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Benefit-Cost Analysis of Lane Marking

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Pavement markings save lives and reduce congestion. A benefit-cost analysis of edgelines, centerlines, and lane lines is presented. The analysis considers marking applied with fast-drying paint or thermoplastic, the most frequently used marking materials in the United States. A literature review and telephone survey suggested striping with fast-drying paint costs $0.035/linear-ft in rural areas and $0.07/linear-ft in urban areas. Thermoplastic lines cost more than painted ones, but they can have lower life-cycle costs; in areas where snowplowing is unnecessary, they have longer lives. Published literature suggests that existing longitudinal pavement markings reduce crashes by 21 percent and edgelines on rural two-lane highways reduce crashes by 8 percent. Applying these percentages to published aggregate crash costs by roadway type yields the safety benefits. The analysis assumes markings improve traffic flow from 6:00 a.m. to 7:00 p.m. on arterials, freeways, and Interstate highways, increasing average speeds by 2 mph. On average, each dollar currently spent on pavement striping yields $60 in benefits. The benefit-cost ratio rises with traffic volume. The urban ratio is twice the rural ratio. The sensitivity analysis shows the benefit-cost ratios are robust. Where striping reduces congestion, the travel time savings alone yield a positive benefit-cost ratio for striping. Most highways already have a full complement of lines; rural two-lane highways, however, sometimes lack edgelines. Edgelines on these roads will yield benefits exceeding their costs if an average of one nonintersection crash occurs annually every 15.5 mi of roadway.

Driving down a dark road on a misty night is never pleasant. The only comfort comes from centerlines and edgelines. These pavement marking, along with lane lines, are important driving aids. The driver's manual advises watching the edgeline when blinded by oncoming headlights. Lane lines organize vehicles into efficient lanes on multilane roads. Centerlines help oncoming vehicles to avoid collisions. Even in daylight, pavement markings make it possible for vehicles to travel more safely and quickly. They reduce congestion and raise roadway capacity.

This paper probes the costs and benefits of roadway pavement markings. It restricts itself to edgelines, centerlines, and lane lines, the longitudinal lines that run parallel to traffic. It shows that existing markings on different classes of roads have benefit-cost ratios ranging from 21 to 103. Most roads already have a full complement of lines. Some rural two-lane highways, however, lack edgelines; a few even lack centerlines. Edgelines would be cost-effective on a mile of rural two-lane highway if one crash a year occurred outside the roadway every 15.5 mi.

MARKING MEDIA

Longitudinal pavement markings typically are applied using a liquid marking medium or binder that is visible during the

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day. The medium binds glass beads that make the lines visible when headlights shine on them at night. The principle underlying night visibility is retroreflectivity. Retroreflection means light reflects off the binder-coated backs of the beads and is returned to its source. Because the beads are almost perfectly round, the retroreflected light is concentrated in a small angle of return, making the marking conspicuous.

Existing binders include fast-drying high-solvent paint, latex paint, thermoplastic, epoxy, and polyester. Some markings are also applied using preformed tape. This paper computes benefit-cost ratios for the marking media that historically captured the largest market shares: high-solvent paint and thermoplastic. Other media, especially latex paint, have gained market share recently.

Fast-drying high-solvent paint has dominated the U.S. market for many years. It is inexpensive to buy and apply. Because it dries quickly, a trailing vehicle moving at 10 to 15 mph can prevent traffic from tracking the newly applied paint. High-solvent paint has two drawbacks: a short life, often as little as 6 to 12 months, and environmentally damaging emissions during application. The newer latex paints are waterborne rather than solvent-borne. Thus, they avoid emission problems. Most latex formulations dry more slowly than high-solvent paint; typically, application proceeds at 5 mph.

Thermoplastic has captured roughly an eighth of the U.S. striping market. Although costly to buy and apply, it has a long life—4 to 7 years. Thermoplastic lines are much thicker than painted lines, which makes them more vulnerable to snowplow damage. Contractors apply most thermoplastic in most states.

BENEFIT-COST EQUATION

The benefit-cost ratio (BCR) computed in this paper equals the monetized benefits from pavement marking divided by the marking costs. Let B equal the benefits expected per year from pavement marking and C equal the annualized marking costs. Then the benefit-cost ratio is

$$BCR = B/C \tag{1}$$

The benefits include increased safety and reduced travel time.

UNIT COSTS OF MARKING

Pavement markings rarely require maintenance between applications. Their useful life ranges from 6 months to 7 years depending on the marking medium, traffic volume, location (lane lines and centerlines require more frequent replacement

than edgelines), and snowplowing (plowing bare road causes rapid deterioration). The annualized application costs are

$$C = M + P + E + \text{ADMIN} \qquad (2)$$

where

M = annualized materials costs, including binder, beads, and fuel;

P = annualized personnel costs, including wages, fringe benefits, and per diem when striping crews are away from home overnight;

E = annualized costs of equipment and storage facilities; and

ADMIN = annualized contract letting, monitoring, and other administrative costs.

The annualized costs include multiple applications for which the useful life is less than a year. The annualization multipliers used were capital recovery factors computed using the formula by Winfrey (1). The analysis used a discount rate (present value factor) of 4 percent. That rate is recommended for use in analyzing highway safety countermeasures with lives less than 5 years (2). The sensitivity analysis examined the benefit-cost ratio at a 10 percent discount rate.

Data on marking costs were drawn from a literature review and a telephone survey. Table 1 summarizes the cost estimates per application. The top panel in the table shows published estimates; the bottom panel shows the estimates from the telephone survey. Typically, the installed cost of high-solvent paint, in 1991 dollars, is $0.035/linear-ft of 4-in. stripe in rural areas and $0.07/linear-ft in urban areas.

Thermoplastic costs vary widely, ranging from $0.15 to $0.40/linear-ft. The average is $0.32/linear-ft. Reasons that the telephone survey suggested for the wide variation include

• Thermoplastic lines range from 60 to 120 mils in thickness (with corresponding differences in materials cost and useful life).
• The war-related surge in oil prices at least temporarily raised materials costs.
• Contractor availability varies—prices are higher where contractors are scarce.
• Thermoplastic is produced primarily in southern and western factories, and shipping it elsewhere is costly.
• Thermoplastic costs are sensitive to propane costs, which vary regionally (propane is used to heat and agitate the thermoplastic).

Rural-Urban Variation

Most published costs are state averages. They mask substantial variability. Costs are low in suburban and rural areas where daylong striping will not disrupt traffic significantly. Urban striping costs often are higher. Reasons that the telephone survey suggested for higher urban costs are

• The striping day is short to avoid delaying rush-hour traffic.
• Striping roads with daylong congestion requires extra staff and equipment to control traffic.
• More time and care are required because the longitudinal pavement markings must mesh with many crosswalks, stop lines, and other special markings.

TABLE 1 PAVEMENT MARKING COSTS

Source	Year	High VOC Paint Avg ($/ft)	Range	Thermoplastic Avg ($/ft)	Range
Henry et al. (14); 14 states	1988	.035	.02-.055	.35	.17-.60
Aurand et al. (11); 9 states, 6 manufacturers	1988	.035		.17	
Hughes et al. (15); state survey	1983	.035	.02-.07		
Attaway et al. (16); N.C.	1988		.03-.045		.28-.40
Mendola (17); N.J.	1988				.15-.28
DePaulo (18); Ohio	1988	.035	.035-.04		
SASHTO (19); 14 states	1991	.035	.02-.05	.24	.12-.40
California	1990	.035	.10contr	.26	
Colorado	1991	.04	.055contr	.40	
Florida	1991	.04	.08contr		.25-.35
Illinois	1991	.02		.37	
Los Angeles, Calif.	1991	.06		.28	
Maine	1991	.035			
Md./Va. contractor	1991			.32	.30-.50
Montana contractor	1991		.04-.045		
North Carolina	1991	.03	.09contr	.35	
Phoenix, Ariz.	1991	.07	.085contr	.29	
Texas	1991	.035rur, .07urb		.35	.22-.45

NOTE: All items inflated to December 1990 dollars using the Consumer Price Index.

Comparing costs between striping media requires caution. The costs for high-solvent paint in Table 1 assume lines will retrace existing lines. Such restriping generally is done by state forces. Striping after repaving or chip sealing requires premarking to establish line locations. This costs perhaps $0.005 to $0.01/linear-ft. The paving contract generally includes premarking and striping. Because striping usually is subcontracted, contract costs include two tiers of administrative expenses and profits. Unlike painting contracts, thermoplastic contracts are often first-tier contracts.

The contract paint and thermoplastic costs in Table 1 exclude the costs of contract letting and monitoring. The Texas Department of Transportation (DOT) estimated these costs at 5 percent of the contract price. The North Caroline DOT, which inspects more extensively than most, estimated the costs at 7 percent.

Values Used

The analysis used the following marking costs and material lives:

• $0.035/linear-ft rural and $0.07/linear-ft urban for high-solvent paint, with restriping every 6 months on Interstates, other freeways, and major urban arterials, and every 12 months on other roads. At a 4 percent discount rate, the annualized costs per mile are $381 for rural Interstates, $192 for other rural roads, $762 for urban freeways and major arterials, and $385 for other urban roads. For striping and premarking by contractors every seventh year, $0.09/linear-ft, implying an annualized premarking premium of $49/mi rural and $18/mi urban. Including the premarking cost, for example, the annualized cost per mile on most rural roads total $241. These costs assume all lines are solid, single stripes. The sensitivity analysis examines an alternative assumption.

• $0.26/linear-ft rural and $0.33/linear-ft urban for thermoplastic, with restriping every 5 years. Where climate is appropriate for thermoplastic, state materials choices suggest its life-cycle costs are competitive with high-solvent paint if average daily traffic (ADT) exceeds roughly 2,500. The annualized costs per mile are $308 rural and $391 urban.

Miles Striped

The miles striped by roadway type and land use were computed using data on number of lanes by roadway mileage from FHWA's 1988 highway statistics (3). Undivided highways require one edge or lane line per lane and a centerline. For example, a four-lane highway requires two edgelines, two lane lines, and a centerline; a six-lane highway requires two more lane lines. Each side of a divided highway requires one edge or lane line per lane and an additional edgeline. Line mileage was computed using the following assumptions:

• Divided Interstate highways with more than four lanes have an average of seven lanes in urban areas and six lanes in rural areas.
• Other divided urban freeways with four or more lanes average five lanes. Divided major arterials average 4.5 lanes.
• Other divided roads with four or more lanes average four lanes.
• Undivided roads with more than two lanes average four lanes.

The first column of data of Table 2 shows the line miles by roadway functional class (excluding local streets, which are rarely wide or heavily traveled enough to stripe) and rural-urban land use. Rural roads, primarily major collectors, account for more than 75 percent of the line miles.

BENEFITS OF MARKING

The benefits of marking, B in Equation 1, are the present value of the sum of the annual benefits. The benefits for a 1-mi road segment are

$$B = A * R * CS + V * T(1/S_O - 1/S) \qquad (3)$$

where

A = crashes per year on road segment,
R = fractional reduction in crashes expected due to marking,
CS = cost savings per crash prevented,
V = annual traffic volume on road segment,

TABLE 2 LINE MILES AND CRASH COSTS BY ROADWAY FUNCTIONAL CLASS AND LAND USE, EXCLUDING LOCAL STREETS

Road Type	Urban		Rural	
	Line Miles	Costs	Line Miles	Costs
Interstate	84,520	$12,230	201,525	$10,489
Other freeway	51,187	6,602	0	0
Major arterial	238,852	58,260	303,499	23,102
Minor arterial	270,822	41,963	460,750	23,094
Major collector	245,512	17,136	1,321,942	30,330
Minor collector	0	0	886,192	14,642
Total	890,893	$136,191	3,173,908	$101,657

NOTE: Costs in millions of December 1990 dollars.

T = value of 1 vehicle-hr of travel time,
S_o = average speed on road segment before marking, and
S = average speed on road segment after marking.

Cost Savings of Crash Prevention

Safety benefits—the crash cost savings—were adapted from data from Miller et al. (4). They include medical, emergency services, workplace, legal, property damage, travel delay, and administrative costs, as well as lost wages and household production; and pain, suffering, and lost quality of life. The benefit values were derived using the method dictated by FHWA (5) and the U.S. Office of Management and Budget (OMB) (6) for valuing life-saving benefits.

The analysis by roadway functional class (e.g., rural Interstate, urban arterial) uses total crash costs by road type and land use from Miller et al. (4). Total crash costs equal A_i * CS. The second data column in Table 2 summarizes the costs. The cost savings equal these costs times R.

To analyze striping benefits for rural two-lane roads in more detail, the nonfatal injury benefits were tailored to the injury distribution for related crashes. These include crashes with first harmful events outside the roadway and head-on crashes. The injury distribution was computed using 1984 National Accident Sampling System data.

The related crashes are costly. The average benefit per related crash prevented, including fatal crashes and property-damage-only crashes, is $95,000 (in December 1990 dollars). The benefits are $3,079,000 per fatal crash prevented and $154,000 per injury crash prevented. By comparison, Miller et al. (4) find that the average benefits of crash prevention are $48,000 for a police-reported crash and $79,000 for a police-reported injury crash.

The safety benefits given by Miller et al. (4) are for a 4 percent discount rate. For the sensitivity analysis, benefits at 10 percent were taken from unpublished tables supporting Miller et al.

Table 3 compares the costs per injury by police-reported severity at 4 percent and 10 percent discount rates. The nonfatal injury costs with a 10 percent discount rate are higher, an apparent anomaly. This occurs for two reasons. First, the value placed on the sum of lifetime earnings and quality of life is computed independent of the discount rate by Miller et al. (4) [using the method prescribed by OMB (6)]. The

sum equals $2.5 million (in December 1990 dollars). Although earnings losses are less at a higher discount rate, because the sum is a constant, the value placed on lost quality of life rises by an offsetting amount. Second, to value the lost quality of life resulting from nonfatal injury, Miller et al. (4) apply the discount rate to compute a value per life year for lost quality of life. At a 4 percent discount rate, the loss per year equals the total loss divided by 20.8; at 10 percent, it equals the total divided by 10.2. Because nonfatal injuries affect quality of life predominantly in the year of the injury, the much higher value for a year of lost quality of life yields a higher average injury cost, even though costs in future years have a lower present value at the higher discount rate.

Percentage Reduction in Crashes Attributable to Pavement Markings

A literature review of the percentage of crashes prevented by longitudinal pavement markings revealed several studies that used treatment and control groups. It also revealed some studies without well-matched controls and values from some studies without proper bibliographic references. Table 4 summarizes all the percentages. Most studies supplemented existing centerlines with edgelines.

Average effectiveness was computed for all the studies and for several subsets. The subsets included

• Studies of edgelines only,
• Studies of edgelines excluding the highest and lowest effectiveness estimates, and
• Studies that were examined and judged sound.

The averages ranged from 20 to 21 percent. The average for sound studies examined was 21 percent. This paper assumes that roads already are marked, meaning the present crash levels are 21 percent lower than the levels without markings. Expressed in terms of current crash rates, the percentage reduction in crashes due to striping is $100 * .21/(1 - 0.21)$ = 26.5 percent.

The best U.S. effectiveness study is that by Bali et al. (7), who examine rural two-lane roads. This 10-state study includes more than 500 sites. Each site had either a significant and adequately maintained, nonexperimental change in delineation 2 or 3 years before the study or an undelineated,

TABLE 3   COSTS OF AN INJURY BY POLICE-REPORTED SEVERITY AND DISCOUNT RATE

Police-Reported Severity	Cost by Discount Rate	
	4%	10%
K - Fatal Injury	$2,392,742	$2,360,330
A - Incapacitating Injury	169,506	190,069
B - Evident Injury	33,227	43,770
C - Possible Injury	17,029	27,757
O - Property Damage Only	1,734	1,734

SOURCE: Miller et al. (4) and unpublished supporting materials, inflated to December 1990 dollars.

TABLE 4 REDUCTION IN CRASHES DUE TO LONG LINES

	Reduction (%)
Edgelines	
United States	
Nationwide (7)	8
Kansas (21)	16.5
Kansas (22)	14.5
Ohio (23)	19
Illinois (22)	21
Idaho (22)	16
Utah (22,24)	38
Arizona (22)	60
Michigan (22)	3
England (25)	
East Sussex	18
South Yorkshire	30
Cornwall	26
Northamptonshire	12
Hertfordshire	22
France (26)	
Lorraine	27
Germany (20)	
Hesse	20
Lower Saxony	25
Centerlines	
United States (7)	29
Bavaria (20)	10

matched control site. Data were obtained on crash experience for 2 to 3 years at each site (at least 2 years before and 2 years after delineation for the sites with delineation added). The study finds that adding edgelines and centerlines reduces crashes by 36 percent. Adding edgelines to a centerline yields an 8 percent reduction. These percentages were used in the more detailed analysis of marking rural two-lane roads.

Using the percentage reduction in crashes to compute safety benefits should yield conservative estimates. Several published studies suggest the percentage of injuries and fatalities reduced is greater than the percentage of crashes reduced.

Travel Time Savings

The benefit-cost ratios by roadway type include travel time saved because edgelines and centerlines let traffic go faster on busy roads. The analysis assumes

● Travel time was saved during the peak period of 6:00 a.m. to 7:00 p.m. Eighty percent of vehicle miles of travel (VMT) occur during this period (8,Table 5-5). Weekend and weekday travel generate roughly the same percentage of travel miles per day (8, Table 5-9). Furthermore, trips are heavy in all hours from 6:00 a.m. to 7:00 p.m., ranging from 5.4 to 6.3 percent of all trips in each peak hour before 4:00 p.m. and after 6:00 p.m. and 8.1 percent between 4:00 and 6:00 p.m. (8,Table 5-5).

● Pavement markings raised speeds, thus saving travel time, only on Interstate highways, other freeways, and arterials.

● The average 56-mph speed on these roads (3) would fall to 54 mph during the peak travel period if the roads were lacking lane lines, edgelines, and centerlines.

The analysis uses travel time values of 60 percent of the wage rate for the driver and 45 percent for passengers. These values are recommended by Miller (9), who critically reviews the literature. They also are used in FHWA's Highway Economics Requirements System model. The average vehicle has 0.7 passengers (8,Table 8-1). Time of day and day of week do not unduly affect occupancy (8,Figure 8-6), so it is reasonable to use this occupancy for peak-hour trips.

The value of travel time saved per vehicle is 60 percent + 45 percent * 0.7 = 91.5 percent of the wage rate. The average nonsupervisory wage in 1990 was \$9.66/hr (10). Thus, a vehicle hour of travel time (T in Equation 3) is worth \$8.84.

Table 5 shows the annual VMT by roadway class (V in Equation 3).

BENEFIT-COST RATIOS BY ROADWAY TYPE AND LAND USE

Applying Equation 3 to the data given above yields benefit-cost ratios by roadway type and land use. Table 5 shows the benefit-cost ratios for high-solvent paint (as well as VMT).

TABLE 5 ANNUAL VMT (IN MILLIONS) AND BENEFIT-COST RATIO FOR LONGITUDINAL PAVEMENT MARKINGS BY ROADWAY FUNCTIONAL CLASS AND LAND USE, EXCLUDING LOCAL STREETS

Roadway Class	Urban		Rural		All
	VMT	BCR	VMT	BCR	BCR
Interstate	258,662	74.1	181,284	46.3	58.3
Other freeway	116,965	63.4	0	--	63.4
Major arterial	319,286	102.0	160,253	105.2	102.9
Minor arterial	231,786	125.8	151,783	68.9	97.1
Major collector	99,245	52.2	183,507	28.6	34.2
Minor collector	0	--	46,985	20.6	20.6
Total	1,025,944	90.6	723,812	40.1	60.0

SOURCE (VMT): FHWA (*3*)

Nationally, pavement striping has a benefit-cost ratio of 60. On average, each dollar spent on longitudinal pavement markings yields $60 in increased safety and reduced congestion benefits. The benefit-cost ratio is highest on arterial roads. The urban ratio is more than twice the rural ratio. Annual benefits average $19,226/line-mi.

The sensitivity analysis showed that the benefit-cost ratios were robust. The ratios by land use were not greatly affected by choice of marking medium, changed assumptions, or introduction of additional cost considerations. Table 6 summarizes the ratios.

Varying the paint cost affects the benefit-cost ratios, but it does not change their order of magnitude. Assuming a uniform restriping frequency of 9 months lowers the rural benefit-cost ratio but raises the urban ratio. Wear and tear, especially in the winter, probably reduces nighttime marking effectiveness to 9 months except on lightly traveled minor rural collectors. Because the effectiveness studies involved annual restriping, the effectiveness estimates already should incorporate this temporal decline. Assuming that they do not would reduce the benefit-cost ratio by 15 percent.

Typically, high-solvent paint releases 69 lb of volatile organic compounds (VOCs) per mile of solid 4-in. stripe (*11*). VOCs oxidize, creating ozone that can cause respiratory distress for sensitive people. They also are suspected carcinogens. Krupnick and Kurland (*12*) suggest valuing the short-term health effects of VOCs at $620/ton (inflated to December 1990 dollars). Each restriping, the cost is $21/mi of solid stripe. This value is primarily for the northeastern United States, but it is suspected to be a reasonable national average (personal communication, 1991). The value does not consider the long-term cancer risk or any effect on plants and animals.

The environmental costs suggest latex paint would be more cost-effective than high-solvent paint if its applied cost were another $0.004/linear-ft ($1.30/gal). The better durability of some latex paints might justify an even greater cost. These conclusions apply only to latex paints with fast drying times.

In climates where thermoplastic markings are practical, their long life makes their life-cycle cost competitive with painted markings. They are especially competitive on high-volume urban roads. For ease of comparison, the ratios for thermoplastic were computed as if it could be used nationwide.

The benefit-cost ratios presented so far assumed all longitudinal pavement markings are single, solid lines. In reality, centerlines often are doubled, then dashed in passing zones. The industry rule of thumb is that a centerline on a two-lane road takes 1.3 times as much paint as a solid line. Conversely, lane lines are dashed. Typical lane lines are 10-ft stripes separated by 30-ft gaps in rural areas and 9-ft stripes with 12-ft gaps elsewhere. Applying these ratios to the estimated line miles marked yields paint miles. Costing with paint miles raises the benefit-cost ratio slightly. Table 6 shows the revised ratios both excluding and including environmental damage.

The benefit-cost ratio of 59 with environmental damage and paint miles may be more accurate than the ratio for 60 for the base case. Considering these additional costs raises the urban benefit-cost ratio but lowers the rural ratio.

Another possible model refinement would assume that longitudinal pavement markings prevent unreported crashes as effectively as they prevent reported crashes. Applying the underreporting estimates from Miller et al. (*4*) yields substantially higher benefits. It raises the benefit-cost ratio for all roads to 76.

Omitting the travel time savings affects the benefit-cost ratios only for congested roads. On these roads, savings in travel time alone would justify longitudinal pavement markings. On major rural roads, the benefit-cost ratios for these markings range from 6.4 to 10.2 if only reduced congestion is considered. On major urban roads, they range from 8.0 to 18.3. Where pavement markings will ease congestion, they almost surely will be cost-beneficial.

Ignoring the extra cost of contract pavement markings at repaving would raise the benefit-cost ratio. Using a 10 percent discount rate would affect the benefit-cost ratio minimally.

EDGELINES ON RURAL TWO-LANE ROADS

The lowest benefit-cost ratios for longitudinal pavement markings are for edgelines on rural two-lane highways. This section examines the benefit-cost ratio for these lines in more detail. It again uses Equations 1 through 3. The analysis is by average daily traffic volume. It ignores any travel time savings.

TABLE 6 BENEFIT-COST RATIOS BY RURAL-URBAN LAND USE, SHOWING EFFECTS OF ALTERNATIVE ASSUMPTIONS AND MARKING MEDIA

	Rural	Urban	Combined
Using High-Solvent Paint (Base Case)	40.1	90.6	60.0
Using a Paint Cost That Is $.005			
Higher	36.2	82.6	54.4
Lower	45.0	100.5	67.1
Uniform 9-Month Striping Cycle	33.4	96.3	54.6
Effective Only for 9 Months Except on			
Minor Rural Collectors	31.6	80.1	50.7
Costing VOC Damage To Environment	36.7	85.7	55.6
Using Thermoplastic			
$.26/ft rural	32.9	130.0	58.9
$.22/ft rural	38.8	130.0	66.4
Adjusting Paint Use for Unpainted			
Parts of Lane Lines and			
Double/Skip Parts of Centerlines	41.6	99.3	63.6
Costing VOC Damage and Adjusting			
Paint Use	38.1	94.0	58.9
Including Crashes Not Reported to			
Police	51.2	114.5	76.0
Omitting Travel Time Savings	38.1	81.9	54.9
Ignoring Higher Cost At Repaving	49.7	93.5	69.1
Applying a 10% Discount Rate	38.8	93.5	59.9

Bali et al. (7) find edgelines prevent 0.72 crashes per million VMT on rural two-lane roads. Multiplying this value times the ratio of fatal crash rates per million VMT on rural federal-aid secondary roads in 1988 and 1978 [from FHWA (13)] suggests 0.48 crashes would be prevented today. This estimate is conservative, because nonfatal injury rates probably fell less than fatality rates (13). The low quality of the nonfatal injury data precludes their use in adjusting to present crash rates.

Figure 1 shows the benefit-cost ratios. Even at 500 ADT, edgelines on rural two-lane roads yield $17 in safety benefits for every dollar invested.

Bali et al. (7) find that edgelines reduce crashes by 7.9 percent on rural two-lane roads with lane widths of 11 ft or more. Using that estimate, the number of crashes per year needed to justify striping (A) can be computed as

$$A = C/(CS * R)$$

$$= 2 \text{ edgelines} * \$240/\text{mi}/(\$95,074/\text{crash} * .079)$$

$$= .064 \tag{4}$$

Edgelines are justified on a rural two-lane highway with .064 or more crashes per mile per year. Interpreting this number conservatively, edgelines are justified if an average of one nonintersection crash occurs annually every 15.5 mi. Bali et al. (7) recommend against edgelines, however, if lane widths are less than 11 ft.
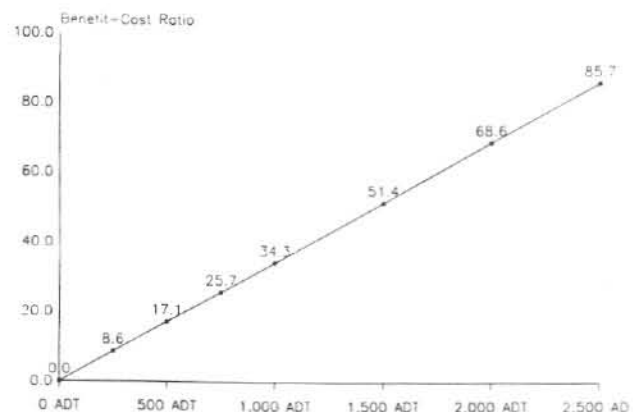

FIGURE 1 Benefit-cost ratio by ADT for edgelines on rural two-lane roads.

CONCLUSION

Existing longitudinal pavement markings yield benefits far greater than their costs. They increase safety and reduce congestion. Much of the safety benefit is achieved during periods of poor visibility. That suggests checking roadway retroreflectivity regularly and restriping promptly when retroreflectivity drops below recommended levels.

Edgelines may not be used often enough on rural two-lane roads in some states. The number of nonintersection crashes needed to justify edgelines is quite small. Rural collectors have far higher crash costs per million VMT than other roads (4). Wider use of edgelines on these roads may be a cost-effective way to cut the crash toll.

ACKNOWLEDGMENTS

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