A Cost-Safety Comparison of Illinois Rehabilitation Design Policies

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ABSTRACT

This evaluation assesses the effects of nonfreeway 3R (resurfacing-restoration-rehabilitation) design criteria used as an alternative to criteria previously developed and adopted for new construction in Illinois. The objectives of this evaluation were to determine if significant accident rate reductions occurred after 3R improvements on 284 mi of 2-lane rural highways in Illinois from 1978 to 1981, and how cost- and safety-effective these 3R improvements were. Accident data were retrieved for 2 years before and after improvement. Statistical testing found the 3R improvements to significantly lower accident rates. Although accident reduction savings were less than 3R improvement costs, safety accounted for only a portion of the benefits derived, which also included the preservation of existing pavements and more efficient vehicle operations. Control sites were not used because aggregate accident data before and after rehabilitation of a relatively large number of projects were to be analyzed. Although the separate effects of improved geometric design elements, improved skid resistance, or general downward trend in accidents were not identified, the study results demonstrated the overall safety effectiveness of the Illinois 3R program.

The Federal-aid Highway Act of 1976 amended the term "construction" to permit the funding of resurfacing, restoring, and rehabilitating (3R) existing highways with more flexible and tailored design guides. The 1982 Surface Transportation Assistance Act intends that 3R projects be constructed to "standards to preserve and extend the life of highways and enhance safety."

From 1976 to 1978, the Illinois Department of Transportation developed nonfreeway 3R design policies for the preservation of existing Illinois highways with due consideration for cost and safety effectiveness, value engineering, and environmental concerns (see Figure 1). Figure 1 is a photograph of a typical Illinois 3R improvement. Illinois 3R design criteria provide for certain alignment corrections and improvements of high accident locations but may permit lower design speeds and narrower traffic lanes, shoulder widths, and clear zones than Illinois' new construction-reconstruction criteria for the same traffic volumes. Table 1 gives a comparison of reconstruction and 3R design policies for typical design speeds in miles per hour (mph) and average daily traffic (ADT) volumes. In many cases, 3R design criteria utilize criteria specified for lower-volume, new construction projects. For example, a 22-ft wide pavement specified for a reconstruction improvement at 60 mph with volumes of 400-2,000 vehicles per day may have been permitted to remain in place on a 3R project for traffic volumes up to 5,000 vehicles per day under certain conditions from 1978 to 1981. Later editions of these policies continue to provide the direction for conducting the 3R program for improving highways (other than expressways and freeways) in Illinois.

The purpose of this evaluation is to determine if

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FIGURE 1 Illinois typical 3R improvement.

TABLE 1 Typical Illinois Design Criteria

Criteria	Reconstruction	Rehabilitation
Design speed[a] (mph)	60-70	55
Design traffic, ADT	3,000-5,000	3,000-5,000
Pavement width (ft)	24	22-24
Shoulders (ft)	8-10	4-6
Paved shoulder (ft)	4-10	1
Clear zones (ft)	34-40	12-18

[a]Existing alignment may remain in place for 10 mph less when practical.

significant accident rate reductions occur after 3R projects are completed and how cost- and safety-effective these projects are. Positive results would provide factual data to support 3R programs, both statewide and nationally. In addition, a comparison of accident rates after improvement will also be made to determine if projects improved with policies developed for highways with average annual daily traffic (AADT) of over 3,000 vehicles have any significant safety or cost difference from projects improved with less stringent policies developed for highways with AADT under 3,000 vehicles.

DATA COLLECTION

Selected projects were on 2-lane Illinois- or U.S.-marked routes without access control in rural areas. The minimum project length was 2 mi. Bridge accidents and rehabilitation costs were omitted.

Monthly construction reports from late 1978 through early 1981 (approximately 2.5 years) were searched for widening and resurfacing projects meeting the preceding criteria. Forty-four projects having a total of 284 mi were located. The projects had a proportion of two-thirds widening and resurfacing (WRS) to one-third resurfacing (RS) (see Table 2).

TABLE 2 Project Distribution

AADT	Type	Projects	Miles	Daily VMT
Under 3,000	RS	9	74	132,434
Under 3,000	WRS	28	159	252,502
Above 3,000	RS	3	26	152,405
Above 3,000	WRS	4	25	114,086
Total		44	284	651,427

Resurfacing projects may also have included some roadside treatment, superelevation correction (where appropriate), and the improvement of high accident locations.

Accident data were retrieved for the study locations for 2 years before and after improvement. Project accident data were investigated before improvement for bias in the following areas:

1. Thirteen high-accident locations in 284 mi were considered too infrequent to influence the effect of 3R policy application.
2. A Student's t-test at a 95 percent confidence level found no significant differences in accident and severity rates in projects having AADTs above or under 3,000 vehicles before improvement. Tables 3 and 4 give information for total accidents (TA), property damage accidents (PD), personal injury accidents (PI), fatal accidents (FA), persons killed (K), persons injured (inj.), mean accident rates per 100 million vehicle mi for TA, and mean severity rates for FA + PI.

It was concluded that project accident data for the period before improvement was reasonably unbiased, and, therefore, suitable for further analysis. Control sites were not used because aggregate accident data before and after rehabilitation of a relatively large number of projects were to be analyzed without investigating the effects of specific geometric design elements.

SAFETY ANALYSIS

Measures of effectiveness (MOEs) included total accident rates, nonintersection accident rates, severity rates, and nonintersection severity rates. Accident rates are expressed as accidents per 100 million vehicle miles of travel (VMT) annually. Severity rates are the number of fatal plus injury accidents per 100 million VMT. Nonintersection accident rates and severity rates are the MOEs that are expected to be most directly affected by 3R policies used in Illinois on 2-lane rural highways. Figure 2 shows mean accident rates before and after improvement.

Total accident rates, nonintersection accident rates, and mean severity rates showed statistically significant reductions from the before period to be after period (see Tables 5 and 6). Similar reductions after improvement were observed in two project groups with AADTs above and under 3,000 (see Tables

TABLE 3 Total Before Accidents--by AADT Group

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
AADT under 3,000	618	380	220	18	22	358	231.70	86.81
AADT above 3,000	439	264	167	8	10	292	235.57	99.57
Percent difference							1.6	14.7
T-statistic							–0.0803[a]	–0.6377[a]

[a]The calculated t-statistic must be outside the 95 percent confidence interval from <–2.021 to >2.021 for a significant difference in rates with 42 degrees of freedom.

TABLE 4 Before Nonintersection Accidents by AADT Group

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
AADT under 3,000	471	295	161	15	18	254	175.24	63.08
AADT above 3,000	330	192	130	8	10	231	176.57	78.29
Percent difference							0.8	24.1
T-statistic							–0.0308[a]	–0.8672[a]

[a]The calculated t-statistic must be outside the 95 percent confidence interval from <–2.021 to >2.021 for a significant difference in rates with 42 degrees of freedom.

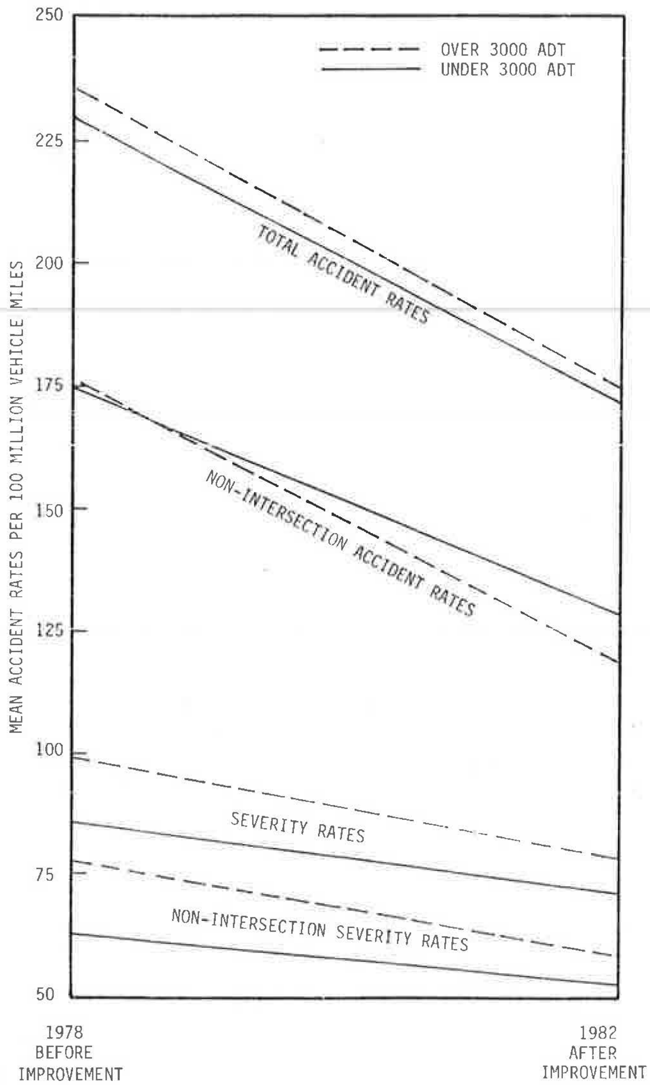

FIGURE 2 Mean accident rates—before and after improvement.

7-10), except that the mean severity rate reductions were not significant for either group. (The 1-tailed, paired t-test at a 95 percent confidence level was used for these analyses.)

No statistically significant differences were found in mean accident rates and mean severity rates in the period after improvement when projects with AADTs above 3,000 were compared to those with AADTs under 3,000 (see Tables 11 and 12). (The 2-tailed, Student's t-test at a 95 percent confidence level was used for these analyses.)

TABLE 5 Total Accidents

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
Before	1,057	644	387	26	32	650	232.32	88.84
After	790	459	314	17	21	510	173.23	72.82
Percent reduction							25.4	18.0
T-statistic							3.323[a]	1.952[a]

[a]The calculated t-statistic must exceed the 95 percent confidence interval limit of >1.682 for a significant rate reduction with 43 degrees of freedom.

TABLE 6 Nonintersection Accidents

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
Before	801	487	291	23	28	485	175.45	65.50
After	564	321	227	16	20	346	126.36	53.95
Percent reduction							28.0	17.6
T-statistic							3.010[a]	1.692[a]

[a]The calculated t-statistic must exceed the 95 percent confidence interval limit of >1.682 for a significant rate reduction with 43 degrees of freedom.

TABLE 7 Total Accidents Before and After Improvement With an AADT Under 3,000

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
Before	618	380	220	18	22	358	231.70	86.81
After	462	275	177	10	11	283	172.70	71.65
Percent reduction							25.5	17.5
T-statistic							2.896[a]	1.5918[a]

[a]The calculated t-statistic must exceed the 95 percent confidence interval limit of >1.690 for a significant rate reduction with 36 degrees of freedom.

TABLE 8 Nonintersection Accidents Before and After Improvement With an AADT Under 3,000

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
Before	471	295	161	15	18	254	175.24	63.08
After	338	203	126	9	10	187	127.51	53.00
Percent reduction							27.2	16.0
T-statistic							2.5375[a]	1.2780[a]

[a]The calculated t-statistic must exceed the 95 percent confidence interval limit of >1.690 for a significant rate reduction with 36 degrees of freedom.

TABLE 9 Total Accidents Before and After Improvement With an AADT Above 3,000

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
Before	439	264	167	8	10	292	235.57	99.57
After	328	184	137	7	10	227	176.00	79.00
Percent reduction							25.3	20.7
T-statistic							2.0678[a]	1.6478[a]

[a]The calculated t-statistic must exceed the 95 percent confidence interval limit of >1.943 for a significant rate reduction with 6 degrees of freedom.

TABLE 10 Nonintersection Accidents Before and After Improvement With an AADT Above 3,000

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
Before	330	192	130	8	10	231	176.57	78.29
After	226	118	101	7	10	159	120.29	59.00
Percent reduction							31.9	24.6
T-statistic							2.027[a]	1.813[a]

[a]The calculated t-statistic must exceed the 95 percent confidence interval limit of >1.943 for a significant rate reduction with 6 degrees of freedom.

TABLE 11 Total After Accidents—By AADT Group

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
AADT under 3,000	462	275	177	10	11	283	172.70	71.65
AADT above 3,000	328	184	137	7	10	227	176.00	79.00
Percent difference							1.9	10.3
T-statistic							−0.0735[a]	−0.3893[a]

[a]The calculated t-statistic must be outside the 95 percent confidence interval from <−2.021 to >2.021 for a significant difference in rates with 42 degrees of freedom.

TABLE 12 After Nonintersection Accidents—By AADT Group

	Accidents				Persons		Mean Accident Rate	Mean Severity Rate
	TA	PD	PI	FA	K	Inj.		
AADT under 3,000	338	203	126	9	10	187	127.51	53.00
AADT above 3,000	226	118	101	7	10	159	120.29	59.00
Percent difference							5.7	10.2
T-statistic							0.2270[a]	−0.4107[a]

[a]The calculated t-statistic must be outside the 95 percent confidence interval from <−2.021 to >2.021 for a significant difference in rates with 42 degrees of freedom.

ECONOMIC ANALYSIS

The present worth of savings resulting from total accident reductions (including those at intersections) were compared to the total project costs for the 3R projects. The analysis period was 20 years with one resurfacing included at 13 years. A constant dollar analysis was performed with an 8 percent interest rate. The Illinois Department of Transportation Construction Price Index was used for 1981 base-year adjustments. The economic value of accidents prevented is $8,340 per accident based on 1981 National Safety Council costs and Illinois Department of Transportation composite statewide average accident distributions of property damage (PD), personal injury (PI), and fatal accident (FA) proportions. Project salvage and maintenance values were assumed to be zero after investigation found them to be minimal cost variables. Road-user benefits from decreased delay, pollution, fuel costs, and vehicle maintenance were not quantified for consideration. The present value of total reconstruction and increased road-user costs as a result of a "no-build" alternative was not calculated. Table 13 gives a summary of the economic analysis.

Figure 3 shows a plot of a sensitivity analysis of various economic service lives and interest rates that show a relatively minimal effect on the benefit/cost (B/C) ratio. A B/C ratio of 0.141 for an 8 percent cost of capital for 20 years would only vary to 0.165 for a 30-year life, or vary to 0.115 for a 10 percent cost of capital.

TABLE 13 Economic Analysis Results

Economic Indicator	Under 3,000 AADT	Above 3,000 AADT	All AADTs
Cost per mile[a]	$180,422	$204,777	$184,781
Benefit-cost ratio[b]	0.098	0.325	0.141
Cost-effectiveness ratio[c]	$80,917	$25,669	$58,444

[a]Adjusted to 1981 costs.
[b]Present value of accident savings to total project costs.
[c]Annualized project cost per accident reduced.

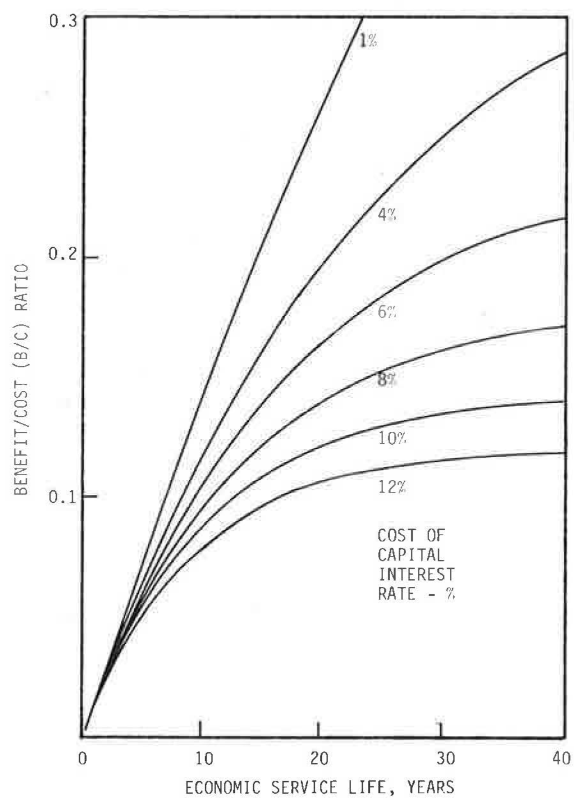

FIGURE 3 Benefit-cost ratio sensitivity analysis.

CONCLUSIONS

The following conclusions are made:

1. The Illinois 3R improvements significantly lowered total and nonintersection accident and severity rates when projects were aggregated, which demonstrates that the Illinois 3R program enhances highway safety.

2. After improvement, total and nonintersection accident and severity rates were not significantly different from one another when project groups with AADTs above 3,000 were compared to those with AADTs under 3,000. This demonstrates that 3R policies are equally safety-effective for projects with AADTs above and under 3,000 (in this study, more stringent policies were applied to projects with AADTs above 3,000).

3. Costs for 3R projects exceeded accident reduction savings. This can be attributed to

a. Prevailing medium-volume rural conditions with minimal high accident locations before improvement,

b. Accident savings spread over entire project section lengths rather than just accident spot lengths in the economic analysis, and

c. Safety or accident savings that account for only a portion of the benefits derived from rehabilitation projects when the accident rates are generally not above the state-wide average.

Although they are not quantified in this evaluation, some other benefits (aside from those associated with accident savings) include

(1) Road-user benefits derived from decreased delay, pollution, fuel costs, and vehicular maintenance;

(2) Road-user benefits derived from the comfort and convenience of travel over a smoother and sometimes wider travelway;

(3) Benefits derived from preservation of the existing highway system, reduced maintenance, and preclusion of further deterioration to the point of costly reconstruction; and

(4) Benefits derived from the overall economy and welfare of the state from an improved system delivery of people and goods.

4. 3R improvements are more cost-effective on projects with AADTs above 3,000 because more accidents are reduced for the same construction cost. Note also that

a. This lends support to priority programming of higher volume projects while recognizing that responsible programming must include lower volume projects to maintain system integrity.

b. This finding would be expected when there is only a 12 percent difference in construction costs per mile, but a much greater percentage increase in traffic exposure allowing for more accident reduction.

c. This finding lends support to continued application of more stringent 3R design policies to projects with traffic volumes above 3,000 ADT.

5. Although the separate effects of improved geometric design elements, improved skid resistance, or general downward accident trends were not identified, the study results from a relatively large number of 3R projects and mileage demonstrates the overall safety of Illinois' 3R program.

a. Although the use of additional control sites without improvement for comparison with rehabilitated sites for the detection of underlying accident reduction factors is desirable, it is very difficult and time consuming to locate comparable control sites without some type of improvement during the study periods.

b. The use of state-wide accident trends as a surrogate control for comparison purposes would not be valid because control sites should be comparable locations without improvement during the study period. Illinois accident trends also reflect an annual $900 million highway program including some type of proposed and scheduled improvement to about 25 percent of all high-accident locations state-wide. However, rehabilitation improvements did have slightly lower average accident rates before and after improvement and about the same reduction as the state-wide average reduction for 2-lane rural highways during the same period.

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