

# Summary of SHRP Research and Economic Benefits of SNOW and ICE CONTROL



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16. Abstract In 1995, a project was initiated to assess the costs versus benefits of the Strategic Highway Research Program (SHRP). Information was collected from State and local highway agencies on their experiences with the SHRP products, and this information was used as the basis for an economic analysis of the costs and benefits of the program and its products.  This report summarizes the preliminary findings of an economic analysis conducted by the Texas Transportation Institute. It also describes the snow and ice control technologies developed under SHRP and the experiences of highway agencies that have used them. In addition, it summarizes the objectives of the research conducted under SHRP on snow and ice control, and outlines the work by the Federal Highway Administration to refine the products and encourage their adoption.					
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## INTRODUCTION

The 1984 Strategic Transportation Research Study identified snow and ice control as one of six priority areas for research and development.<sup>1</sup> As a result, snow and ice control became one of the key areas in the Strategic Highway Research Program (SHRP).<sup>2</sup> Established by Congress in 1987, SHRP had a mission to increase the durability and safety of our Nation's roads and bridges.

Research conducted under SHRP targeted six areas: snow and ice control, concrete and structures, long-term pavement performance, pavement maintenance, asphalt, and work zone safety. One hundred and thirty products, including new specifications, tests, equipment, and reports, resulted from SHRP research contracts, which expired in March 1993.

In 1995, shortly after SHRP concluded and during the early stages of the Federal Highway Administration's (FHWA) national program to encourage implementation of the SHRP products, the Transportation Research Board (TRB) SHRP Committee suggested that an objective assessment of the program and its products be conducted. The study, which was conducted during 1996 and 1997, was launched and funded by FHWA. Overall direction for the study was provided by FHWA with the help of the SHRP Assessment Steering Group. The assessment project was managed by the transportation technology transfer center at the University of Nevada-Reno (UNR). The technology transfer centers in Florida, Indiana, Minnesota, Pennsylvania, and Texas assisted UNR in collecting information on how State and local highway agencies were using SHRP products. This information was turned over to a team of engineers and economists at the Texas Transportation Institute (TTI) for use in an economic analysis of the costs versus benefits of SHRP and the SHRP products.

This report presents the preliminary findings of the economic analysis conducted by TTI. It describes the objectives and accomplishments of the research conducted under SHRP on snow and ice control, as well as the products developed from that research. It also summarizes how State and local governments are using those products.

Four other summary reports, describing the results of the benefits-versus-costs analysis of SHRP's asphalt, concrete and structures, pavement maintenance, and work zone safety products, are also available.<sup>3-6,\*</sup>

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\* The long-term pavement performance (LTPP) program is only at its midpoint, and thus it is too early to report on the economic benefits of its products.

## **BACKGROUND**

The \$150 million spent on SHRP over 5 years is the largest single expenditure ever devoted to transportation infrastructure research. Product refinements and implementation continue with the support of FHWA, State highway agencies, and industry.

The Intermodal Surface Transportation Efficiency Act of 1991 authorized an additional \$108 million for SHRP implementation and for continuation of the long-term pavement performance (LTPP) program. Funding for SHRP came from a set-aside of one-quarter of 1 percent of Federal-aid highway funds apportioned to the States.

SHRP was administered by the National Research Council in cooperation with FHWA and the American Association of State Highway and Transportation Officials (AASHTO). FHWA has taken the lead in helping State and local highway agencies make effective use of SHRP products.

## **OBJECTIVES**

Snow and ice control costs State and local highway agencies in excess of \$1.8 billion annually.<sup>7</sup> Eliminating or reducing snow and ice on pavements and bridges improves the safety of our highways and provides year-round mobility. However, the widespread use of salt (about 10 million tons annually) for snow and ice control accelerates the deterioration of highways, bridges, and vehicles. In addition, snow and ice removal concentrates salts near the roadside, which may cause damage to vegetation and water supplies.<sup>2</sup>

The major objectives of the SHRP snow and ice control research were to:

- Develop more cost-effective ways to remove the buildup of snow and ice on highways.
- Increase highway safety while reducing motorist accident costs.
- Reduce corrosive effects on pavements, structures, and vehicles.
- Mitigate the adverse environmental effects of winter maintenance.

## **RESEARCH PROJECTS**

The proposed SHRP research on snow and ice control identified five projects:<sup>2</sup>

1. Prevention of ice-pavement bond.
2. Destruction of ice-pavement bond.
3. Development of improved displacement plows.
4. Improved methods of controlling blowing snow.

## 5. Management of snow and ice control operations.

### ACCOMPLISHMENTS

SHRP snow and ice control research and development produced 13 products that can be grouped into 5 areas: anti-icing technology, ice disbonding, snow drift control, snowplow design, and road weather information systems. Table 1 lists the types of products available from each of the snow and ice control areas. A brief summary of these products is presented below.

#### Anti-Icing Technology

Anti-icing products include *Development of Anti-Icing Technology*,<sup>8</sup> a manual on when and how to apply chloride and nonchloride agents for optimum performance with a minimum amount of chemicals. The manual also evaluates equipment application rates.

#### Ice Disbonding

Two products were developed related to ice disbonding: the *Handbook of Test Methods for Evaluating Chemical Deicers*<sup>9</sup> and the truck-mounted attenuator for salt spreaders.

The handbook describes 12 tests for evaluating ice-control chemicals. These tests assess performance qualities; operational parameters; environmental, health, and safety aspects; and compatibility with metals, concrete, and asphalt.

The truck-mounted attenuator for salt spreaders consists of an impact attenuator with a spreader attachment that is mounted on the rear of a truck. The device distributes salt on pavements and provides a "crash cushion" that makes salt spreading safer.

#### Snow Drift Control

Research-based improvements in snow fence design and placement optimize drift control on highways. The fences also reduce snow and ice removal costs and provide a safe pavement surface. Snow drift control products include the *Snow Fence Guide*<sup>10</sup> and *Design Guidelines for the Control of Blowing and Drifting Snow*.<sup>11</sup>

#### Snowplow Design

Technological advances in snowplows have reduced the amount of energy needed to remove snow and ice from pavements. Standard plows waste fuel and accelerate wear on equipment because of the force needed to remove snow. Snowplow design products include the snowplow cutting edge, the snowplow scoop, and the report, *An Improved Displacement Snowplow*.<sup>12</sup>

### **Road Weather Information Systems**

Road weather information systems (RWIS) provide precise, real-time data on road and weather conditions. These data enable better scheduling of crews and allow more effective use of chemical anti-icing or deicing strategies. The RWIS systems incorporate pavement temperature sensors and ice detectors, meteorological sensors that measure the atmosphere, and weather forecasts from various sources. *Road Weather Information Systems Volume Two: Implementation Guide*<sup>13</sup> and the customized weather prediction system are products of this research.

### **POST-SHRP ACTIVITIES**

The SHRP research on snow and ice control led to additional research, development, and implementation activities. The centerpiece of the snow and ice implementation effort is the FHWA technology transfer showcase workshops. Other technology transfer activities include FHWA's participation in the "Blizzard of '96" conference held in Washington, D.C., and in the Western and Eastern States Snow and Ice Conferences.

In 1993, 15 States participated in a 2-year FHWA study, titled Test and Evaluation Project No. 28, that evaluated the use of anti-icing technology.

States that have experimented with the timing of the application of various anti-icing chemicals under different climatic conditions report that anti-icing operations were effective in a large number of storm conditions.

The use of RWIS technology for snow and ice control grew at a rapid rate during SHRP. By 1994, more than 750 RWIS sites had been established throughout the country.

Twelve new test procedures have been developed to evaluate the effectiveness and environmental impact of deicing chemicals. AASHTO has included one of the procedures in its provisional standards.<sup>14</sup>

Snow scoop design improvements have been pursued by industry and several States.

### **Case Studies**

For the purposes of the economic analysis, 38 case studies on snow and ice control were obtained from 30 States. Table 2 contains a State-by-State listing of these case studies.

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<sup>13</sup> FHWA has published 104 RoadSavers case studies, many of which were based on case studies collected for the economic analysis. The RoadSavers case studies are available on the Internet at [www.ota.fhwa.dot.gov/roadsvr](http://www.ota.fhwa.dot.gov/roadsvr).

The following are short summaries of the benefits of three products—anti-icing, RWIS, and snow fences—as reported in the case studies.

#### *Anti-Icing*

Anti-icing techniques provide safer and substantially lower winter maintenance costs as a result of reduced crew overtime and use of chemicals. Environmental benefits include reduced airborne particulate pollution, less sand and silt in roadside streams, and less sand that can damage vegetation along the roadside.

#### *Road Weather Information Systems*

RWIS takes the guesswork out of weather forecasting and provides accurate information about conditions at specific highway locations. The improved efficiency provided by the system:

- Makes for better-informed decisions about snow and ice control.
- Helps maintain ice-free pavements.
- Reduces the amount of time needed to remove ice and snow accumulations.
- Reduces labor costs.
- Reduces chemical use.

The result is a safer driving surface for motorists at lower cost and with less impact on the environment.

#### *Snow Fences*

Snow fences solve problems caused by blowing snow and are an excellent long-term investment. By preventing snow from drifting across roadways, the fences greatly reduce maintenance costs.

In addition, the fences make roads safer. The number of accidents caused by poor visibility are reduced on stretches of highway protected by the fences.

### **ECONOMIC BENEFITS**

The use of SHRP's snow and ice control technologies can result in significant cost savings for both highway agencies and highway users. Particularly substantial cost savings can result from the implementation of both RWIS technology and an anti-icing strategy, as reported in the case studies. The economic benefits described below are based on implementation of anti-icing techniques in conjunction with RWIS technology.

RWIS technology provides accurate data on current and forecast conditions on highways and bridges. Anti-icing techniques, which involve treating roadways before a storm starts, reduce or eliminate the multiple applications of sand and salt that can be necessary when using conventional deicing methods.<sup>8</sup>

A preliminary estimate of the cost savings from anti-icing techniques is reported in a study conducted under SHRP on anti-icing methods.<sup>8</sup> Public highway agency cost savings were calculated for reductions in labor, vehicle operations, and materials resulting from the need for fewer passes of snowplow trucks during a storm. These savings are partially offset by the equipment costs associated with implementing anti-icing treatments.

Estimated public highway agency cost savings for five levels of winter storm severity are presented in Table 3. The savings, which are based primarily on information provided by the Minnesota Department of Transportation (DOT), vary from \$1,266 to \$30,152 per typical maintenance snowplow truck route per year. The amount of the savings depends on the number of storm hours during which an agency conducts snow and ice control operations.

The reduction in exposure to icy and snowy pavement conditions resulting from fully implemented anti-icing operations was used to estimate the potential reduction in motor vehicle accidents during winter storms. The user cost savings from reduced numbers of accidents are presented in Table 3. Based on accident information provided by New York State DOT, the savings vary from \$11,924 for 100 storm hours to \$107,312 for 900 storm hours. The total annual cost savings (including agency savings and user savings) for a typical truck route range from \$13,900 to \$137,464.

National cost savings estimates per mile of highway were developed from the typical truck route savings. An average truck route length of 40 lane-miles (64 lane-kilometers) was used and converted to 20 centerline miles (32 kilometers). Cost savings shown in Table 3 were recalculated and are shown in Table 4. The total annual cost savings vary from about \$650 per mile (\$400 per kilometer) to \$6,879 per mile (\$4,286 per kilometer).

The cost savings estimates in Table 4 compare favorably with the findings of a Washington State anti-icing experiment. Two 20-mi (32-km) highway sections were compared during a 10-day period of ice and freezing conditions. The total cost for traditional deicing methods was \$4,400, compared with \$383 for the anti-icing treatment using liquid magnesium chloride. The savings of \$4,017 translated into savings of about \$200 per mile (\$120 per kilometer) of highway.

Boulder, Colorado, reported the largest savings. The estimated cost for use of magnesium chloride was \$2,500 per lane-mile (\$1,600 per lane-kilometer), compared to \$5,200 per lane-mile (\$3,200 per lane-kilometer) for sanding operations. This translates into an estimated savings of \$5,400 per centerline mile (\$3,400 per centerline kilometer)—higher than any estimate in Table 4, including the most severe category of 900 storm hours per winter.

These findings indicate that using magnesium chloride in an anti-icing strategy can result in significant cost savings. The evidence also shows that the numbers in Table 4 are reasonable, given the limited implementation experience available.

To produce an estimate of the potential nationwide savings, it was necessary to determine the highway mileage in each winter storm severity category. Historical average annual snowfall amounts from the *Statistical Abstract of the United States*<sup>15</sup> were used for this purpose. Each severity category was associated with a range of snowfall for the cities listed in each State.

The third row in Table 5 shows that 24 percent of the highway network is in the lowest severity category of 100 storm hours per year, with lower percentages going up the severity scale. Only 3 percent of the U.S. highway network is in the highest severity category of 900 storm hours per year. A total of 56 percent of the network is estimated to fall into one of these winter storm severity categories.

Table 5 shows that if anti-icing operations were fully implemented, the potential savings would be about \$325 million in reduced public highway agency costs and about \$1.35 billion in reduced user accident costs, for a total savings of approximately \$1.67 billion annually. The estimates are made using the total highway mileage in the United States excluding the local functional class.

Snow and ice control technology will not be immediately implemented by all highway agencies. Taking the maximum annual savings amount of \$1.67 billion, savings for slow, moderate, and fast implementation scenarios for 20 years were calculated using a 5 percent discount rate (Tables 6, 7, and 8).<sup>16</sup> Each scenario assumes that implementation is slow in early years and gradually increases over time.

#### *Slow Implementation*

- Implementation reaches 50 percent after 20 years
- Estimated public highway agency savings: \$700 million
- Estimated user savings: \$2.8 billion
- Estimated public highway agency and user savings: \$3.5 billion

*Moderate Implementation*

- Implementation reaches 75 percent after 20 years
- Estimated public highway agency savings: \$1 billion
- Estimated user savings: \$4.2 billion
- Estimated public highway agency and user savings: \$5.2 billion

*Fast Implementation*

- Implementation reaches 100 percent after 20 years
- Estimated public highway agency savings: \$1.3 billion
- Estimated user savings: \$5.6 billion
- Estimated public highway agency and user savings: \$6.9 billion

The cost of SHRP-related snow and ice control research, development, and implementation was estimated at \$45 million over 20 years. Table 9 shows the benefit-cost ratios for the three implementation scenarios given above. For each dollar spent on research, development, and implementation, public highway agencies can expect an annual return of \$15 for slow implementation, \$22 for moderate implementation, and \$29 for fast implementation. Annual cost savings to users will be \$62, \$93, and \$124 for slow, moderate, and fast implementation scenarios, respectively. The combined annual saving to agencies and users is expected to range from \$78 to \$153.

**SUMMARY**

In many States, winter maintenance consumes a big portion of the highway agency's budget. But it is now possible for agencies to provide safer winter driving conditions at less cost and with fewer negative environmental consequences. This is all due to SHRP snow and ice control research related to anti-icing methods, RWIS technology, and snow fences.

The use of anti-icing strategies that involve applying a chemical to the pavement before the start of a storm makes snow and ice removal easier. Less chemical is needed, costs are reduced, and the roads are safer because ice never has a chance to bond to the pavement.

The success of an anti-icing strategy hinges on proper timing of the chemical application. With the aid of RWIS, highway agencies can pinpoint when and where to begin anti-icing operations. This information is used to provide rapid response to changing weather conditions and to eliminate unnecessary deployment of crews.

In addition, new snow fence designs greatly reduce maintenance costs by making it unnecessary to plow drifted snow off roadways. The fences also improve motorist safety by preventing snow from blowing across the road and obscuring visibility.

Benefit-cost ratios will increase substantially with greater implementation of SHRP snow and ice control technology.

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**Table 1. SHRP Snow and Ice Control Products**

Product Area	Product Number and Title
Anti-Icing Technology	3024 Anti-Icing Operations Guide
	3030 Anti-Icing Equipment Evaluation
	3031 Anti-Icing Application Rates
	3032 Anti-Icing Chemical Evaluation
Ice Disbonding	3020 Handbook on Deicer Test Methods
	3021 Truck-Mounted Attenuator for Salt Spreaders
Snow Drift Control	3001 Snow Fence Guide
	3025 Snow Fence Engineering Design Manual
Snowplow Design	3022 Snowplow Cutting Edge
	3026 Snowplow Scoop
	3027 Snowplow Design Manual
Road Weather Information Systems	3023 Guide for Road Weather Information System
	4006 Customized Weather Prediction System

**Table 2. Snow and Ice Control Case Studies**

State	Case Study Title
Alaska	Making Snow-Covered Roads Easier to Open
California	Protecting a National Forest with New Snow Removal Methods
Colorado	Anti-Icing Saves Time and Money
	Road Weather Data Give Colorado DOT a Jump on Snow Storms and Avalanches
Idaho	Protected by Snow Fences Idaho Road Stays Open to Traffic
Illinois	Better Weather and Pavement Information Mean Faster Storm Cleanup
Iowa	Snow and Ice Control: The New Generation
	Iowa Gets a Jump on Storms with New Technology
	Snow Fences Increase Visibility and Reduce Drifts
Kansas	Anti-Icing Improves Road Safety
	Beating Winter Storms to the Punch with an Advance Warning System
	Combined Technologies Prove Winter Worthy
Maryland	Timing is Key to Effective Winter Maintenance
Massachusetts	Clearer Roads at Least Cost
Michigan	Michigan Finds a Solution for Icy Bridges
Minnesota	Monitoring System Gives Highway Crews the Edge in Winter Maintenance
	Snow Fences Spell End of Blocked Highways

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<b>State</b>	<b>Case Study Title</b>
Missouri	Anti-Icing Techniques Key to Safer Roads
	Weather System Saves Money and Improves Service
Montana	Weather Monitoring Stations Improve Operations
Nebraska	Keeping the Snow at Bay
Nevada	A Cleaner, Safer Way to the Slopes
	Snow Fences Prove to be a Valuable Maintenance Tool
New Hampshire	Advanced Cutting Edge Clears More Ice in New Hampshire
New Jersey	Real-Time Data Slashes Winter Maintenance Costs
New York	No More Snow Drifts on Upstate Road
North Dakota	Weather Information System Helps Keep North Dakota Roads Clear
Oklahoma	Anti-Icing Reduces Bridge Corrosion
Oregon	Saving Money and the Environment
South Dakota	Timing is Everything with Winter Maintenance
Texas	Weather System Increases Productivity and Safety
Utah	Making Better Use of Snow Fences
Virginia	New Pavement System Great for Trouble Spots
Washington, D.C.	New Weather System Keeps Routes Open in the Nation's Capital
Washington	A Preemptive Strike on Ice
West Virginia	New Technology Slashes Winter Maintenance Costs
Wisconsin	Clear Roads Ahead for Wisconsin Counties
Wyoming	Snow Fences Save Money and Lives

**Table 3. Annual Cost Savings Based on a Typical Truck Route**

Winter Storm Severity					
Storm Hours per Winter	100	300	500	700	900
Storms per Winter	5	12	18	25	30
Annual Agency Cost Savings (\$)					
Labor	43	332	689	978	1,403
Vehicle Operations	40	312	648	920	1,320
Materials	3,160	9,673	16,251	22,764	29,406
Equipment	-1,977	-1,977	-1,977	-1,977	-1,977
Subtotal	1,266	8,340	15,611	22,685	30,152
Annual User (Motorist) Accident Cost Savings (\$)	11,924	35,771	59,618	83,465	107,312
Total Annual Cost Savings per Truck Route (\$)	13,190	44,111	75,229	106,150	137,464

SOURCE: *Development of Anti-Icing Technology*. Publication No. SHRP-H-385, Strategic Highway Research Program, Washington, D.C., National Research Council, 1994.

**Table 4. Estimated Annual Cost Savings per Mile of a Typical Truck Route**

Winter Storm Severity					
Storm Hours per Winter	100	300	500	700	900
Storms per Winter	5	12	18	25	30
Annual Agency Cost Savings (\$)					
Labor	2.15	16.60	34.45	48.90	70.15
Vehicle Operations	2.00	15.60	32.40	46.00	66.00
Materials	158.00	483.65	812.55	1,138.20	1,470.30
Equipment	-98.85	-98.85	-98.85	-98.85	-98.85
Subtotal	63.30	417.00	780.55	1,134.25	1,507.60
Annual Motorist Accident Cost Savings (\$)	596.20	1,788.55	2,980.90	4,173.25	5,365.60
Total Annual Cost Savings per Truck Route (\$)	659.50	2,205.55	3,761.45	5,307.50	6,873.20

SOURCE: Calculated from Table 3, assuming an average 20-mi truck route.

**Table 5. Total Annual Cost Savings with Full Implementation on the U.S. Highway Network**

Winter Storm Severity						
Storm Hours per Winter	100	300	500	700	900	Total
Storms per Winter	5	12	18	25	30	
U.S. Highway Mileage in Each Category (Percent)	24	12	11	6	3	56
Annual State Agency Cost Savings (Million \$)						
Labor	0.63	2.45	4.66	3.61	2.59	13.94
Vehicle Operations	0.59	2.30	4.38	3.39	2.44	13.10
Materials	46.64	71.38	109.93	83.99	54.25	366.19
Equipment	-29.18	-14.59	-13.37	-7.29	-3.65	-68.08
Subtotal	18.68	61.54	105.60	83.70	55.63	325.15
Annual Motorist Accident Cost Savings (Million \$)	175.99	263.97	403.29	307.97	197.98	1,349.20
Total Annual Cost Savings with Full Implementation by State Agencies (Million \$)	194.67	325.51	508.89	391.67	253.61	1,674.35

**Table 6. Total Anti-Icing Cost Savings with a Slow Implementation Scenario**

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million \$)	Discounted Motorist Savings (Million \$)	Total Discounted Savings (Million \$)
1	1.0	3.25	13.49	16.74
2	1.7	5.26	21.84	27.10
3	2.7	7.96	33.04	41.00
4	3.9	10.95	45.45	56.40
5	5.4	14.45	59.94	74.39
6	7.1	18.09	75.06	93.15
7	9.0	21.84	90.61	112.45
8	11.1	25.65	106.43	132.08
9	13.4	29.49	122.37	151.86
10	15.9	33.33	138.28	171.61
11	18.5	36.93	153.23	190.16
12	21.4	40.68	168.81	209.49
13	24.4	44.18	183.31	227.49
14	27.6	47.59	197.48	245.07
15	30.9	50.75	210.56	261.31
16	34.4	53.80	223.25	277.05
17	38.1	56.75	235.49	292.24
18	41.9	59.44	246.64	306.08
19	45.9	62.02	257.32	319.34
20	50.0	64.34	266.96	331.30
20-Year Total		686.75	2,849.56	3,536.31
Equiv. Ann. Total		55.11	228.66	283.77

**Table 7. Total Anti-Icing Cost Savings with a Moderate Implementation Scenario**

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million \$)	Discounted Motorist Savings (Million \$)	Total Discounted Savings (Million \$)
1	1.0	3.25	13.49	16.74
2	2.0	6.19	25.70	31.89
3	3.5	10.32	42.83	53.15
4	5.4	15.17	62.94	78.11
5	7.6	20.33	84.36	104.69
6	10.2	25.99	107.83	133.82
7	13.0	31.54	130.88	162.42
8	16.2	37.44	155.33	192.77
9	19.7	43.36	179.90	223.26
10	23.5	49.26	204.38	253.64
11	27.5	54.90	227.78	282.68
12	31.8	60.46	250.85	311.31
13	36.3	65.73	272.72	338.45
14	41.1	70.87	294.07	364.94
15	46.2	75.87	314.82	390.69
16	51.5	80.55	334.23	414.78
17	57.0	84.91	352.31	437.22
18	62.8	89.09	369.67	458.76
19	68.8	92.96	385.70	478.66
20	75.0	96.51	400.44	496.95
20-Year Total		1,014.70	4,210.23	5,224.93
Equiv. Ann. Total		81.42	337.84	419.26

**Table 8. Total Anti-Icing Cost Savings with a Fast Implementation Scenario**

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million \$)	Discounted Motorist Savings (Million \$)	Total Discounted Savings (Million \$)
1	1.0	3.25	13.49	16.74
2	2.4	7.43	30.84	38.27
3	4.3	12.68	52.62	65.30
4	6.8	19.10	79.25	98.35
5	9.8	26.22	108.78	135.00
6	13.3	33.88	140.60	174.48
7	17.1	41.49	172.16	213.65
8	21.4	49.45	205.19	254.64
9	26.0	57.22	237.43	294.65
10	31.0	64.98	269.61	334.59
11	36.4	72.66	301.50	374.16
12	42.2	80.23	332.89	413.12
13	48.3	87.45	362.87	450.32
14	54.7	94.32	391.38	485.70
15	61.5	101.00	419.08	520.08
16	68.6	107.30	445.20	552.50
17	76.0	113.21	469.74	582.95
18	83.7	118.74	492.70	611.44
19	91.7	123.90	514.09	637.99
20	100.0	128.68	533.92	662.60
20-Year Total		1,343.19	5,573.34	6,916.53
Equiv. Ann. Total		107.78	447.22	555.00

**Table 9. Twenty-Year Cost Savings (Billion \$) and Benefit-Cost Ratio\* for SHRP Snow and Ice Control Research**

Basis of Cost	Implementation Rate					
	Slow		Moderate		Fast	
	Savings (Billion \$)	Ratio	Savings (Billion \$)	Ratio	Savings (Billion \$)	Ratio
Agency Savings	0.7	16	1.0	22	1.3	29
User Savings	2.8	62	4.2	93	5.6	124
Total Agency Plus User Savings	3.5	78	5.2	115	6.9	153

\* Based on an estimated 20-year research, development, and implementation cost of \$45 million.

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**Notice**—The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

