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16. Abstract

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The literature review generally supported the notion that paved shoulders are economically justifiable under certain conditions. However, there was no consensus on the specific conditions. The survey results showed that 91.4 percent of the state DOTs surveyed use paved shoulders on two-lane roads to some degree. Most or all shoulders were paved by 42.9 percent of these DOTs, and 40.0 percent have threshold values to warrant paved shoulders.

For the average new two- and four-lane road projects, initial cost increases of 16.7 and 8.3 percent, respectively, and a corresponding service life increase of 14.3 percent are realized with 2-ft paved shoulders. For a resurfacing project, initial cost increases of 72.0 and 36.0 percent are realized with a 2-ft paved shoulder on two- and four-lane roads, respectively. Through an economic analysis using the equivalent uniform annual cost method, it was revealed that 2-ft paved shoulders for new two-lane roads are economically justifiable under certain ADT volumes that depend on the road's functional classification and terrain type. Two-foot paved shoulders are not economically justifiable for most existing two-lane roads. For four-lane and six-lane roads, 2-ft paved shoulders are economically justifiable for all new roads and for existing roads above certain ADT volumes.

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FINAL REPORT

REVIEW OF PAVED SHOULDERS

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
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For the average new two- and four-lane road projects, initial cost increases of 16.7 and 8.3 percent, respectively, and a corresponding service life increase of 14.3 percent are realized with 2-ft paved shoulders. For a resurfacing project, initial cost increases of 72.0 and 36.0 percent are realized with a 2-ft paved shoulder on two- and four-lane roads, respectively. Through an economic analysis using the equivalent uniform annual cost method, it was revealed that 2-ft paved shoulders for new two-lane roads are economically justifiable under certain ADT volumes that depend on the road's functional classification and terrain type. Two-foot paved shoulders are not economically justifiable for most existing two-lane roads. for four-lane and six-lane roads, 2-ft paved shoulders are economically justifiable for all new roads and for existing roads above certain ADT volumes.

FINAL REPORT

REVIEW OF PAVED SHOULDERS

B. H. Cottrell, Jr.

INTRODUCTION

This report is a follow-up to the study *Value Engineering Review on Paved Shoulder Extensions for New Roads* (*1*) conducted by a value engineering (VE) team from the Virginia Department of Transportation (VDOT). The study team recommended that VDOT adopt a policy of providing a 2-ft paved shoulder on each side of roadways with pavement widths 20 ft or wider that does not include an asphalt plant mixture or portland cement concrete shoulder. A review of the study by two VDOT directors and the chief engineer raised several questions and concerns about the study's findings and recommendations.

Consequently, the Virginia Transportation Research Council conducted a literature review and cost analysis to address these questions and concerns. The objectives were (1) to review the literature on paved shoulders, (2) to survey other state DOTs on the use of paved shoulders, (3) to perform a cost analysis on paved shoulders, and (4) to draw conclusions based on the findings.

The scope of the analysis is limited to shoulders made of asphalt plant mixture used to extend the mainline pavement. Surface treatment was considered in the VE review but not recommended. Because there are only a limited number of primary roads with portland cement concrete surfaces, concrete pavement and shoulders were omitted. By limiting the analysis to arterial and collector roads, implementation may be phased in on these roads before local roads are considered. Thus, the impact of paved shoulders on arterial and collector roads may be evaluated and reviewed before considering implementation on local roads. Moreover, the potential maintenance cost savings and accident reduction are higher for arterial and collector roads.

LITERATURE REVIEW

There have been numerous studies of paved shoulders. Many of them are either outdated (i.e., more than 20 years old) or flawed based on data reliability (study design and quality of the data) or data analysis and results (statistical tests and interpretation of findings). Seven pertinent reports are reviewed below.

1. *Investigation of the Relative Cost-Effectiveness of Paved Shoulders on Various Types of Primary Highways in North Carolina for the Purpose of Establishing Priority Warrants* (2).

Through a literature review, Heimbach noted that many inconsistencies found in previous studies were probably the result of the fact that shoulders were treated as independent variables when in fact they are related to a design policy based on such factors as traffic volume, terrain type, percent of trucks, etc.

The investigation compared accident rates for two-lane rural primary highways having paved shoulders with accident rates for similar highways having only grass or sod shoulders. The average daily traffic (ADT) volumes ranged from 2,000 to 10,000. Only nonintersection accidents were considered. Sections of highways with 10 geometric and traffic variables matched were compared; the only distinction between them was the type of shoulder design. The significantly lower accident rates on paved shoulder highways were utilized to develop numerical values for the dollar amount of accident cost reduction directly attributable to the presence of a paved shoulder. Treating the dollars of accident cost reductions as benefits, an investment return analysis was performed, relating the benefits to paved shoulder construction costs.

The study utilized an analysis of covariance to identify the highway classification variables sensitive to accident rate differences between highway sections with paved and unpaved shoulders.

The study concluded that a range of paved shoulder construction costs can be economically justified on the basis of accident cost reductions for two-lane, two-way rural primary highways with ADT volumes greater than 2,000. The benefits used in the analysis were conservative because (1) extremely conservative dollar values were used for accident costs, (2) maintenance benefits were not included, and (3) increased pavement service life was not included.

The results of this investigation were derived from data in which the paved shoulders were predominantly 3 to 4 ft wide and were "added on" to an existing highway with little or no change in the alignment. Paved shoulder construction costs did not exceed $14,000 per highway mile. (The North Carolina DOT's current policy is presented in the survey of state DOTs.)

2. *Shoulder Geometric and Use Guidelines* (3).

The objectives of this research were (1) to identify the highway shoulder design practices and the various operational uses of shoulders throughout the United States; (2) to determine optimum utilization of highway shoulders after consideration of such factors as safety, economics, traffic operations, and roadway classifications; and (3) to encourage greater uniformity with the development of shoulder geometric design and use guidelines.

Data were collected by reviewing existing research literature, available in-house reports, and policy manuals prepared by nearly 35 state, city, and highway agencies. Additional data were obtained through interviews with highway agency officials and through on-site observations.

The results of the research indicated that highway shoulders are subjected to a variety of uses by the traveling public, by the adjacent property and business owners, and by the agencies that build and maintain highways, enforce laws, and provide other public services. Twenty-three uses of highway shoulders were identified, and design, geometric, and operational practice data were collected for each use. Each use was examined to determine the reason for the use, the safety of the use, the extent of the use among the sampled agencies, the problems the use may solve, the problems the use may invoke (and their solutions), the economics of the use, the signing and marking required, the geometric designs the use may require, the public acceptance of the use, and the conditions of the use.

Based on the successful practices of representative highway agencies throughout the country, the research results suggested preferences for shoulder geometrics and the signing and marking of shoulders. The report presented acceptable and optimal combinations of shoulder widths, surface types, cross slopes, special signings and markings, and conditions of use that best satisfy the requirements of each of the identified shoulder uses on freeways, arterials, and collectors and locals. For example, for lateral support of mainline pavement, a 1.5-ft paved shoulder at normal depth is acceptable for arterials and a 1-ft stabilized or paved shoulder at normal depth is acceptable for collector and local roads. A 3-ft paved shoulder at full depth is optimal for arterials and collector and local roads. The application of these guidelines should encourage greater uniformity for a given shoulder use. On the basis of the experiences of representative highway agencies in all sections of the country, the guidelines also allow determination of the suitability of various shoulder designs to satisfy the diverse needs of the users of highway shoulders.

3. *A Safety Evaluation of Three-Foot Paved Shoulder Projects* (4).

This report evaluated the effect on accident experience of providing 3-ft paved shoulders. Fifteen project locations were selected from five of the Michigan DOT's nine highway district areas. Control sites selected for comparison had similar operational, geometric, and geographic characteristics. These rural roadway segments were high speed, two-lane, two-way roadways. Approximately 111 miles of 3-ft paved shoulder projects and 97 miles of unpaved shoulder control sites were evaluated. The ADT ranged from about 1,300 to 8,300 for the project locations and control sites. The accident experience for two years "before" and "after" was reviewed for each project and for the corresponding control site. Only accident information for mid-block locations was used with intersection-related accidents excluded. The selection of both project locations and control sites was not random.

It was concluded that the provision of 3-ft paved shoulders on rural, high-speed roadways had little effect on overall accident experience. Run-off-roadway, sideswipe-same-direction, and sideswipe-opposite-direction collisions decreased, whereas the remaining types generally increased.

The overall accident experience and various accident types increased at the control sites. These increases, when compared to the reduction in the accident types at the project locations, provide evidence to support the view that 3-ft paved shoulders have an impact on specific accident types.

In practice, however, careful attention must be placed on the specific type, and the expected accident reduction must be included in the cost/benefit analysis used for project justification. It was apparent that the anticipated savings resulting from the expected reductions in accident types are not sufficient to warrant a shoulder treatment for safety alone. Although such projects do yield safety benefits, continuation of such programs should be based on other than safety-related factors.

The intent of shoulder edge treatments was to reduce maintenance activity and increase overall traffic safety on trunkline roadways where a large number of trucks in the traffic stream was evident. The systematic inclusion of this treatment in most rural resurfacing projects in 1978 was prompted by earlier litigation against the Department.

4. *Feasibility of Paving Shoulders on Low ADT Highways (5).*

An examination of the effectiveness of paved shoulders in reducing accidents and maintenance costs was made using a benefit/cost analysis of present worth. The results indicated that 3-ft paved shoulders were cost-effective when the initial ADT was higher than 1,640 for virgin mixtures (initial cost = $12,700/mile) and 1,085 for recycled mixtures (initial cost = $7,800/mile) (see Table 1).

Table 1

Summary of the Effectiveness of Paved Shouders in Reducing Accidents and Maintenance Costs

Virgin Mixture:

Initial ADT	Initial Cost	Accident Benefits*	Maintenance Benefits*	Total Benefits*	B/C
1,000	$12,700	$ 5,545	$1,500	$ 7,045	0.55
1,500	$12,700	$ 9,975	$1,305	$11,280	0.89
2,000	$12,700	$14,400	$2,145	$16,545	1.30

Recycled Mixture:

Initial ADT	Initial Cost	Accident Benefits*	Maintenance Benefits*	Total Benefits*	B/C
1,000	$7,800	$ 5,545	$1,500	$ 7,045	0.90
1,500	$7,800	$ 9,975	$1,305	$11,280	1.45
2,000	$7,800	$14,400	$2,145	$16,545	2.12

All values are per mile of highway.

*Benefits converted to present worth.

Source: *Feasibility of Paved Shoulders on Low ADT Highways.*

Accident benefits were determined using an accident prediction model based on regression analysis, and maintenance benefits were based on engineering judgment. Detailed information was not available.

Other assumptions made in this analysis included a 2 percent annual increase in traffic; an annual interest rate of 5 percent; a 15-year design life; and accident costs of $200,000/fatal accident, $8,000/injury accident, and $1,090/property damage accident.

During the course of analysis, it was thought that perhaps a policy could be derived based solely on achieving a B/C of 1 or more. This idea was rejected. If it were adopted, there would be no consistency statewide for paving shoulders. This would result in adding a degree of complexity to the design and programming process that would be intolerable.

Wisconsin's policy requires a 3-ft paved shoulder for an ADT above 1,250.

5. *Safety Effects of Cross-Section Design for Two-Lane Roads* (6).

This study was intended to quantify the benefits and costs resulting from lane widening, shoulder widening, shoulder surfacing, sideslope flattening, and roadside improvements. Detailed traffic, accident, and roadway data were collected on 4,951 miles of two-lane roads in seven states. An accident predictive model was developed to determine expected accident reductions related to various geometric improvements. The accident prediction model is presented later in the report. Factors found to be most related to reduced accidents were wider lanes and shoulders, improved roadside conditions, and flatter sideslopes. Paved shoulders were found to have a marginal safety benefit compared to unpaved shoulders.

The effects of shoulder widening on related (AO) accidents was determined for paved and unpaved shoulders. For shoulder widths 0 to 12 ft, the percent reduction in related accidents resulting from adding paved shoulders is 16 percent for 2 ft of widening, 29 percent for 4 ft of widening, and 40 percent for 6 ft of widening. Adding unpaved shoulders would result in 13 percent, 25 percent, and 35 percent reduction in related accidents for 2, 4, and 6 ft of widening, respectively. Thus, it was concluded that paved shoulders are slightly more effective than unpaved shoulders in reducing accidents.

6. Guidelines for Wide Paved Shoulders on Low-Volume, Two-Lane Rural Highways *(7)*.

This study considered the relative benefit/cost ratio for the provision of wide paved shoulders on rural two-lane highways. Cost elements considered were accidents, pavement edge maintenance, paved shoulder surface maintenance, and travel time.

The Maximum Abbreviated Injury Scale (MAIS) was used to determine accident costs per vehicle and per victim. On a seven-point scale, the costs ranged from $1,148 for no injury to $999,343 for a fatality. Annual cost savings and benefit/cost ratios are shown in Table 2 and 3, respectively.

Table 2

Calculation of Annual Cost Savings and Twenty-Year Benefits (Texas)

AADT Group	Annual Cost Savings Per Mile Accidents Savings	Net User Cost Savings	Maintenance Costs	Sum	Benefits Sum Times 12.4622
0–240	N/A	2	-550	N/A	N/A
251–750	4,772	16	-550	4,238	$ 52,814
751–1500	1,624	92	-550	1,166	14,531
1501–3000	15,289	362	-550	15,101	188,192

Interest Rate = 5 percent

Source: *Guidelines for Wide Paved Shoulders on Low–Volume, Two–Lane Rural Highways.*

Table 3

Benefit/Cost Ratios for Driveable Shoulders on Two–Lane Highways (Texas)

Driveable Shoulder Cost/Mile	Benefit/Cost Ratio New Construction $59,840	Existing Roads $42,240
ADT Group		
0–250	N/A	N/A
251–750	0.88	1.25
751–1500	0.24	0.34
1501–3000	3.14	4.46

Source: *Guidelines for Wide Paved Shoulders on Low-Volume, Two-Lane Rural Highways.*

It is concluded that wide paved shoulders (6 to 10 ft wide, that is, driveable shoulders) are cost beneficial for ADTs above 1,500.

7. *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation (8).*

In response to a provision of the Surface Transportation Assistance Act of 1982, the Secretary of Transportation, acting through the Federal Highway Administration, requested the National Academy of Sciences to study the safety cost-effectiveness of geometric design standards and recommend minimum standards for resurfacing, restoration, and rehabilitation (RRR) projects on existing federal-aid highways, except freeways. RRR projects may include resurfacing and other pavement repairs, minor widening of lanes and shoulders, minor alterations to vertical and horizontal alignment, bridge improvements, and removal of roadside hazards.

RRR projects can extend the service life of existing highways through pavement and other repairs and at the same time improve highway safety by making selective improvements to highway geometry and other roadside features. Striking a balance between preservation and safety improvements on RRR projects has proved controversial, however. The controversy has centered on which minimum geometric design standards should be applied to RRR projects to qualify for federal aid.

Minimum lane and shoulder width values that FHWA and state highway agencies can use to set minimum RRR design standards were recommended (Table 4). These recommended values are similar to the minimum lane and shoulder width values proposed by the FHWA in 1978 but include several modifications to improve safety cost-effectiveness. Most important, the ADT ranges are adjusted so that a larger number of roads with high ADT and fewer roads with low ADT would be improved. Lane and shoulder width improvements are more cost-effective on high-volume roads than on low-volume roads.

In terms of cost per accident eliminated, the recommended values are more cost-effective than other standards proposed for nationwide use. For all federal-aid, two-lane rural highways combined, the recommended minimum values require approximately the same overall investment as the FHWA standards proposed in 1978: a total of roughly $13 billion (if all of the lane and shoulder improvements were made at current cost levels). Application of these values, however, would eliminate about 10,000 (40 percent) additional accidents annually.

Less is known about the safety cost-effectiveness of widening urban and multilane rural highways, and minimum values that highway agencies can adopt as standards have not been proposed.

Although paved shoulders are not directly mentioned, issues related to RRR projects were of interest.

Table 4

Recommended Minimum Lane and Shoulder Width Values for Two-Lane Rural Highways for RRR Projects

		10 Percent or More Trucks[b]		Less Than 10 Percent Trucks	
Design Year Volume (ADT)	Running Speed[a] (mph)	Lane Width	Combined Lane and Shoulder Width	Lane Width	Combined Lane and Shoulder Width[c]
1–750	Under 50	10	12	9	11
	50 and over	10	12	10	12
751–2,000	Under 50	11	13	10	12
	50 and over	12	15	11	14
Over 2,000	All	12	18	11	17

[a]Highway segments should be classified as "under 50" only if most vehicles have an average speed of less than 50 mph over the length of the segment.
[b]For this comparison, trucks are defined as heavy vehicles with six or more tires.
[c]One foot less for highways on mountainous terrain.

Source: *Designing Safer Roads: Practices for Resurfacing, Restoration, Rehabilitation.*

Summary

There are numerous similarities and differences in the analysis methods and findings in these studies. The notion that paved shoulders are economically justifiable under certain conditions was generally supported. However, there is no consensus on these conditions.

SURVEY OF STATE DEPARTMENTS OF TRANSPORTATION ON PAVED SHOULDERS ON TWO-LANE ROADS

State departments of transportation were surveyed to determine their policies and practices on paved shoulders on two-lane roads. Thirty-five state DOTs responded to the survey for a 70 percent response rate.

Paved Shoulder Use

Thirty-two of the thirty-five state DOTs (91.4 percent) used paved shoulders on two-lane roads in their design standards to some degree. Information on the types of two-lane roads and the corresponding number of state DOTs is given below.

Types of Two-Lane Roads	Number of State DOTs (percent)
Unspecified	20 (57.1)
Arterials/primary/state	10 (28.6)
Arterials/primary, collector, and local	3 (8.6)
Arterials/primary and collector	2 (5.7)

It is assumed that unspecified state DOTs provided paved shoulder information for arterials/primary/state roads. This assumption is based on (1) the ADT volumes, (2) design standards, and (3) the fact that only 4 of the 50 state DOTs (North Carolina, Virginia, West Virginia and Delaware) maintain the local or secondary road system. Types of two-lane roads considered by North Carolina and West Virginia DOTs were unspecified whereas Delaware specified primary routes.

Minimum paved shoulder widths greater than or equal to 2 ft were used by 21 of the 32 state DOTs (65.6 percent). A 2-ft minimum paved shoulder is used by 10 of the 32 state DOTs (31.3 percent). Most or all shoulders were paved by 15 state DOTs (42.9 percent).

Paved shoulder criteria and the corresponding number of state DOTs are listed below.

Paved Shoulder Criteria	Number of State DOTs (percent)
Most or all shoulders paved	15 (42.8)
ADT and functional classification	4 (11.4)
ADT only	3 (8.6)
All principal arterials only	3 (8.6)
ADT and truck volume	3 (8.6)
Generally no paved shoulders	3 (8.5)
Criteria for RRR and construction/reconstruction only	2 (5.7)
ADT for new and reconstruction	1 (2.9)
Truck volume	1 (2.9)
Totals	35 (100.0)

A summary of the detailed criteria by state is shown in the Appendix.

From a review of demographics and paved shoulder use, it was revealed that all of the northwestern state DOTs pave all shoulders. Since the winters are long and snow plow use frequent, paved shoulders provide a smoother, safer place for plows to operate. The ability of paved shoulders to keep water out of the base and subgrade is even more important when snow is plowed on to the shoulders. No other demographic trend was noted.

Paved Shoulder Benefits

The state DOTs were asked to identify the benefits of paved shoulders. Twenty-one of the thirty-five state DOTs (60 percent) responded to this question. The responses are shown in Table 5. Ten state DOTs (28.6 percent) identified lateral support to the highway (longer service life) and reduced maintenance costs as benefits. In addition to the above, other benefits of interest to this study are improved drainage, providing a recovery area, edge raveling/pavement drop-off control, and decreased accident rate. Although less important, some other benefits may also be experienced.

Table 5

Benefits of Paved Shoulders

Benefits	No. of State DOTS
Lateral Support to the Highway (Longer SVC Life)	10
Reduced Maintenance Costs	10
Accommodating Stopped Vehicles/Emergency Parking	6
Improved Drainage of Roadway	6
Providing a Recovery/Maneuvering	6
Edge Raveling/Pavement Drop-off Control	5
Decreased Accident Rate, Protecting Errant Vehicles	5
Bicycle Safety	4
Reduced Damage by Encroachment of Vehicles	3
Providing a Traffic Lane During Highway Rehab Work	2
Increased Safety for Pedestrians	2
Smoother, Safer Snow Plow Operation	2
A Cleaner Highway/Aesthetic Value	2
Providing for Agricultural Equipment	1
Providing a Sense of a Safe, Open Highway	1
Increased Sight Distance at Horizontal Curves	1
Maintain Capacity	1
Compensation of Off-Tracking	1
Providing a Bus Stop Area	1

Cost Data and Analysis

The state DOTs were asked to provide cost data or a cost analysis on paved shoulder costs. No state DOTs submitted a cost analysis, although nine state DOTs (25 percent) provided some cost data. The useful data will be discussed later in this report. Most state DOTs did not provide data because the data were not readily available. In many instances, costs were not separated by shoulder or roadway maintenance activities.

COST ANALYSIS

This cost analysis examines costs under the current design policy of using unpaved shoulders and the proposed use of 2-ft asphalt paved shoulders. The VDOT value engineering study was a primary data source. The analysis focused on two-lane minor arterials and collector roads and four-lane principal and minor arterials based on functional classification. VDOT data are collected by administrative classification. Consequently, data for the primary system were used because the major target groups are in the primary system.

Initial Cost

Initial costs were considered for two conditions: a new road and resurfacing an existing road.

The initial pavement cost for an average project (24-ft width) and an average project with full depth 2-ft paved shoulders is given below for a new road with asphalt concrete mixtures of VDOT Type B-3 at 6-in depth and S-5 at 1.5 in over a 6-in cement-treated aggregate base (Type I, 21A). The cost for resurfacing an existing 24-ft-wide road and resurfacing with 2-ft paved shoulders through trench widening provide for 1.5 in of S-5 and traffic control. The trench widening consists of cutting out sod to make a 2-ft trench on each side, filling the trench with 6-in aggregate stone, 6 in of VDOT type B-3 asphalt concrete mixture, and overlaying with 1.5 in of S-5 to make the shoulder even with the existing pavement. Service life information is also provided.

	New Road	Resurfacing Existing Road
Average project cost/mile =	$214,292	$50,000
Cost/mile with 2-ft shoulders =	$249,974	$86,000
Cost/mile increase =	$ 35,682	$36,000
Percent increase =	16.7	72.0

Average project service life = 7 yrs
Service life with 2-ft shoulders = 8 yrs
Service life increase = 1 yr
Percent increase = 14.3

The initial cost increase on the average new road project is $35,682 or 16.7 percent. The initial cost increase for the average resurfacing project is $36,000 or 72.0 percent. Trench widening accounts for the increase. The corresponding service life increase is 14.3 percent for both road types. The cost data were obtained from the Construction Division, and service life data were from the value engineering study. The 7-year service life is based on historical data that reveal a 7.3-year average service life for primary roads.

Maintenance Costs

Two types of maintenance activities are related to the use of paved shoulders: general shoulder maintenance (primarily for aggregate shoulders) and edge-of-pavement patching. Computerized printouts of maintenance expenditures for FY 1987–1988 for shoulder maintenance (activity series 140) and patching (activity series 110 except 119) on the primary system were provided by the Maintenance Division.

The total number of centerline miles of primary roads was used to determine the cost per mile. On the primary system, 69.5 percent of the miles are two-lane roads. The actual maintenance expenditures on two-lane primary roads are not available from the computerized records.

North Carolina DOT staff conservatively estimates that a 75 percent reduction in shoulder maintenance is realized when the pavement is extended into the shoulder 2 ft. From the state DOT survey, Iowa DOT listed the following annual costs per mile: for unpaved shoulders (earth/granular 6 to 10 ft wide)—shoulder maintenance cost was $560; for paved shoulders—shoulder maintenance cost was $208. Maintenance cost savings per mile resulting from paved shoulders were $352 or 62.9 percent. Consequently, shoulder maintenance cost savings of 62.9 percent for paved shoulders was used in the analysis. An estimated 25 percent reduction in the cost of pavement patching could be realized as a result of less raveling, less cracking, and improved drainage. The potential cost savings for asphalt shoulders on two-lane primary roads are calculated below using these estimated reductions.

VDOT average annual shoulder maintenance cost/mi = $594
Expected savings with paved shoulder/mi = $374
Annual shoulder maintenance cost with paved shoulder/mi = $220

VDOT average annual pavement patching cost/mi = $553
Expected savings with paved shoulders/mi = $138
Annual pavement patching costs with paved shoulders/mi = $415

VDOT total average annual shoulder-related maintenance cost/mi = $1147
Expected savings with paved shoulders/mi = $512
Annual shoulder-related maintenance cost/mi with paved shoulders = $635

Accident Analysis

There were two objectives in the accident analysis: (1) to determine the expected reduction in accidents attributable to the use of 2-ft paved shoulders and (2) to determine the expected cost savings from the reduction in accidents.

Accident Reduction

The accident prediction model developed by Zeeger, et al., was selected because it was developed in a recent study based on an extensive sample size of 4,951 miles of two-lane roads in seven states. This model was selected because (1) it includes head-on and sideswipe accidents as well as single-vehicle accidents (all of which logically should be affected by roadway geometric features); (2) the coefficients and the R^2 value, 0.456, appear to be reasonable and consistent with the literature; and (3) terrain effects (flat, rolling, or mountainous) are incorporated into the model (*6*). The accident prediction model/equation is (*6*):

$$AO/M/Y = 0.0019\ (ADT))^{0.8824}(0.8786)^{W}(0.9192)^{PA}(0.9316)^{UP}(1.2365)^{H}\ (0.8822)^{TER1}(1.3221)^{TER2}$$

where:

AO/M/Y = related accidents (i.e., single-vehicle plus head-on plus opposite direction sideswipe plus same direction sideswipe accidents) per-mile-per-year,

ADT = average daily traffic,

W = lane width, ft,

PA = average paved shoulder width, ft,

UP = average unpaved (i.e., gravel, stabilized, earth, or grass) shoulder width, ft,

H = median roadside hazard rating (scale of 1 to 7 with 7 as the highest hazard rating)

TER1 = 1 if flat, 0 otherwise,

TER2 = 1 if mountainous, 0 otherwise.

Conditions for Use:

1. Two-lane rural roads with an ADT of 100 to 10,000.

2. Lane widths of 8 to 12 ft.

3. Shoulders 0 to 12 ft wide, which are paved or unpaved (or partly paved and partly unpaved).

Since the current concern is not site specific, a median roadside hazard rating in the middle (4 to 6) was assumed, and 5 was selected as recommended in the informational guide (*9*).

Although a confidence interval for AO/M/Y was desired, it was not determined because the standard error of the estimate was unknown.

A four-step process was used to determine the accident reduction and cost savings based on the reduction in accident frequency for 2-ft paved shoulders compared to the existing unpaved shoulder standards.

1. Use the VDOT Road and Bridge Standards (*10*) to select ADT ranges (with some expansion), two functional road classes (arterials and collectors), and three terrain types, which in turn determine the lane and shoulder widths.

2. For improved accuracy, enter the equation on a microcomputer spreadsheet program in lieu of using nomographs provided in the information guide. The equation is entered twice: (1) for the current unpaved shoulder design width and (2) for the proposed 2-ft paved shoulder plus the remaining shoulder design with unpaved. All other variables are the same for a given road design.

3. Determine the reduction in the number of related accidents per mile per year for the 2-ft paved shoulder versus the standard shoulder design and the corresponding cost savings. This difference and the corresponding cost savings were calculated automatically with data entry of the variables in the model.

4. Develop two matrix tables, one for each road class, for the accident frequency reduction and for the related cost savings for various ADT and terrain types.

When the current road design unpaved shoulder width is changed to a 2-ft paved shoulder and the remaining width unpaved, a 2.6 percent reduction in accident frequency is realized.

Accident Cost Savings

The FHWA recommended approach for determining motor vehicle accident costs was used (*11*). The FHWA recommended accident costs are $1,500,000 per fatality, $11,000 per injury, and $2,000 per vehicle for property damage only (PDO) accident. These costs per incident were used instead of cost per accident in order to include accident experience in Virginia for the specific accident types and accident severity. The following equation is used.

Average cost/accident = (percent of fatal accidents x number of fatalities/ fatal accident x cost/fatality + percent of injury accident x number of injuries/injury accident x cost/injury + percent of PDO accidents x number of vehicles/PDO accident x cost/vehicle) ÷ 100

Average cost/accident was determined for head-on, side-swipe same direction and opposite direction, and fixed-object off-the-road accidents on the primary system.

Using Virginia accident data for 1985 to 1987 (*12*, *13*, *14*), the equation yields:

$$\text{Average cost/accident} = (1.9401 \times 1.1812 \times 1,500,000 + 42.1759 \times 1.4613 \times 11,000$$
$$55.8840 \times 1.4703 \times 2,000) \div 100 = \$42,797$$

The FHWA approach also states that the accident costs should be updated at least every two years. Consequently, a 7.8 percent increase was used based on the increase in the Consumer Price Index (CPI) from 1986 (the base year) to 1988 (*15*). Consequently, the average cost per accident becomes $46,135.

The cost savings per mile per year, determined by multiplying the average cost/accident and the accident frequency per mile per year, are shown in Table 6. The accident cost savings range from $87 to $2,954 depending on the type of highway, ADT, and terrain.

Table 6

Accident Cost Savings

MINOR ARTERIAL

ADT	MOUNTAINOUS	ROLLING	LEVEL
<200	131	99	87
400	210	160	140
1000	472	358	315
2000	755	571	504
4000	1208	913	806
8000	2225	1683	1486
	131–2225	99–1683	87–1486

RANGE 87–2225

COLLECTOR

ADT	MOUNTAINOUS	ROLLING	LEVEL
<200	196	148	131
400	314	210	184
1000	704	469	404
2000	990	658	581
4000	1605	1213	1072
8000	2954	2234	1971
	196–2954	148–2234	131–1971

RANGE 131–2954

For principal arterials and four- and six-lane divided minor arterials, the average cost/accident was determined for side-swipe same direction, and fixed-object off-the-road accidents on the primary system. Including increases from the CPI, the average cost/accident for divided roads was $33,186.

Analysis

The two alternatives were analyzed using the equivalent uniform annual cost (EUAC) method (*16*) as follows.

$$EUAC_A = -I(CR\text{–}i\%\text{–}SL) - SM - PC$$

where

$EUAC_A$ = equivalent uniform annual cost for alternative A

I = initial cost

CR = capital recovery factor

i% = interest rate

SL = service life, years

SM = annual shoulder maintenance cost

PC = annual pavement patching cost

An interest rate of 5.0 percent is used because the real time value of money is 4.5 to 5.0 percent.

For a new road, the EUAC for the two alternatives are

$$\begin{aligned} EUAC_{current} &= -214{,}292(CR\text{–}5.0\%\text{–}7) - 594 - 553 \\ &= -214{,}292\ (.1728) - 594 - 553 \\ &= -37{,}030 - 1147 \\ &= -38{,}177 \end{aligned}$$

$$\begin{aligned} EUAC_{proposed\ new} &= -249{,}974(CR\text{–}5.0\%\text{–}8) - 220 - 415 \\ &= -249{,}974\ (.1547) - 220 - 415 \\ &= -38{,}671 - 635 \\ &= -39{,}306 \end{aligned}$$

$$EUAC_{current} - EUAC_{proposed\ new} = -38{,}177 - (-39{,}306) = 1{,}129$$

When comparing the EUAC of the initial cost alone, the proposed alternative is $1,641 higher than the current design. If the annual savings from the shoulder maintenance, pavement patching, and accident reduction exceeds $1,641, then the proposed alternative has a lower cost. A total maintenance cost savings of $512 is realized with the proposed alternative. Therefore, the proposed alternative, paved shoulders, has an EUAC $1,129 higher than the current design standard before accident cost savings are considered. In other words, an annual accident savings of $1,129 or more is necessary to economically justify the use of paved shoulders. The next step is to determine the ADT threshold that will result in the accident cost savings being equal to $1,129 for the three terrain types for each functional classification. At this ADT value, the costs of the two alternatives are equal; any ADT greater than the threshold will yield a savings for the 2-ft asphalt paved shoulder alternative.

RESULTS

Two-Lane Roads

The analysis results (including ADT threshold values) are shown in Table 7 for new roads and for resurfacing existing roads. The ADT threshold values for new roads can be expected to be exceeded by some minor arterials and collectors.

Table 7

Analysis Results for Two-Lane Road

	New Road	Resurfacing Existing Road
Average project cost/mi	$214,292	$50,000
Cost/mi with 2-ft shoulder	249,974	86,000
Cost/mi increase	35,682	36,000
Percent increase	16.7	72.0
EUAC present	- 38,177	- 9,787
EUAC proposed	- 39,306	-13,939
Difference in EUAC	1,129	4,152
Minor Arterial		
ADT Threshold by Terrain Type		
Mountainous	3,705	16,210
Rolling	5,085	22,240
Level	5,860	25,635
Collector Roads		
ADT Threshold by Terrain Type		
Mountainous	2,690	11,755
Rolling	3,690	16,130
Level	4,250	18,595

The ADT threshold values for resurfacing existing roads are so high that almost all two-lane roads will not exceed the threshold values; therefore, the use of 2-ft paved shoulders is not economically justified by trench widening with the resurfacing of existing two-lane roads.

Four-Lane Roads

The analysis results for one direction of a four-lane road are presented in Table 8. For a new road, a savings of $1,631 is realized with a 2-ft paved shoulder. The increase in service life more than offsets the initial cost increase and accounts for $1,119 of the savings. The remaining savings ($512) is from maintenance cost reductions. These savings are realized without considering accident reductions. Two-foot paved shoulders are economically justified for all new four-lane roads.

Table 8

Analysis Results for One Direction of a Four-Lane Road with Two-Foot Right Shoulder

	New Road	Resurfacing Existing Road
Average project cost/mi	$214,292	$50,000
Cost/mi with 2-ft shoulder	232,133	68,000
Cost/mi increase	17,841	18,000
Percent increase	8.3	36.0
EUAC present	- 38,177	- 9,787
EUAC proposed	- 36,546	-11,155
Difference in EUAC	- 1,631	1,368
Undivided Road		
One Direction ADT Threshold by Terrain Type		
Mountainous	0	4,605
Rolling	0	6,320
Level	0	7,285
Divided Road		
ADT Threshold by Terrain Type		
Mountainous	0	5,700
Rolling	0	9,180
Level	0	10,580

The ADT thresholds for four–lane existing roads should be used with caution. The accident model used was developed for two-lane roads. The model was used to determine the reduction in accidents expected when a paved shoulder exists. It is assumed that this accident reduction for four-lane roads would be similar to the accident reduction for two-lane roads. The same primary system accident data were used for both two- and four-lane roads. Moreover, there was no model available to predict such accident reductions specifically for four-lane roads.

Many four-lane undivided and divided roads exceed the threshold values. Therefore, the use of 2-ft paved shoulders are economically justified with the resurfacing of existing roads with certain ADT volumes.

Limitations for Use of ADT Thresholds for Paved Shoulders

A 2-ft paved shoulder provides a benefit by removing the pavement edge away from the travel lane. Consequently, reductions in shoulder maintenance and pavement edge raveling repairs are realized. To ensure that the 2-ft paved shoulder is not used as part of a wider travel lane, it is required that all roads eligible for paved shoulders have a road width of 20 ft or greater and have edgeline and centerline pavement markings. To be effective, edgeline markings must be installed to maintain a 2-ft paved shoulder. In other words, the lane width must remain the same after installation of the paved shoulders.

Summary

This analysis of the alternatives was conducted with the available data. Consequently, the analysis has a reasonable level of confidence. It is acknowledged that although the maintenance-related costs and accident costs are not exact, they are supported by the information available.

OTHER ISSUES

Several issues were identified in the review of value engineering studies on (1) paved shoulder extensions on new roads and (2) bikeway facilities. The issues regarding bikeway facilities are scheduled to be addressed in an FHWA pooled-fund research project entitled *The Effect of Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations*. Seven issues are discussed below.

Paved Shoulders for All Roads Versus Selected Roads

The Value Engineering study recommended 2-ft paved shoulders for all new roads 20 ft wide or wider. Expanding this to a policy to pave 2 ft of shoulders on all roads with pavement widths of 20 ft or wider would provide the most widespread impact. The design and programming process would be facilitated compared to a process with a decision-making step to determine if paved shoulders are required. Blanket use of paved shoulders would yield statewide uniformity and consistency. Fifteen state DOTs (42.9 percent) pave most or all shoulders on arterials/primary/state roads.

By limiting paved shoulders to selected roads, usage may be restricted to roads that yield lower EUAC. Fourteen state DOTs (40 percent) use a threshold to determine when to use paved shoulders. The analysis indicated that paved shoulders provide a savings compared to the current design for new and existing roads with an ADT equal to or above those identified in the previous section. However, 2-ft paved shoulders are not economically justified for existing two-lane roads.

Therefore, paved shoulders are economically justified for all new four-lane roads, selected new two-lane roads, and existing four-lane roads.

Wider Pavements on STAA Routes

It was suggested that the need to widen the pavement to accommodate longer vehicles on STAA (Surface Transportation Assistance Act) routes be examined as part of this effort because it involved extending the pavement. The Traffic Engineering Division is responsible for approving STAA routes. It is difficult to predict what routes need improvement as a result of the longer vehicles that are to travel on them. In the current process, the following steps occur: (1) the trucker or firm requests permission to use a non-STAA route; (2) the Traffic Engineering Division then examines the route and determines if it is safe for travel; (3) if it is not approved for use, then the improvements needed to make the road acceptable are identified. The Traffic Engineering Division has found this case-by-case approach to be acceptable and preferable.

Opposition from Subdivision Developers

If subdivision streets are required to have 2-ft paved shoulders, then VDOT can expect to receive a considerable amount of opposition and protests from developers. The additional costs will likely be passed on to home buyers. The costs can be justified based on lower maintenance costs for VDOT and safer roads for the subdivision residents. Paved shoulders should be used on new subdivision collector streets that exceed the ADT threshold values.

Two-Foot Paved Shoulders Versus a One-Foot Wider Lane and a One-Foot Paved Shoulder

When a current unpaved shoulder is changed to a 2-ft paved shoulder with the remainder unpaved, a 2.6 percent reduction in accident frequency is realized. When the lane width is increased by 1-ft and 1-ft of the shoulder width is paved, a 6.9 percent reduction in accident frequency is realized. An additional 4.3 percent reduction in accident frequency is realized for a 1-ft wider lane and 1-ft paved shoulder compared to the 2-ft paved shoulder. When the design lane width is less than 12 ft, substantial additional accident cost savings may be experienced without an increase in the initial cost. For example, a $1,129 accident cost savings increases to $2,969. The lane widening and paved shoulder combination is promising. Another alternative is to widen the lanes to 12 ft and provide 2-ft paved shoulders. On the other hand, based on the road designs standards (*10*) and ADT threshold values, a 12-ft lane width (11 ft for selected mountainous areas) is expected at most locations that justify a 2-ft paved shoulder.

One Direction of a Six-Lane Road

Since the conditions where 2-ft paved shoulders are economically justifiable on two- and four-lane roads have been identified, it is suspected that there may be some interest in identifying such conditions for six-lane roads. This analysis is presented in Table 9. As with four-lane roads, the accident analysis must be used with caution.

A 2-ft paved shoulder is economically justified for all new six-lane roads. VDOT does not typically design new six-lane undivided roads. However, six-lane undivided roads sometimes result from the widening of a four-lane undivided road. The resurfacing of existing roads with 2-ft paved shoulders are economically justifiable for many six-lane roads.

Four-Foot Paved Shoulders For Bicyclists

It was suggested that a minimum paved shoulder of 4 ft be used to accommodate bicyclists. This recommendation was based in part on the Commissioner's interest and support for accommodating bicyclists. The VDOT Bicycle Advisory Committee was established to examine the extent to which VDOT policies and standards accommodate bicyclists. The preferred method for accommodating bicyclists, be it a paved shoulder, a wider right lane, or other alternative has not been identified. Nevertheless, the analysis results for 4-ft paved shoulders are shown in Tables 10, 11, and 12 for two-, four-, and six-lane roads, respectively.

From Table 10, only on a limited number of new two-lane roads and practically on no existing two-lane roads can 4-ft paved shoulders be economically justified. On the majority of new four-lane roads and a limited number of existing four-lane roads, 4-ft paved shoulders can be economically justified. On all new six-lane roads and a limited number of existing six-lane roads, a 4-ft paved shoulder can be justified. Two-foot paved shoulders are economically justified for a greater number of road miles than 4-ft paved shoulders. Consequently, the potential cost savings are greater with implementation of the 2-ft paved shoulder.

Table 9

Analysis Results for One Direction of a Six-Lane Road
with Two-Foot Right Shoulder

	New Road	Resurfacing Existing Road
Average project cost/mi	$321,438	$75,000
Cost/mi with 2-ft shoulder	339,279	93,000
Cost/mi increase	17,841	18,000
Percent increase	5.5	24.0
EUAC present	- 56,691	-14,107
EUAC proposed	- 53,121	-15,022
Difference in EUAC	- 3,570	915
Undivided *		
ADT Threshold by Terrain Type		
Mountainous	0	2,920
Rolling	0	4,005
Level	0	4,620
Divided		
ADT Threshold by Terrain Type		
Mountainous	0	4,240
Rolling	0	5,820
Level	0	6,710

*VDOT typically does not design new six-lane undivided roads.

Table 10

Analysis Results for Two-Lane Road with a Four-Foot Shoulder

	New Road	Resurfacing Existing Road
Average project cost/mi	$214,292	$ 50,000
Cost/mi with 4-ft shoulder	285,679	122,000
Cost/mi increase	71,387	72,000
Percent increase	33.3	134.6
EUAC present	- 38,177	- 9,787
EUAC proposed	- 44,830	-19,508
Difference in EUAC	6,653	9,721
Minor Arterial		
ADT Threshold by Terrain Type		
Mountainous	12,800	19,670
Rolling	17,565	26,995
Level	20,245	31,115
Collector Roads		
ADT Threshold by Terrain Type		
Mountainous	9,285	14,270
Rolling	12,740	19,580
Level	14,685	22,565

Table 11

Analysis Results for One Direction of a Four-Lane Road with a Four-Foot Right Shoulder

	New Road	Resurfacing Existing Road
Average project cost/mi	$214,292	$50,000
Cost/mi with 4-ft shoulder	249,974	86,000
Cost/mi increase	35,682	36,000
Percent increase	16.7	72.0
EUAC present	- 38,177	- 9,787
EUAC proposed	- 39,306	-13,939
Difference in EUAC	1,129	4,152
Undivided		
ADT Threshold by Terrain Type		
Mountainous	1,460	7,505
Rolling	2,355	10,295
Level	2,715	11,865
Divided		
ADT Threshold by Terrain Type		
Mountainous	2,125	9,280
Rolling	3,420	14,955
Level	3,940	17,235

Table 12

Analysis Results for One Direction of a Six-Lane Road with a Four-Foot Right Shoulder

	New Road	Resurfacing Existing Road
Average project cost/mi	$321,438	$ 75,000
Cost/mi with 4-ft shoulder	357,120	111,000
Cost/mi increase	35,682	36,000
Percent increase	11.0	48.0
EUAC present	- 56,671	-14,107
EUAC proposed	- 55,881	-17,807
Difference in EUAC	- 809	3,699
Undivided *		
ADT Threshold by Terrain Type		
Mountainous	0	6,580
Rolling	0	9,030
Level	0	10,410
Divided		
ADT Threshold by Terrain Type		
Mountainous	0	9,560
Rolling	0	13,120
Level	0	15,120

*VDOT does not typically design six-lane undivided roads.

CONCLUSIONS

The following conclusions can be drawn from this study:

1. The literature review identified similarities and differences in the results of studies:

   - One study recommended use of 3- to 4-ft shoulders for ADT above 2,000 based solely on accident reductions, whereas another study concluded accident reductions alone do not warrant 3-ft paved shoulders.
   - One study resulted in a policy of 3-ft paved shoulders for ADT above 1,250, and another recommended 6- to 10-ft paved shoulders for ADT > 1,500.

- The literature review generally supported the notion that paved shoulders are economically justifiable under certain conditions. There was no consensus on the specific conditions.

2. From a survey of state departments of transportation, it was found that:

   - Paved shoulders were used to some degree by 32 of 35 state DOTs (91.4 percent).
   - Most or all shoulders are paved by 15 state DOTs (42.9 percent)
   - Fourteen state DOTs (40.0 percent) have threshold values to warrant paved shoulders.
   - Minimum paved shoulder widths greater than or equal to 2 ft were used by 21 of 32 state DOTs (65.6 percent).
   - Two-foot paved shoulders are used by 10 of the 32 state DOTs (31.3 percent).
   - Ten state DOTs (28.6 percent) each noted lateral support of the highway and reduced maintenance costs as benefits of paved shoulders.

3. From the cost analysis, it was found that:

   - Initial cost increases on the average new road project are 16.7 and 8.3 percent with a corresponding service life increase of 14.3 percent when 2-ft asphalt paved shoulders are used on two- and four-lane roads, respectively.
   - When the current road design unpaved shoulder width is changed to a 2-ft paved shoulder and the remaining width unpaved, a 2.6 percent reduction in accident frequency is realized.
   - An annual total maintenance cost savings of $512 is expected when using 2-ft paved shoulders; therefore, an annual accident cost savings per mile of $1,129 is needed to economically justify 2-ft paved shoulders on new roads.
   - Two-foot paved shoulders are economically justifiable on (1) all new four-lane roads and (2) new two-lane roads and existing four-lane roads that exceed ADT threshold values. They are not economically justifiable on most existing two-lane roads.
   - Roads that are eligible for paved shoulders must be greater than 20 ft wide and have edgeline and centerline markings. For the paved shoulders to be effective, edgeline markings must be installed to maintain a 2-ft paved shoulder.

4. Discussions on other issues concluded that:

   - The current procedure for examining STAA routes for use by longer vehicles is sufficient.
   - Two-foot paved shoulders are economically justified on all new six-lane roads and many existing six-lane roads.
   - Four-foot paved shoulders are economically justified on (1) all new six-lane roads, (2) a majority of new four-lane roads, and (3) a limited number of new two-lane roads and existing four- and six-lane roads.

- The potential for installation and subsequent cost savings for 2-ft paved shoulders is much greater than for 4-ft paved shoulders.

RECOMMENDATIONS

Based on the results of this study, the following recommendation is made:VDOT should consider using 2-ft, asphalt paved shoulders (mainline pavement extended) for all new four- and six-lane roads and for all roads that have ADT values that exceed those shown in Table 13. For existing roads that exceed the threshold, 2-ft paved shoulders should be installed when resurfacing is scheduled. For paved shoulders to be considered, the roadway width must be 20 ft or wider, and the road must have edgeline and centerline pavement markings. After installation of the 2-ft paved shoulders, centerline markings must be installed to keep the lane width unchanged and to maintain a 2-ft paved shoulder. It may be desirable to round up the threshold values or otherwise simplify these values. For existing roads that have lane widths less than 12 ft, it is suggested that the need to widen the lanes be determined through the appropriate VDOT process.

Table 13

Recommended ADT Threshold Values for Two-Foot Paved Shoulders

	Mountainous	Rolling	Level
New Two-Lane Minor Arterials	3,705	5,085	5,860
New Collector	2,690	3,690	4,250
All New Four- and Six-Lane undivided, and divided roads	0	0	0
Existing Four-Lane Undivided Road	4,605	6,320	7,285
Existing Four-Lane Divided Road	5,700	9,180	10,580
Existing Six-Lane Undivided	2,920	4,005	4,620
Existing Six-Lane Divided	4,240	5,820	6,710

Notes:
1. Principal arterials are four- and six-lane divided roads. Multilane minor arterials are either divided or undivided.
2. For two-lane roads, the ADT threshold values are for total ADT and for a 2-ft paved shoulder on both sides of the roadway. For multilane highways, the ADT threshold values are for one direction only and for a 2-ft paved right shoulder.

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APPENDIX

PAVED SHOULDER CRITERIA FOR TWO-LANE ROADS

State DOT	
Alabama	For ADT > 2500 (considering shoulder continuity), 8 ft paved + remainder stabilized — also for topographic conditions that encourage high shoulder usage. For ADT > 1800 (considering shoulder continuity), 4 ft paved + remainder stabilized — Also if truck volume is > 18%.
Alaska	Shoulders on rural arterials are generally paved. AASHTO.
Arkansas	For 12 ft lanes, 2 ft paved shoulder + 6 - 8 ft prime coat. For 10 ft lanes, 4 ft paved shoulders. AASHTO or RRR standards.
Arizona	All shoulders are paved. Shoulder width is 2, 5, or 8 ft for R5, R4, and R3 road types, respectively. R5, R4, and R3 are similar to local, collector, and arterial roads, respectively.
California	Paved shoulders for new construction: ADT < 400, 2 or 4 ft; ADT = 400–1500, 6 ft; ADT> 1500, 8 ft. Paved should option for RRR: ADT = 3000–6000, 2 ft min.; ADT > 6000, 4 ft min.
Colorado	For DHV > 100, minimum of 3 ft of paved shoulder required (remainder stabilized); consider paving full shoulder if it is used for escape, parking, or if truck volume is significant. AASHTO.
Connecticut	Most state routes have paved shoulders except minor routes without shoulders. AASHTO.
Delaware	Paving shoulders to 8 ft min. width on primary routes. Currently, 64% of these routes have paved shoulders. AASHTO.
Florida	4–ft paved shoulder on all principal arterials and all ADT > 5000 and all ADT > 1600 within 1 mi of an urban area and on coastal routes where borrowing materials are of poor quality for growing grass.
Idaho	All shoulders are paved. For primary routes, 5 ft min.; for collector routes, 2 ft min. AASHTO.
Illinois	For construction and reconstruction on arterials: 10 ft paved shoulders; for RRR: ADT < 1000, 1 ft paved + 3 ft aggregate; ADT + 1000 - 2999, 1 ft paved + 3–4 ft aggr.; ADT > 3000, 3 ft paved + 3–4 ft Aggr.
Indiana	All paved shoulders. ADT < 800, 8 ft; ADT = 800–2000, 10 ft; ADT > 2000, 11 ft.
Iowa	Generally no paved shoulders.
Kentucky	For rural Arterials, 2- to 4–ft paved shoulder + remainder stabilized. AASHTO.

Maryland	Paved shoulders if: truck ADT > 500 one way in 10th yr of life (use min. 4 in depth); truck ADT > 50 one way in 10th yr of life; shoulders designed to carry 2 yrs of mainline traffic in 10th yr or life; designated bike paths. On collectors, shoulder width = 8 ft. On local roads: ADT > 400, 4 ft; ADT = 400–700, 6 ft; ADT > 700, 8 ft.
Minnesota	For Principal arterials: ADT = 1000 - 1999, 2 - 8 ft paved of 5 - 10 ft shoulder; ADT = 2000 - 3999, 2 - 10 ft paved of 6 - 11.5 ft; ADT > 4000, 2 - 10 ft paved of 8 - 11.5 ft. for minor arterials: ADT = 1000 - 1999, 2 ft paved of 3 - 9 ft; ADT = 2000–3999, 2 - 8 ft paved of 4 - 10 ft; ADT > 4000, 2 - 8 ft paved of 6 - 10 ft shoulder and paved width depends on 4 tier set of designs.
Mississippi	No paved shoulders. AASHTO.
Missouri	ADT = 750 - 3500, 2 ft or 6–10 ft shoulder paved option; ADT > 3500, full shoulder paved 8–10 ft. AASHTO.
Montana	All shoulders are paved. AASHTO.
Nevada	Paved shoulders almost entirely. AASHTO.
New Jersey	All two lane roads are primary roads and have 8 ft. min. paved shoulders. AASHTO.
New Mexico	Most shoulders are paved. Seldom use of surface treatment. AASHTO. TRB special report 214 on RRR for design exceptions to AASHTO.
New York	All shoulders are paved. AASHTO.
North Carolina	For new and reconstruction: ADT > 4000, 2 ft paved shoulders. Paved shoulders on existing roads are decided on a project basis. Shoulder continuity considered. AASHTO.
Ohio	For arterials with ADT > 400 - DHV < 200, 6 ft bit. surface treatment shoulder; with DHV > 200, bit. surface treatment shoulder if truck ADT = 250 - 1000; paved shoulder if truck ADT > 1000.
Oklahoma	Paved shoulders for: principal arterials - ADT > 5000, 10 ft; ADT < 5000, 8 ft; minor arterials - ADT > 2500, 8 ft; ADT < 2500, 2 ft paved + 6 ft sod; major collectors - ADT > 2500, 8 ft; ADT = 1250 - 2500, 2 ft paved + 6 ft sod
Oregon	All paved shoulders. AASHTO.
Pennsylvania	Paved shoulders for RRR projects: ADT < 1000 and truck < 100, 2 ft; ADT = 1000 - 2000 and trucks < 200, 2 - 3 ft; ADT = 2000–4000 and truck < 400, 3 - 4 ft; ADT = 4000 - 10,000 and trucks < 1000, 4 - 5 ft; ADT > 10,000 and trucks < 2000, 5 ft; ADT > 20,000 and trucks > 10%, 6 ft. Truck ADT criteria governs. AASHTO.

South Carolina	For only one two-lane road, 2 ft of a 10–ft shoulder paved. AASHTO.
South Dakota	All shoulders are paved. Typically 8 ft on new construction, 4 ft on resurfacing for asphalt.
Texas	Full width paved shoulders for all arterials. Also for collectors with future ADT > 3000. Shoulder surfacing is not required but is desired even if partial for other collectors and all local roads.
Utah	All paved shoulders. ADT < 50, 3 ft; ADT 50 - 400, 4 ft; ADT = 400 - DHV = 200, 6 ft; DHV > 200, 8 ft.
Vermont	All shoulders are paved. AASHTO.
Wisconsin	3–ft paved shoulder on Arterials with ADT > 1250. Full width paved shoulders where ADT > 1000 and 2-way bike volumes > 25/day and suburban areas where closely spaced driveways and/or frequent turning movements result in excessive maintenance. Consider shoulder continuity.
West Virginia	ADT = 1000 - 2999, 8 ft paved shoulder; ADT > 3000, 10 ft paved shoulder. Selective shoulder paving where run-off-road or pavement edge drop problems exist or are likely, and steep grades with shoulder erosion problems.