<td>40.1</td>
<td>40.7</td>
</tr>
<tr>
<td>Miles with more than one deficiency</td>
<td>4.5</td>
<td>23.9</td>
<td>26.5</td>
<td>11.2</td>
</tr>
<tr>
<td>Total miles with deficiency</td>
<td>22.3</td>
<td>65.5</td>
<td>66.6</td>
<td>51.9</td>
</tr>
</tbody>
</table>

**Note:** Estimates based on HPMS data for 1981.

- **a**Pavement condition is based on the Present Serviceability Rating (PSR). A pavement with a PSR of 2.0 or lower (2.5 for Interstates) is considered deficient.
- **b**Highway segments with curves that require reduced speed, or any grades with insufficient sight distance that require trucks to slow on arterials and major collectors, or more than an occasional such curve or grade on minor collectors.
- **c**Lane widths less than 11 ft on principal arterials, 10 ft on minor arterials and major collectors, or 8 to 9 ft on minor collectors; or shoulder widths on arterials and major collectors of less than 4 to 8 ft, depending on terrain and traffic.
- **d**Operational deficiencies in rural areas occur when operating speed drops below a threshold that is a function of classification, average daily traffic (ADT), and terrain. In urban areas the definition is based on the peak period volume-to-capacity ratio.
- **e**A deficiency results when a segment of highway that should be access controlled is not; this applies to all Interstates and certain primary and urban routes.
23 percent of these (more than 60,000 bridges) are eligible for special federal bridge replacement and rehabilitation funds because of existing deficiencies in design and condition. About 80 percent of these bridges are on either the primary or secondary federal-aid system.

**Funding Programs**

The overall federal-aid highway program\(^1\) consists of more than 40 separate funding assistance programs (8). However, the construction programs for the designated federal-aid systems (regular federal aid plus minimum state allocations) account for about 80 percent of all federal assistance (Table 1-3). In general, these funds are apportioned to the states by formulas that vary depending on the system.

Although most highway programs have some direct or indirect effect on safety, over the years Congress has established three programs that fund safety

<table>
<thead>
<tr>
<th>TABLE 1-3</th>
<th>Expenditure of Federal-Aid Highway Funds Administered by the Federal Highway Administration During 1985</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expenditures Paid from the Highway Trust Fund ($millions)</td>
</tr>
<tr>
<td>Primary</td>
<td>2,239</td>
</tr>
<tr>
<td>Secondary</td>
<td>590</td>
</tr>
<tr>
<td>Urban</td>
<td>833</td>
</tr>
<tr>
<td>Interstate</td>
<td>3,923</td>
</tr>
<tr>
<td>Interstate resurfacing</td>
<td>2,322</td>
</tr>
<tr>
<td>85 percent minimum allocation funds</td>
<td>316</td>
</tr>
<tr>
<td>Planning and research</td>
<td>202</td>
</tr>
<tr>
<td>Highway safety</td>
<td>423</td>
</tr>
<tr>
<td>Bridge replacement</td>
<td>1,511</td>
</tr>
<tr>
<td>Other</td>
<td>525</td>
</tr>
<tr>
<td>Total</td>
<td>12,884</td>
</tr>
</tbody>
</table>

**Source:** *Highway Statistics 1985* (4), Table FA-3.

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\(^1\)This section contains a description of federal funding programs as authorized through fiscal year 1986. Shortly before this writing (in April 1987), the Surface Transportation and Uniform Relocation Assistance Act of 1987 became law. This act authorizes expenditures on federal-aid highway projects and safety programs for fiscal years 1987 through 1991. Although the act provides some changes in funding priorities, it does not substantially change those elements of the federal-aid highway program that are of interest in this study.
improvements at specific locations, often involving construction or rehabilitation:

- **Bridge replacement and rehabilitation:** Since 1979 this program has funded bridge replacement and rehabilitation projects on and off the federal-aid system. Before the 1978 Highway Act, bridges on the federal-aid system could be partially replaced (e.g., new deck) under the special bridge replacement program.

- **Rail-highway grade crossings:** Established by the Highway Safety Act of 1973, this program provides funds for safety improvements at on- and off-system rail crossings, including grade separation, relocations, automatic gates, and warning devices.

- **Hazard elimination:** Since 1974 this program and its predecessors have funded on- and off-system spot safety improvements, frequently at locations with histories of high accident rates. Through fiscal year 1982, program funds were directed to improvements such as traffic signals and intersection channelization (34 percent), guardrail installation (15 percent), signs and breakdown supports (2 percent), and pavement skid treatments (4 percent) (9).

Just as it has done with regular federal-aid funds, Congress has authorized some transferability between the bridge replacement and rehabilitation, rail-highway grade crossings, and hazard elimination categorical programs.

In recent years federal aid from all programs has accounted for approximately 25 to 30 percent of total highway disbursements ($54 billion in 1985) at all levels of government. During the years when major Interstate construction was underway, capital outlays, which include most federal aid, represented more than one-half of total disbursements; but in recent years, capital outlays have shrunk to less than one-half of the total while maintenance and operational disbursements have increased as a percentage. Moreover, the buying power of capital funds decreased dramatically during periods of rapid inflation in the 1970s so that, despite recent improvements in construction buying power, the FHWA (5) reported that 1982 capital outlays were expected to be less in constant dollars than any year since the early 1950s. This trend was reversed, at least temporarily, by the Surface Transportation Assistance Act of 1982, which increased 1983 federal-aid highway system authorization levels about 40 percent over the 1982 level. Further, it authorized annual increases in the Interstate resurfacing, restoration, rehabilitation, and reconstruction (4R) and primary system categories each year between 1983 and 1986. Fiscal year 1986 Interstate 4R authorizations were nearly four times the 1982 level, and primary authorizations were nearly twice the 1982 amount.
Resurfacing, Restoration, and Rehabilitation

Under the classification of resurfacing, restoration, and rehabilitation, the federal-aid highway program funds the following types of improvements to existing federal-aid highways: 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. In making RRR work eligible for regular federal aid, Congress made federal funds available for the heavier, more costly types of maintenance and at the same time provided highway agencies the opportunity to use federal funds for incremental geometric and safety improvements short of full reconstruction. RRR is not a separate federal-aid program but rather a collection of improvement types that became eligible for regular federal aid in 1976. Currently, in distinguishing between RRR work and ineligible routine maintenance, FHWA classifies as maintenance any overlays less than 3/4 in., pavement repairs on short segments, and patching and repair of minor pavement failures (10).

Between 1977 and 1982, when federal law required at least 20 percent of regular primary and secondary funds be used for RRR, FHWA also had to distinguish between RRR work and reconstruction so that compliance could be verified. In general, FHWA views the complete removal and replacement of pavement structure or the addition of new continuous traffic lanes as reconstruction, rather than RRR (11). After 1983, when the law changed to require at least 40 percent of non-Interstate regular federal aid be used for the combination of RRR and reconstruction, the distinction between the two became less important because the treatment was identical in the revised program.

Not all federal-aid RRR work is funded with regular federal-aid construction funds. Some RRR-type projects may be funded with either regular federal aid or separate categorical aid. For example, state or local highway agencies might seek federal funds for a bridge rehabilitation project through either regular federal aid (as an eligible RRR project) or through the bridge replacement and rehabilitation program. Similarly, roadside hazard removal and guardrail installation might, in some circumstances, be funded with either regular federal aid or hazard elimination program funds.

State highway agencies spent $2.9 billion on RRR projects in 1985, including $1.7 billion federal-aid and state matching funds and $1.2 billion state funds (4). Counties and municipalities spent approximately $2.1 billion on
RRR projects.\textsuperscript{2} Total spending on RRR projects in 1985 was $5.0 billion, about 10 percent of expenditures for highways by all levels of government combined.

Many state highway agencies use RRR federal aid as a means of addressing critical pavement preservation and repair needs while making selective improvements to road geometry and roadside features. For example, a state might use federal aid for a resurfacing project that would also widen the shoulder and replace obsolete guardrail. The extent of such geometric and roadside improvements varies among the states and is at the center of the controversy that has existed regarding geometric design standards for federal-aid RRR projects.

GEOMETRIC DESIGN STANDARDS AND FEDERAL RULEMAKING

Responsibility for Standards—Federal and State Roles

Historically, the primary responsibility for developing and adopting design standards has rested with state legislatures, state highway agencies, and local governments. These standards generally set minimum values for key geometric features and sometimes call for specific design procedures or practices as well. Over the years highway design standards have been developed principally for the construction of new highways or the complete reconstruction of existing highways.

With the passage of the Federal-Aid Road Act of 1916, the federal government became involved with highway design standards for the first time. Initially, it exercised oversight by approving designs for federal-aid projects on a project-by-project basis. It did not develop or seek to apply nationwide standards but did begin sponsoring early research on geometric design, the results of which were later incorporated in state standards and American Association of State Highway and Transportation Officials (AASHTO) design policies. For example, in 1925 the Bureau of Public Roads, predecessor of FHWA, reported that 18 ft was the minimum pavement width for trucks and automobiles to pass safely; later in 1944 a federal study recommended a lane width of 12 ft (7).

\textsuperscript{2}RRR accounted for 47 and 26 percent, respectively, of capital outlay for state-funded projects on rural and urban collectors. These percentages were applied to total capital outlays by counties and municipalities ($2.4 and $3.6 billion, respectively) to estimate their RRR expenditures, yielding $1.1 billion for counties and $1.0 billion for municipalities.
Until the late 1920s, state agencies generally adopted standards independently of one another, leading to design inconsistencies between adjacent states as well as duplications of effort. To address these problems, the American Association of State Highway Officials (AASHO) (now the American Association of State Highway and Transportation Officials), which initially confined itself to disseminating information, began to adopt design policies in 1928 (12). These policies, though not obligatory, were intended by AASHO to guide its members on technical matters in which state-to-state uniformity was needed. By 1944 it had adopted seven design policies that were incorporated into the design standards of many states (13).

Over the years, AASHTO has revised these design policies a number of times and issued many additional policies (14) that not only recommend minimum design values but also procedures to be used in the planning and design of highways. For example, AASHTO has recommended procedures for citizen participation, environmental studies, and project evaluation (15) and has issued guidance materials for designing pavements (16), traffic barriers (17), and lighting (18).

The federal government adopted many of AASHTO's design policies and guides as standards for federal-aid projects; approximately 20 are incorporated into federal regulations of highway design (19). Although FHWA has supplemented AASHTO design policies in some areas, it has generally preferred to adopt them rather than develop design standards independently and has participated in AASHTO committees responsible for developing design policies. In practice, each state highway agency continues to incorporate AASHTO policies in its design standards, often with some alterations or extensions. FHWA reviews and must approve these standards for use on federal-aid projects.

For road geometry, AASHTO policies recommend minimum (or maximum) design values for features such as

- Lane widths,
- Shoulder widths,
- Horizontal and vertical curves,
- Superelevation at curves,
- Sight distance,
- Bridge widths,
- Sideslopes and ditch drainage, and
- Pavement cross slopes.

To increase flexibility and adaptability to a variety of nationwide conditions, AASHTO recommends different design values for variations in terrain, setting (urban versus rural), traffic volume, traffic characteristics (e.g., per-
percentage of heavy trucks), and function (local, collector, arterial, etc.). The recommended values also vary with speed. For roads intended for high-speed driving, the values specify wider lanes and shoulders, longer sight distances, and more gentle curves. AASHTO policies recommend design speeds based on function, setting, terrain, and traffic characteristics.

Not all highway features are treated with firm, numerical design standards. Roadside features such as obstacle-free clear zones and protective barriers generally have been covered by guidelines rather than recommended minimum design values. As a result, new construction design is more uniform on the roadway than on the adjacent roadside.

**Geometric Standards for RRR Projects**

Geometric standards for RRR projects specify whether particular geometric features must be upgraded as part of the project. Features that do not meet minimum standards must be upgraded unless a design exception is sought and approved.

When Congress authorized federal aid for RRR projects in 1976, AASHTO had not developed design policies specifically for RRR work, nor had FHWA adopted minimum geometric standards for RRR projects. Existing standards and policies were geared to new construction or reconstruction. As an interim measure, the FHWA applied its new construction standards to RRR projects while it considered separate RRR standards for nonfreeway highways. For freeways, mostly Interstate highways constructed in the past 30 years, FHWA concluded that no special RRR standards were warranted because these highways generally met the most stringent new construction standards.

Design exceptions, permitted on a case-by-case basis for any federal-aid project quickly became commonplace for nonfreeway, federal-aid RRR projects because upgrading to the geometric standards for new highways is often extraordinarily expensive. In the northeastern states, where highway systems are relatively old and the topography is severe, the FHWA reported that 75 to 90 percent of RRR projects were granted design exceptions. In those middle and far west states where highways are newer and the topography is relatively flat, the percentage of RRR projects granted design exceptions was far lower (0 to 30 percent) (20). Differences in highway widths contribute to the higher percentage of projects in the northeast granted design exceptions. For example, in all but one state west of the Mississippi more than 60 percent of the primary highways now have lanes 12 ft wide, whereas few primary highways in northeastern states have 60 percent of primary highways with lanes of this width (4).

FHWA noted that not all of the differences among states in the percentages of RRR projects granted design exceptions can be explained by differences in
topography and the age of highway systems (20). As discussed in more detail in Chapter 2, other factors that affect these percentages include the amount of state funds available for RRR, the design standards in effect, and the procedures followed by FHWA division offices in approving design exceptions.

By November 1976, AASHTO had developed and adopted a policy on geometric design for RRR work, which was published in the RRR geometric design guide the following year (21). Commonly referred to as the "purple book," this guide contains recommended minimum design values for lane and shoulder widths, cross slopes, superelevation, and bridge widths, as well as advisory information on grades, curvature, sight distance, and clear zones. Overall, it is considerably less stringent than AASHTO policies for new construction (Appendix A). The purple book was opposed by safety organizations, and within FHWA it was opposed by the Office of Highway Safety.

The FHWA's interim measure of requiring new construction standards for RRR projects, with lenient exceptions, lasted far longer than expected because selecting separate RRR geometric design standards for nonfreeway highways proved to be complex and controversial. Safety and design issues were raised that involved a large number of geometric features affecting different types of highways in rural and urban settings. Underlying the question of standards was the need to use federal RRR funds in the most cost-effective manner to enhance safety while preserving and restoring federal-aid highways for the nation as a whole. Controversy was introduced by the different perspectives of safety organizations and state highway agencies.

It was not until June 1982 that the FHWA issued new regulations addressing RRR standards. During the intervening 6 years, the FHWA considered a number of alternative policies and reversed itself with respect to preferred action. The following alternatives were considered:

1. Continue to use new construction geometric design standards with exceptions permitted on a case-by-case basis.
2. Adopt guidelines contained in the AASHTO RRR design guide.
3. Adopt RRR standards developed by the FHWA. In August 1978, after opposition to the AASHTO RRR guidelines arose, the FHWA proposed RRR standards developed internally (22). In general, the FHWA standards are somewhat more stringent than the standards in the AASHTO RRR guidelines, but are similar in terms of scope and format (Appendix A, Table A-1).
4. Adopt a flexible approach under which states could develop and use their own RRR standards subject to FHWA approval.

This protracted rulemaking process attracted comments from a variety of institutions and individuals, including safety-oriented organizations such as the Center for Auto Safety, the Insurance Institute for Highway Safety, and the
National Transportation Safety Board. Safety organizations generally opposed any regulation that might lead to special standards for RRR projects and favored the first alternative as least objectionable.

Although the FHWA had granted a large number of design exceptions under the first alternative, safety organizations believed the process of explicitly considering design exceptions on a project-by-project basis will occasionally result in substantial geometric improvements. Safety organizations acknowledged the need for design exceptions, but they viewed the AASHTO RRR guidelines and FHWA proposed standards as too lax, permitting the RRR program to focus almost exclusively on road surface improvements and discouraging a safety-conscious design process. In addition, it was argued that reductions in standards for federally assisted RRR projects would violate legislative mandates concerning safety. The fourth alternative, permitting states to develop their own standards, also was unpopular with safety organizations, which feared that states would choose, and the FHWA would approve, standards similar to the AASHTO RRR guidelines (23).

State highway agencies initially supported the AASHTO RRR guidelines, but later indicated a general willingness to accept the more stringent RRR standards proposed by the FHWA. New construction standards were viewed by many states as inappropriate for RRR projects. State officials generally believed that the new standards, if followed rigorously, would greatly increase project costs, thereby concentrating available funds on a small number of improvement projects. Such a policy, it was argued, would leave unattended many miles of federal-aid highways in need of pavement repair and would meet neither safety nor repair objectives. It was also contended that if widespread exceptions were permitted, needless administrative costs and delays would be incurred (23).

In June 1982 the FHWA selected the fourth approach, permitting states to develop their own RRR standards subject to FHWA approval. By this time, some states had grown accustomed to using new construction standards, with case-by-case exceptions, and under the June 1982 rule, states were permitted to continue this practice (9). However, the issue remained unsettled because of congressional reservations concerning this approach. These reservations initially surfaced during the fall of 1981 when FHWA officials, representatives of safety organizations, state highway officials, and others debated RRR issues extensively in hearings held by the House Subcommittee on Investigations and Oversight of the Committee on Public Works and Transportation (24).

Safety Considerations

In the congressional hearings on RRR standards, debate focused on (a) the practical impact of RRR standards on safety and (b) the role of safety in the
RRR program. A number of questions were raised with respect to the impact of the standards on safety. Will accident rates increase if highways with existing geometric deficiencies are resurfaced and no other improvements are made? What changes in accident rates can be expected if different types of geometric improvements are made? What would be the nationwide consequences on safety and highway condition of alternative RRR standards when budgetary resources are fixed? What would be the biggest safety payoff? Although such questions could not be answered fully, the FHWA prepared the RRR Technical Analysis report to address them. This analysis, which concluded that standards less stringent than those for new construction would be appropriate for RRR projects (1), was criticized by the National Transportation Safety Board for methodological shortcomings (25). Overall, many issues concerning the desired level of safety to be included in the program, and the type of standards and policies needed to balance safety and pavement preservation, were left unresolved during the RRR rulemaking process.

With respect to the second issue, the role of safety in the RRR program, the FHWA adopted the position that safety was an essential consideration of the RRR program, but secondary to preserving and extending the service life of highways. On the other hand, safety organizations expressed the concern that efforts to upgrade the safety of federal-aid roads were being relaxed in the RRR program. Debate over the relative priority of safety and repair arose repeatedly in the testimony during the congressional RRR hearings (23).

Ultimately, this debate led to a provision in the Surface Transportation Assistance Act of 1982, which stated that the objective of the RRR program is "...to preserve and extend the service life of highways and enhance highway safety." Congressional deliberations were unclear about how much of a change, if any, was required by this provision (26). Subsequently, the FHWA modified its June 1982 rule on RRR standards to echo this restatement of program objectives. Reflecting the legislative ambiguity, the FHWA changed the policy statement in the preamble to the rule, but made no changes to the procedures (27).

These changes to statutory language and rules have not resolved the problem of the cost-safety trade-off within the RRR program. To address "safety cost-effectiveness," an additional provision was included in the Surface Transportation Assistance Act of 1982 that called for the National Academy of Sciences to study the safety cost-effectiveness of highway geometric design standards and recommend minimum standards for resurfacing, restoration, and rehabilitation projects on existing federal-aid highways, except freeways.
KEY ISSUES

Many questions and issues that bear on minimum RRR standards were left unresolved during the RRR rulemaking process and related debate. In organizing a study that would respond to the congressional request, the study identified six key areas of inquiry that address these issues and, taken together, provide the technical foundation necessary for specific recommendations.

State and Local Procedures for Selection, Design, and Construction of Highway Improvement Projects (Chapter 2)

To analyze alternative design standards, it is necessary to understand the relationship between standards and other parts of the RRR process: What types of RRR projects are funded with federal aid? How are these projects selected? What design standards are currently used? Are stringent design standards frequently circumvented? How are safety needs taken into account? All of these questions are directed to state and local highway agencies because they have the primary responsibility for selecting and performing RRR work.

During the congressional hearings on RRR standards (24), witnesses relied heavily on either nationwide statistical data or personal observations about specific state and local practices. Although useful, nationwide statistical data or studies may mask significant variations among the states with respect to RRR needs and the ways by which they are met. Personal observations may be accurate but are difficult to compare systematically. Further, they may portray an atypical situation reflecting the practices of a single highway agency.

To obtain a more balanced picture, reviews of prior studies and analyses of nationwide data bases were supplemented with in-depth case studies of highway practices in 15 states and interviews with local public works officials throughout the country.

Relationship Between Safety and Geometric Design (Chapter 3)

What are the safety payoffs (i.e., reductions in the number and severity of accidents) from geometric changes such as increasing lane and shoulder widths, straightening sharp curves, or removing roadside obstacles on existing highways? The trade-off between the cost of such improvements and their safety payoff is fundamental to the issue of minimum RRR design standards. To make this trade-off requires quantitative knowledge of the relationships between safety and different roadway features. Despite numerous statistical
studies of accident data, these relationships are not well known, and divergent relationships are suggested by different analyses (28). Isolating the effects of a specific geometric feature from other conditions of the roadway environment, vehicle characteristics, and driver characteristics has proved to be a formidable research task. This task is often complicated by the lack of comprehensive and consistent accident and exposure (usage) data.

Highway researchers will probably never develop definitive safety relationships that cover the full range of highway design features. The complexity of the causes of accidents, the infrequency of accidents, and the continuing evolution of highway vehicles, traffic regulations, and enforcement policies work against this. Nevertheless, wherever possible, the study committee made judgments about the most probable relationships between safety and key highway features using what was considered to be the most credible data available. To help provide a basis for these judgments, the committee sponsored critical reviews of prior research and two special studies that addressed major gaps in existing knowledge.

Relationship Between Cost and Geometric Design (Chapter 4)

Like the relationships between safety and geometric design, the relationships between cost and geometric design are critical in determining how safety and road repair needs can most effectively be balanced. How much does it cost, for example, to widen lanes and shoulders in addition to resurfacing as opposed to simply resurfacing? Nationwide statistics compiled by FHWA for federal-aid projects indicate that typical resurfacing projects on rural arterials cost approximately $150,000 to $200,000/mi. When minor widening is included, the cost more than doubles. Full reconstruction, with wide lanes, costs approximately $1.25 million/mi, more than six times the unit cost of simple resurfacing (29).

Although these rough estimates provide a sense of the magnitude of costs involved, they mask the large variability that exists from region to region, state to state, and from project to project.

To develop cost relationships for use in the study, the committee examined published cost data, cost records, and estimating procedures for a sample of state highway agencies throughout the country. This work supplemented reviews of existing nationwide cost records and data sets.

Safety Cost-Effectiveness of Geometric Design Standards (Chapter 5)

The principal questions that underlie earlier debate over RRR standards are
• What are the cost and safety trade-offs of making incremental geometric improvements to existing highways?
• How do minimum RRR standards affect the balance between preserving highways and improving safety on a systemwide basis, when available funds are limited?

These questions were addressed from project-level and system-level perspectives using the safety and cost relationships identified. The added cost per accident eliminated that can typically be expected for improvements to existing highway geometry was estimated at the project level. How much does it cost, for example, to eliminate an accident by lane widening, and how does this compare with shoulder widening or straightening a sharp horizontal curve? Where system data were available for existing highway conditions, on a nationwide basis and for selected states, the study estimated the effect of alternative RRR minimum standards on systemwide safety and the total expenditure needed to meet the standards. Also considered was the likely impact that such standards would have on the frequency of major pavement repairs and operational benefits in the form of reduced user costs that may result from geometric improvements along with improved safety.

Tort Liability and Geometric Design (Chapter 6)

Highway agencies have become increasingly concerned about the number of tort claims filed against them and the resulting costs of settlements, awards, and legal defense. These claims allege negligence in the design or operation of public highways.

Some highway agencies have feared that special geometric design standards for RRR projects, less stringent than new construction standards, might make them more susceptible to tort claims; others have concluded just the opposite. The limited data available on tort claims against highway agencies were analyzed to determine how frequently geometric design is at issue as opposed to maintenance practices, signing, or other aspects of highway management. In addition to standards, other ways were considered in which the design and construction of RRR projects may reduce a highway agency’s exposure to tort claims.

REFERENCES

23. Unpublished summaries of comments to rulemaking Dockets No. 77–4 and No. 77–10, FHWA, U.S. Department of Transportation (undated).


26. House (p. H10717, December 21, 1982) and Senate (p. S16067, December 23, 1982) colloquies to the effect that the “enhance safety” provision would not require the application of full new design standards.

