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Effects of Snow Fences on Crashes and Road Closures: A 34-Year Study on Wyoming Interstate-80

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Abstract

This study evaluates the effectiveness of snow fences in reducing crashes and road closures on an 80.4 km remote rural section of Interstate Highway 80 (I-80) in southeastern Wyoming, and summarizes results from a detailed study to identify the need for additional safety improvements on this highway (Tabler 2006). No snow fences were in place when this section of I-80 was first opened to traffic in 1970, but serious snow drifting problems necessitated a large-scale snow fencing program from 1971 to 1990. The proportion of road protected by snow fences has increased to a present level of 73%, consisting of 69.7 kilometers of snow fence ranging in height from 1.8- to 4.3 m and constructed at a cost of $1,910,000.

Total crash rates for October through April have declined in proportion to the percent of road protected by snow fences at the rate of approximately 18 crashes for every 10% increase in snow fence protection. This decline is equivalent to a 70% reduction in areas protected by snow fences, and is attributable to the elimination of snowdrifts, improved visibility in blowing snow, and reduced road ice. At the 2003-04 seasonal traffic volume of 1.9 million vehicles, the existing snow fences prevent 244 crashes, 106 injuries, and 2.2 fatalities per year. This implies an annual return of $5,777,000 on the original capital investment of $1,910,000. The snow fence system also reduces road closure time by an average of approximately 8 days per year, providing an additional annual economic benefit of at least $2,120,000. If the fences were replaced at current costs for construction and easement, annual maintenance costs were equal to 5% of the initial capital investment, and if traffic volume remained constant at the 2003-04 level, the benefits described above would yield a benefit-to-cost ratio of approximately15:1, given an amortization period of 20 years and 4% interest rate.

Description of Study Area

The study section of I-80 is located in southeast Wyoming between Rawlins and Laramie at elevations ranging from about 1980 m near Fort Steele, to 2395 m near Arlington (Figures 1 and 2). Vegetation is typical of short-grass prairie and sagebrush rangeland (Figure 3), with only a few deciduous shrubs and trees near stream crossings. The 124 km section between Saratoga Interchange and Laramie was first opened to traffic in October, 1970. This new alignment was in a different location from US-30 which it replaced, and there was little information available about winter weather conditions on the new route. No snow fences were in place when the highway was first opened, but serious snow drifting problems necessitated a large-scale snow fencing program from 1971 to 1990. The section of I-80 between Quealey Dome and the Saratoga Interchange is particularly prone to adverse winter weather because of higher elevations and the proximity to the Medicine Bow Mountains. Snowfall over the snow accumulation season in this area averages about 2.9 m, more than half of which is relocated by the wind because of the prevalent strong westerly winds and low-growing vegetation. Most of the snow fences are located in the 80.4 km section from Reference Marker (RM) 240 to 290.

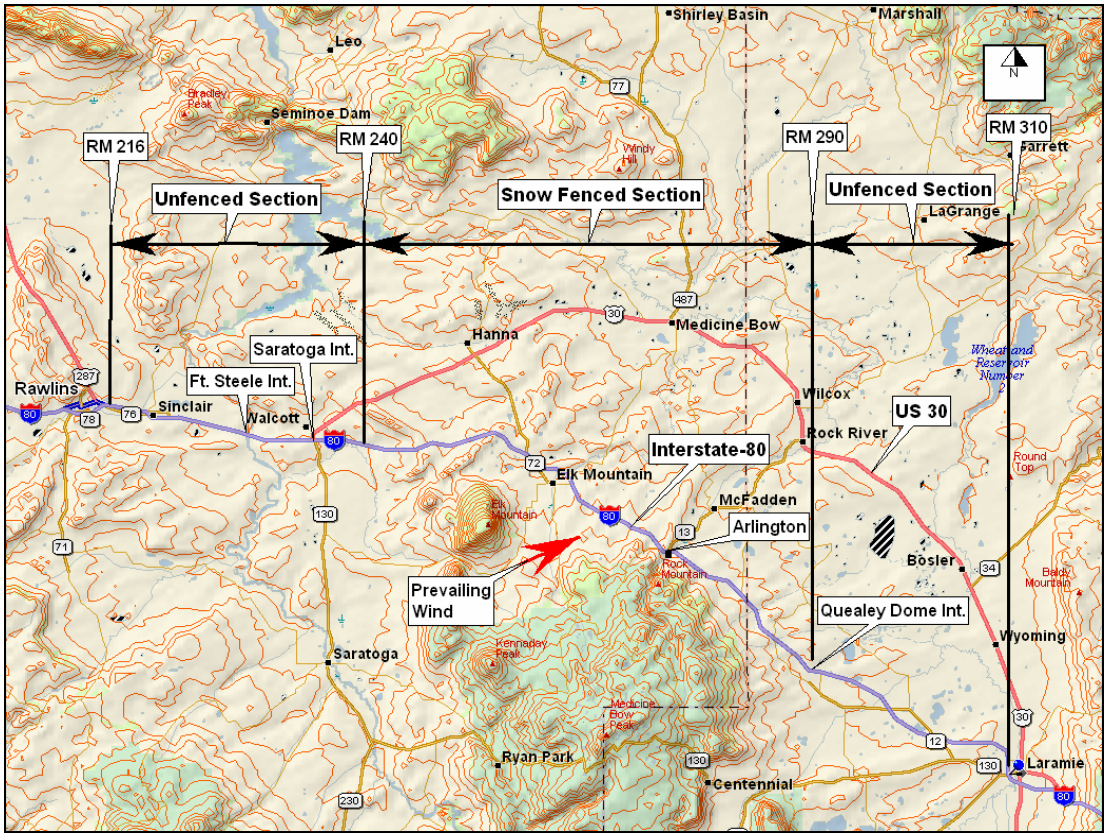

Figure 1. Location of study area. Map © 2002 DeLorme (www.delorme.com) XMap®4.5 and 3-D Topoquads® 1.0.

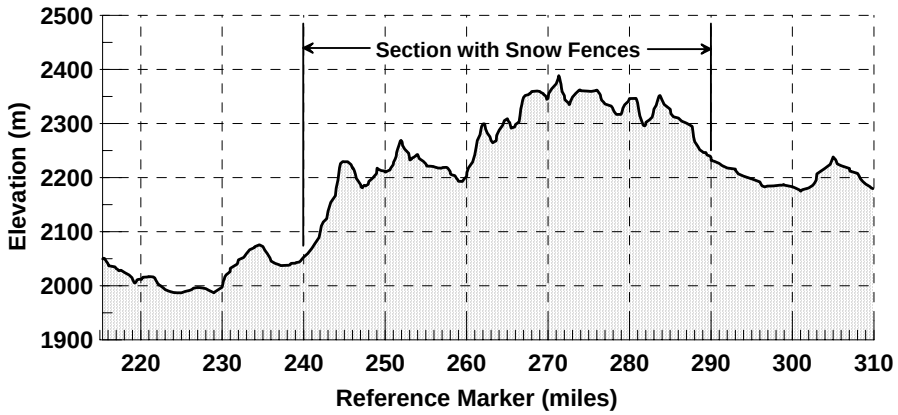

Figure 2. Approximate elevation profile of I-80 between Rawlins and Laramie.

Figure 3. Aerial view of I-80 with blowing snow looking westbound, RM 271 to 268, shows typical topography and vegetation, and one of the first snow fence systems constructed in 1971. Photo Feb. 11, 1972, by R. L. Jairell.

Construction of the first snow fences began in the summer of 1971 and was completed in the summer of 1972. This first contract consisted of 18 379 m of fence ranging in height from 1.8- to 3.8 m, installed at a cost of approximately $470,000. The first fences proved to be extremely effective in preventing snowdrifts and mitigating blowing snow, and by 1990 the length of snow fence in the project area had increased to the current total of 69.7 km, protecting 73.3% of the roadway between RM 240 and 290 and constructed at a cost of $1,910,000. The progression of snow fence protection on the fenced section of highway (Figure 4) provides a unique opportunity to quantify the benefits of snow fences. Fence lengths are tabulated by fence height in Table 1.

Table 1. Length and height of snow fence, Wyoming I-80 RM 240-290, as of December, 2004.

	Fence height (m)						Totals
	1.8	2.4	2.7	3.0	3.8	4.3	
Length (m)	312	13 433	2960	2638	40 773	9597	69 714

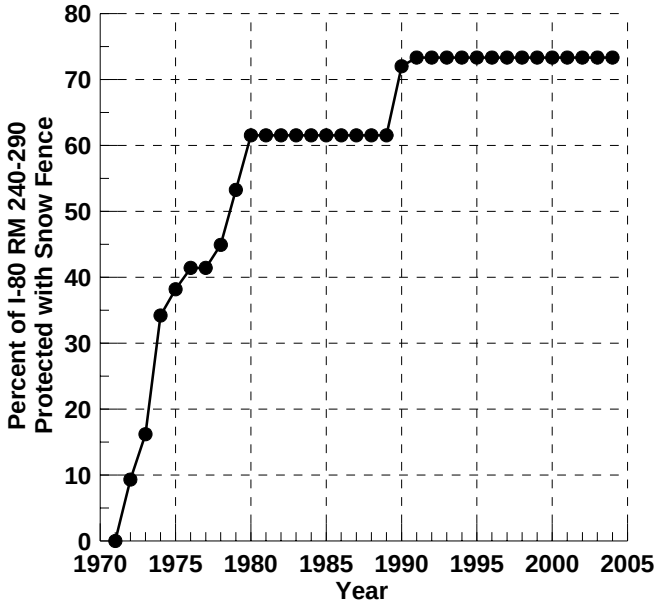

Figure 4. Snow fence protection on I-80, RM 240-290, by years.

Effect of Snow Fences on Snowdrifts, Visibility and Road Ice

The effectiveness of the fences in eliminating snow drifts has been reported previously (Tabler 1973, Tabler and Furnish 1982, Tabler 1994), and two examples are reproduced in Figures 5 and 6. The fences have also improved visibility in blowing snow (Figure 7) and reduced road ice (Figure 8).

Figure 5. Snow accumulation at Wyoming I-80 RM 280.8 before snow fencing (left), and conditions as they have appeared throughout the 35 years after building snow fences (upper right). Aerial view shows the fence system at this location (from Tabler 2003).

Figure 6. Snow accumulation at RM 274.9 in 1970 before fencing (above) compared with conditions typical of the 35 years since fences have been in place (upper right). The drift formed by the 3.8 m fence was 6 m deep and contained about 80 metric tons of snow per meter of fence length (from Tabler 2003).

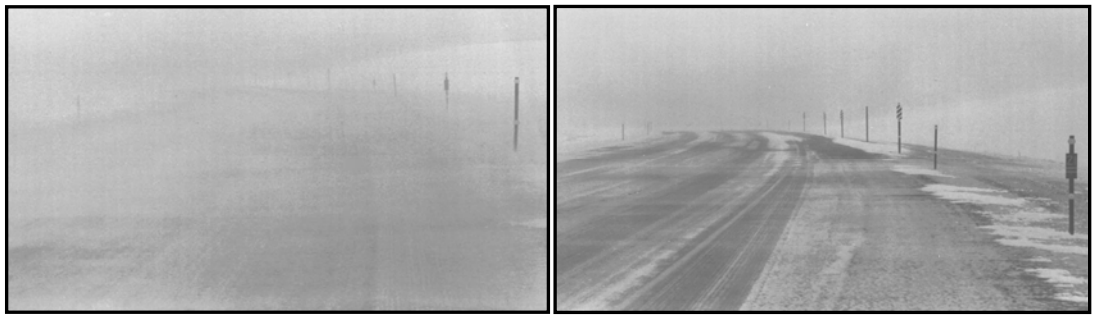

Figure 7. These photos illustrate the improved visibility downwind of a 3.8 m snow fence during moderate drifting. The left photo was taken 60 m outside of the protected area, and the right photo was taken a few minutes later, standing at the boundary of the protected area. Photos are by Keith Rounds, Wyoming Department of Transportation (from Tabler 1973).

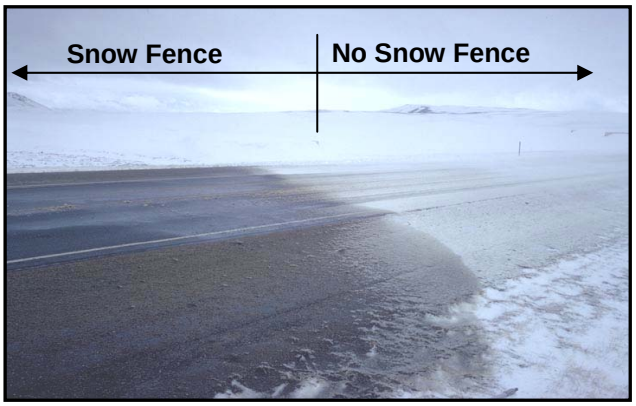

Figure 8. Transition from frozen slush to wet pavement at RM 247.6 corresponds to the beginning of a 3.8 m snow fence located about 150 m upwind (view facing wind). The upper corner of the fence is visible near the center of the picture (from Tabler and Furnish 1982).

Effect of Snow Fences on Crash Incidence

Effects of the snow fences on snow accumulation, visibility and road ice suggest that crash rate should have declined in proportion to snow fence protection. Although an earlier study confirmed that crashes in ground blizzard conditions had significantly decreased with time (Tabler and Furnish 1982), fences constructed since that study, and twenty years of additional data, provide a more definitive test. The limits for the previous study were RM 235 to 295, coinciding with maintenance sections where snow removal costs could be more readily retrieved. The road section for the updated analysis reported here was from RM 240 to 290 to provide a comparable length of "unfenced" road between Rawlins and Laramie that could be used to test the possibility that the trend in crash frequencies was attributable to a change in climate. Although there are some snow fences in the project area external to the 240-290 section, this fencing constitutes less than 1% of the total fence length and provides negligible protection for travel lanes.

Table 2 summarizes the extent of snow fence protection, traffic count, number of crashes, and days of closure by years. As shown in Figure 9, the frequency of crashes with "ground blizzard" conditions (defined as blowing snow with strong winds) has declined, and the correlation with the extent of snow fence protection is significant at the 0.99 confidence level. The ground blizzard crash rate has been reduced from 93 per million vehicles (MV) with no fence protection, to 19 per MV with 73.3% protection. Extending fence protection to 92% of the road would, statistically, eliminate ground blizzard crashes.

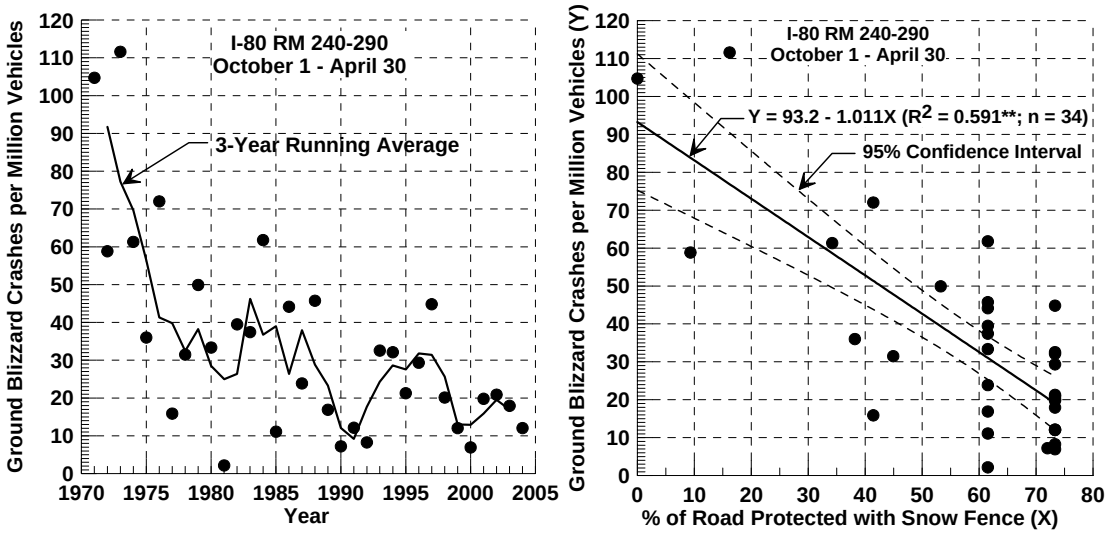

Figure 9. Crash frequency in "ground blizzard" conditions in relation to years and percent of snow fence protection, RM 240-290. Year refers to the January-April portion of each season. The double asterisks after the coefficient of determination (R^2) indicates statistical significance at the 0.99 confidence level.

Table 2. Snow fence protection, number of crashes, and seasonal traffic count and days closed, by years (--- indicates missing data).

Year	Traffic count, Oct-Apr (no. of vehicles)	Days closed, Oct-Apr	RM 240-290			Unfenced section	
			Roadway protection (km)	Ground blizzard crashes (no.)	Total crashes (no.)	Total crashes (no.)	Ground blizzard crashes (no.)
1970-71	525 230	8.4	0.0	55	136	----	----
1971-72	662 946	6.2	7.6	39	120	----	----
1972-73	528 717	14.8	13.0	59	176	----	----
1973-74	554 560	7.8	27.5	34	122	----	----
1974-75	666 669	5.3	30.7	24	88	----	----
1975-76	708 192	4.4	33.3	51	136	----	----
1976-77	818 456	1.5	33.3	13	73	----	----
1977-78	857 638	4.8	36.2	27	128	----	----
1978-79	941 747	9.4	42.8	47	130	----	----
1979-80	779 442	15.6	49.6	26	148	----	----
1980-81	923 824	0.7	49.6	2	48	----	----
1981-82	911 796	1.9	49.6	36	115	----	----
1982-83	854 906	2.3	49.6	32	111	----	----
1983-84	857 866	5.3	49.6	53	254	74	4
1984-85	901 446	0.8	49.6	10	87	55	2
1985-86	928 753	----	49.6	41	177	14	1
1986-87	1 006 029	----	49.6	24	132	62	0
1987-88	1 071 375	----	49.6	49	234	91	12
1988-89	1 184 253	----	49.6	20	146	65	7
1989-90	1 247 983	----	57.9	9	136	102	0
1990-91	1 236 158	----	59.1	15	182	45	1
1991-92	1 331 898	----	59.1	11	108	69	5
1992-93	1 290 739	----	59.1	42	171	127	12
1993-94	1 370 152	----	59.1	44	176	73	3
1994-95	1 457 206	----	59.1	31	169	62	1
1995-96	1 499 927	----	59.1	44	214	97	7
1996-97	1 517 560	----	59.1	68	316	85	7
1997-98	1 640 122	----	59.1	33	188	91	12
1998-99	1 745 618	0.5	59.1	21	229	130	23
1999-00	1 875 506	0.7	59.1	13	150	86	4
2000-01	1 819 308	3.0	59.1	36	245	132	12
2001-02	1 868 040	1.5	59.1	39	222	90	7
2002-03	1 896 009	2.9	59.1	34	188	116	6
2003-04	1 910 009	0.5	59.1	23	185	93	1

The frequency of all crashes has also decreased with time to a level approximately half of the average from 1970-75, and the correlation with fence protection is statistically significant at the 0.95 confidence level (Figure 10). Total crash rate for October through April has declined in proportion to the percent of road protected by

snow fence at a statistically significant rate of approximately 18 crashes for every 10% increase in snow fence protection, equivalent to a 70% reduction in crash rates in areas protected by snow fences. The relationship for all crashes in Figure 10 indicates a reduction of 129 crashes per MV, reflecting the mitigating effects of the fences on snowdrifts, visibility, and road ice (Tabler 2004). With the 2003-04 seasonal traffic volume of 1.9 million vehicles, the existing fence system prevents about 244 crashes per year. The ratio of (injuries/crashes) for the October-April season has averaged 0.434 from 1983 to 2004, and the (fatalities/crashes) ratio has averaged 0.009. These statistics suggest that with 2003-04 traffic volume, the existing snow fences prevent 106 injuries and 2.2 fatalities per year. Assuming that the frequencies of injury severity in the study area are the same as reported nation-wide for the year 2000 (Blincoe et al. 2002), the benefits (in 2000 Dollars) from the reduced fatalities, injuries and "property damage only crashes" would total $5,776,559 on the original capital investment of $1,910,000.

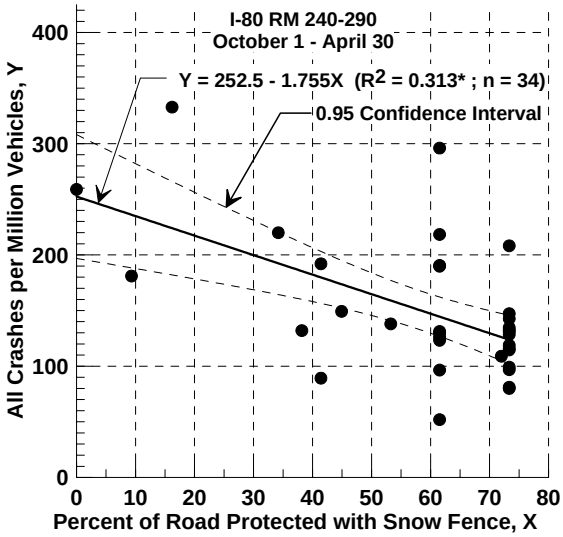

Figure 10. Frequency of all crashes for the period October 1 through April 30, in relation to percent of snow fence protection, RM 240-290. The asterisk after the coefficient of determination (R^2) indicates statistical significance at the 0.95 confidence level.

To test the possibility that climate change has been responsible for the reduced crash incidence, crash rates in the "fenced" section were compared with those in the "unfenced" section (RM 216-240 and RM 290-310). As shown in Figure 11, crash rates have remained constant in the unfenced section over the last 20 years, compared to the 50% decline in the "fenced" section, suggesting that the reduction in crashes is not attributable to a change in winter weather.

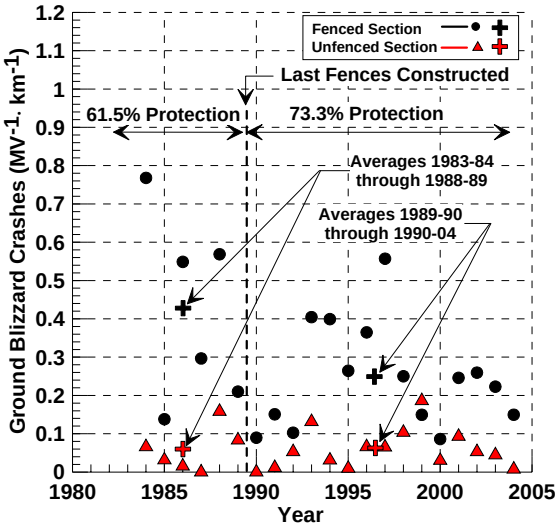

Figure 11. Ground blizzard crash rate has decreased in the fenced section but remained constant in the unfenced section since the 1983-1984 winter.

Effect of Snow Fences on Road Closure

Mandatory road closures are imposed in Wyoming when warranted by crash blockages or severe weather conditions. Because numerous factors affect road closures, including administrative changes in closure criteria, the relationship between closure time and snow fence protection is variable, but significant at the 0.95 confidence level (Figure 12, left). An effect of the fences is also implied from the relationship between annual road closure time and ground blizzard crash rate (Figure 12, right). Both relationships imply an 8 day reduction in closure. Using the current lane rental cost in Wyoming, an 8 day reduction in closure time provides an additional annual economic benefit of at least $2,100,000.

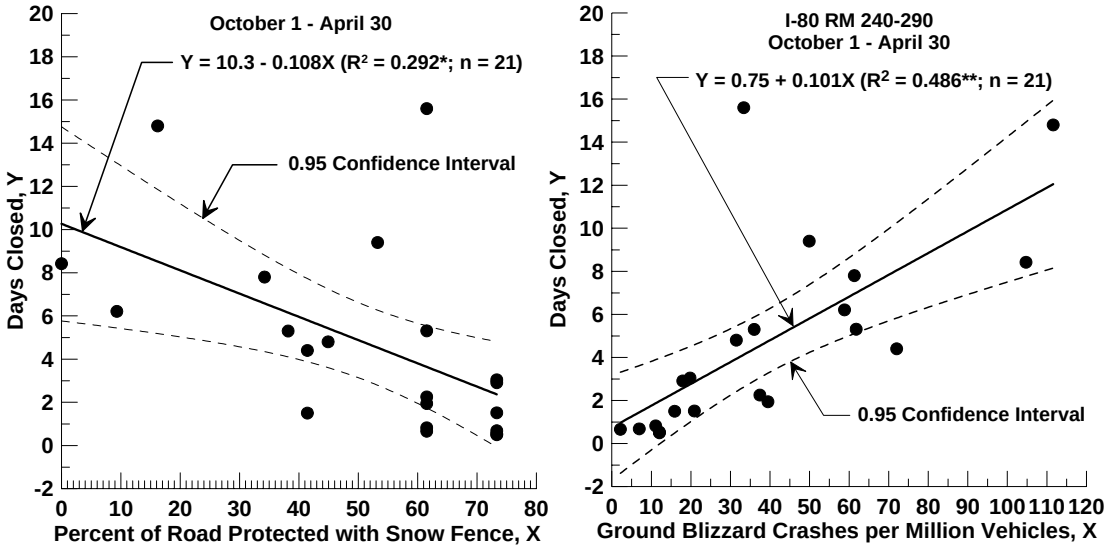

Figure 12. Highway closure time in relation to snow fence protection between RM 240 and 290 (left), and crash rate in ground blizzard conditions (right). The asterisks following the coefficient of determination indicate significance at the 0.95 and 0.99 confidence levels. Both relationships imply that the snow fences reduce road closure time by approximately 8 days per season.

Benefit-to-Cost Ratio

If the fences were replaced at current costs for construction and easement, annual maintenance costs were equal to 5% of the initial capital investment, and if traffic volume remained constant at the 2003-04 level, the benefits described above would yield a benefit-to-cost ratio of about 15:1, given an amortization period of 20 years and 4% interest rate (Figure 13).

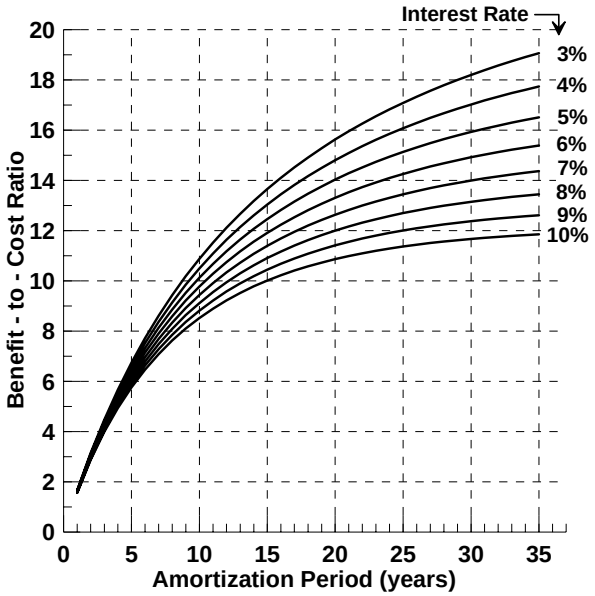

Figure 13. Benefit-to-cost ratio for existing snow fences in relation to amortization period and interest rate, assuming an annual maintenance cost equal to 5% of the initial construction cost.

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