Summary of SHRP Research and Economic Benefits of

WORK ZONE SAFETY

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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 work zone safety 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 work zone safety, and outlines the work conducted 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 work zone safety as one of six priority areas for research and development.[1] As a result, work zone safety became one of the key areas in the Strategic Highway Research Program (SHRP).[2] 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: work zone safety, concrete and structures, long-term pavement performance, pavement maintenance, asphalt, and snow and ice control. 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 work zone safety, 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 snow and ice control products, are also available.[3–6,*]

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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

The major objectives of the SHRP work zone safety research program were to reduce the number of accidents in work zones and to increase worker productivity through improved equipment.

RESEARCH PROJECTS

The proposed SHRP research on work zone safety identified four projects:[2]

- Evaluation of existing devices and procedures.
- Development of guides for new traffic controls.
- Development and testing of new traffic controls.
- Documentation for implementation.

WORK ZONE SAFETY RESEARCH

In 1994, 706 people were killed in highway work zones. This dramatic rise is a graphic reminder of how dangerous work zones are for both crews and motorists.

The concrete barriers commonly used to protect workers in highway construction sites are too heavy and cumbersome for use in temporary rehabilitation and maintenance work zones. This inspired SHRP research on the development of lightweight safety devices that would effectively control traffic and protect workers. The devices were also designed for quick installation and removal, to give crews more time to do their work.

ACCOMPLISHMENTS

SHRP work zone safety research and development produced 10 devices that can be grouped into 3 areas: signs, detectors, and protective devices. Table 1 lists the types of products available in each of the work zone safety areas. A brief summary of the types of products available in each of these areas is presented below.

Signs

SHRP developed four types of signs: the flashing stop/slow paddle, the direction indicator barricade, the opposing traffic lane divider, and the portable all-terrain sign stand.

Flashing Stop/Slow Paddle

The device is similar to paddles commonly used by flaggers in work zones, but with two high-intensity quartz halogen lamps mounted on the "stop" side of the paddle. When the flagger presses a button on the handle, the lights alternatively flash several times in a short sequence.

Direction Indicator Barricade

The flexible and lightweight barricade features a horizontal arrow panel that directs drivers entering work zones through the taper area and into the temporary travel lane. Its orange-and-white stripes and black directional arrow make it easy for drivers to see and help them to follow the appropriate path through a work zone. The easy-to-set-up barricade is equipped with both left- and right-pointing directional arrows.

Opposing Traffic Lane Divider

When work zones require that a one-way road be temporarily converted to two-way operation, opposing traffic lane dividers can help delineate the two directions of traffic. The upward- and downward-pointing arrows on the divider indicate that traffic on both sides of the divider is flowing in opposite directions. Placed in sequence, the signs function as temporary centerline markers, clearly dividing the roadway into opposing travel lanes for two-way operation. The signs continually remind drivers of "no-passing" restrictions.

Portable All-Terrain Sign Stand

The device was developed for use on steep slopes or in cut-and-fill areas lacking flat shoulders. The stand, which supports a 48-in (1,200-mm) all-weather fabric sign face, withstands wind gusts when its feet are anchored by stakes. The sign and the stand fold to a compact size for transport and storage.

Detectors

SHRP developed three types of detectors: two different intrusion alarms and the queue-length detector.

Intrusion Alarm

The devices monitor the buffer area between a work zone and passing vehicles. When an errant vehicle enters the work zone, the alarms sound a loud (130 decibel) siren to alert workers of the danger. SHRP developed two models of the intrusion alarm, one that uses an infrared beam to monitor the buffer area and one that uses an ultrasonic sensor.

Queue-Length Detector

The detector was developed to monitor traffic backups in work zones. If traffic slows to the preset level or stops, however, the detector activates a message board or other device to warn approaching drivers of the changing travel conditions ahead.

Protection Devices

SHRP developed three types of protection devices: the portable crash cushion, the portable rumble strip, and the remotely driven vehicle.

Portable Crash Cushion

This tilt-bed trailer is fitted with several rows of sand-filled barrels that can easily be placed in advance of a highway work zone to act as a portable crash cushion. Rollers on the trailer bed allow the articulated pallet that holds the barrels to easily slide up and down the bed. A winch controls the deployment and retrieval of the sand barrels. The trailer has a 12-ton (13.2-metric ton) capacity.

Portable Rumble Strip

As vehicles travel over the strip, an audible rumble is produced, getting the attention of drivers and alerting them to changing traffic conditions. The device works best when placed in a series in flagger-controlled work zones. Made of relatively lightweight, durable neoprene rubber or plastic, the rumble strip is designed for low-speed operations and is easily transported and put in place.

Remotely Driven Vehicle

This radio-controlled dump truck follows a work crew and serves as a barrier to errant vehicles. The vehicle operator stands a safe distance away, out of the travel lane, and operates the truck using a remote control linked to a computerized console mounted

inside the cab. The remote control features can be disabled, allowing the truck to be used for other maintenance operations.

POST-SHRP ACTIVITIES

Initial field trials of some work zone safety devices determined that improvements were needed before they could be used on a routine basis by public highway agencies. Manufacturers and some States provided funding to improve the products.

Although none of the 10 work zone safety devices have been in use long enough to permit a valid evaluation of potential accident reductions, the use of these products is likely to result in a decrease in accidents, an increase in driver mobility through work zones, and more effective traffic control.

Through exhibits, field demonstrations, and workshops, FHWA is taking these products directly to State and local highway agencies. It also is providing technical assistance in the early stages of product use. This commitment has generated substantial interest in the devices and has attracted a number of manufacturers, who have refined some of the products and now produce them.

Under contract with FHWA, John Hibbs was responsible for providing work zone safety products to the Local Technical Assistance Program (LTAP) centers in each State. The LTAP centers' mission is to transfer transportation technologies to local governments.

Case Studies

For the purposes of the economic analysis, 31 case studies on work zone safety were obtained from 24 States and Puerto Rico.[*] Table 2 contains a State-by-State listing of these cases studies. The following are brief summaries of the benefits of the half-dozen products that have been implemented and evaluated.

Flashing Stop/Slow Paddle

Road crews indicate that the flashing stop/slow paddle gives them an improved sense of safety because the device attracts the immediate attention of motorists. Indeed, motorists report that the flashing paddle attracts their attention better than nonlighted paddles. Its warning signal, which is bright enough to be seen on even the sunniest

[*] 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.

days, appears to be particularly effective during periods of poor visibility, such as fog, rain, or snow, and at night, dusk, and dawn.

Intrusion Alarm

If a vehicle intrudes into a work zone buffer area, an alarm is instantly triggered. The piercing warning siren gives workers the time to run to safety. Maintenance workers experienced with the alarm rate it as one of the best new safety devices.

Direction Indicator Barricade

The direction indicator barricade has proven successful at attracting motorist attention and improving traffic flow. Workers report that they feel safer with the new device in place. Although the lightweight sign costs more initially than traditional barricades, it requires less time to set up and needs minimal maintenance, thus providing long-term savings.

Opposing Traffic Lane Divider

The lightweight, portable dividers can be used to separate opposing lanes of traffic in situations where it would be too expensive and time-consuming to set up concrete barriers. The dividers are easy to set up and to remove. The Texas Department of Transportation (DOT) estimates that use of the device could provide statewide annual savings of $1.6 million.

Portable Rumble Strip

Portable rumble strips help alert drivers to changing traffic patterns and advisories in road repair zones. As drivers cross the strip they hear and feel a rumble, getting their attention and causing them to slow down, which increases worker safety. There have, however, been problems with the strips remaining in place under high-speed traffic.

Remotely Driven Vehicle

A dump truck customized to serve as a traffic barrier for work crews performed well and was easy to use, according to Minnesota DOT. The highway agency reported that safety improved as workers were far less exposed to errant vehicles.

ECONOMIC BENEFITS

A panel of safety experts from the Texas Transportation Institute was convened to review the State case studies and provide a consensus estimate of accident reductions that could reasonably be expected from additional implementation of the work zone safety products.[7]

Because SHRP work zone safety devices have not been used extensively, economic benefits were based on the implementation of two of the more widely used products—the flashing stop/slow paddle and the opposing traffic lane divider. The potential cost savings for these two work zone safety devices is based on a reduced accident estimate of 5 percent, a figure determined by the panel of experts.[7] It was assumed that two paddles and a divider would be used every 500 ft (150 m) in work zones and that the devices would last 4 years.

To estimate the potential cost savings, work zone lengths of 3 mi (5 km) and 0.5 mi (0.8 km) were assumed. The annual cost of implementing the devices was estimated at $429 for a 3-mi (5-km) work zone and $222 for a 0.5-mi (0.8-km) work zone.[7]

According to FHWA's *Highway Statistics 1994,* there are 14,790 mi (23,800 km) of reconstruction and rehabilitation projects each year.[8] Assuming that 50 percent of these projects are under way at a given time, this would equate to a total of 2,465 3-mi (5-km) work zones or 14,790 0.5-mi (0.8-km) work zones. The annual implementation cost would be $1.06 million if all work zones were 3 mi (5 km) long and $3.28 million if all work zones were 0.5 mi (0.8 km) long. To calculate the annual implementation cost, an average of $2.17 million for the two types of work zone was used (Table 3).

In 1994 there were 706 fatal accidents and 4,942 injury accidents unrelated to alcohol in work zones. Accidents involving property-damage-only numbered 20,885. The number of fatal and injury accidents in work zones was obtained from FHWA. The number of property damage accidents was calculated from average accident rates compiled from MicroBENCOST data.[9] The average annual cost of fatal accidents was estimated at $1.9 billion, the cost of injury accidents was estimated at about $123 million, and the cost of property-damage-only-accidents was estimated at about $44 million (Table 3).

The National Highway Traffic Safety Administration estimates that about 86 percent of work zone fatalities are vehicle occupants. Therefore, 86 percent of the total accident cost savings were assigned to users and 14 percent were assigned to highway agencies.

The estimated potential savings for State and local highway agencies from using the flashing stop/slow paddle and opposing traffic lane divider is $12 million annually. The estimated potential savings for users based on the reduction of work zone–related accidents is approximately $89 million. Total estimated savings for public highway agencies plus users is $102 million (Table 3) if the two devices are implemented immediately.[7] But implementation will be gradual. Taking the maximum amount of $102 million, savings for slow, moderate, and fast implementation scenarios were calculated for 20

years using a 5 percent discount rate (Tables 4, 5, and 6). 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: $26 million
- Estimated user savings: $189 million
- Estimated public highway agency and user savings: $215 million

Moderate Implementation

- Implementation reaches 75 percent after 20 years
- Estimated public highway agency savings: $39 million
- Estimated user savings: $279 million
- Estimated public highway agency and user savings: $318 million

Fast Implementation

- Implementation reaches 100 percent after 20 years
- Estimated public highway agency savings: $51 million
- Estimated user savings: $369 million
- Estimated public highway agency and user savings: $420 million

The cost of SHRP-related work zone safety research, development, and implementation was estimated at $30 million over 20 years.[7] Table 7 shows savings and benefit-cost ratios for the three implementation scenarios given above. Savings are associated with accident cost savings and include neither cost savings resulting from increased worker productivity nor user cost savings resulting from reduced time delays in work zones.

Based on the implementation scenarios given above, for each dollar spent on research, development, and implementation, public highway agencies can expect an annual return of $0.90 if implementation is slow, $1.30 if implementation is moderate, and $1.70 if implementation is fast. Annual savings to users will be $6.30, $9.30, and $12 for slow, moderate, and fast implementation respectively. Agency and user savings combined are expected to range from $7.20 to $13.70.

SUMMARY

Highway rehabilitation and maintenance work is dangerous for both crews and motorists. The work zones are usually temporary sites that change as the crews move down the road. Therefore, these temporary work zones lack many of the formidable safety features found in highway reconstruction zones. Shifting traffic patterns and advisories in these work zones often are confusing to drivers.

A new battery of SHRP work zone safety devices keeps motorists and workers safe in highway rehabilitation and maintenance zones by clearly alerting drivers to changing road conditions and by quickly warning workers of threats to their safety from errant vehicles. Work crews report that the products give them an improved sense of safety. States familiar with the devices contend that they have begun to help reduce work zone accident rates.

Benefit-cost ratios will increase substantially with greater use of the work zone safety devices.

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Table 1. SHRP Work Zone Safety Products

Product Area	Product Number and Title
Signs	3011 Opposing Traffic Lane Divider
	3012 Multi-Directional Barricade Sign
	3016 Flashing Stop/Slow Paddle
	3017 Portable All-Terrain Sign Stand
Detectors	3008 Ultrasonic Intrusion Alarm
	3009 Queue-Length Detector
	3010 Infrared Intrusion Alarm
Protection Devices	3013 Remotely Driven Vehicle
	3014 Portable Crash Cushion
	3015 Portable Rumble Strip

Table 2. Work Zone Safety Case Studies

State	Case Study Title
Alabama	Alabama DOT: Pointed in the Right Direction
	A Better Way to Control Traffic
Arkansas	New Barricade Sign Proves Eye Catching
Georgia	Opposing Traffic Lane Divider Shows the Way During Georgia Floods
	Georgia Finds Better Alternative for Directing Traffic Through Taper Lanes
Idaho	Alarm Provides Life-Saving Warning
Illinois	Less Confusion in Work Zones
Indiana	Sign Improves Motorist Safety in Highway Work Zone
Iowa	Flashing Sign Grabs Drivers' Attention
Kansas	Lighted Paddle Improves School Safety
Kentucky	New Device Gives Audible Warning of Upcoming Work Zones
	Lane Divider Eases Redirecting Traffic
	Flaggers Won't Give Up New Safety Device
Maine	Flashing Sign Protects Workers on Back Roads
Minnesota	Robot Shadow Vehicle Protects Maintenance Crew
Mississippi	Mississippi Helps Drivers Find the Right Lane
Missouri	Lighted Paddle Improves Road Work Safety
New Mexico	Lighted Paddle Increases Flagger Safety
	Rumble Strip Gets Drivers' Attention
New York	New York State Finds Intrusion Alarm a Potential Lifesaver
North Dakota	New Warning Device Makes Work Zones Safer
Ohio	Lighted Paddle Makes Flaggers More Visible
Oklahoma	New Device Improves Safety in Work Zones
Pennsylvania	Flashing Paddle Creates Safer Highway Work Zones
Puerto Rico	New Device Keeps Traffic Under Control at Elementary School
South Dakota	Lighted Paddle Improves Flagger Visibility
	New Direction Indicator Improves Motorist and Worker Safety
Tennessee	Rugged Terrain No Problem for New Warning Sign
Texas	A Better Way to Channel Traffic
Vermont	Alarm System Improves Safety on Work Zones
Washington	Intrusion Alarms Offer Workers Peace of Mind

Table 3. Estimated Savings from SHRP Work Zone Safety Products

	Accident Category			
	Fatal	**Injury**	**PDO***	
No. Work Zone-Related Accidents/Year	706	4,942	20,885	
Accident Value (Mill. $)	2.709	0.0248	0.0021	**Total**
Total Work Zone Accident Cost (Mill. $)	1,912.55	122.56	43.86	2,078.97
SHRP Accident Savings (Mill. $) (5% of Total Work Zone Cost)	95.63	6.13	2.19	103.95
Annual Agency Savings with Full Implementation (Mill. $)				
Accident Savings (14%)	13.39	0.86	0.31	14.56
Implementation Cost				-2.17
Net Savings				12.39
Annual Motorist Savings with Full Implementation (86%) (Mill. $)	82.24	5.27	1.88	89.39
Total Annual Savings with Full Implementation (Mill. $)				101.78

* PDO: Property-damage-only.

Table 4. Total Work Zone 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	0.12	0.89	1.01
2	1.7	0.20	1.45	1.65
3	2.7	0.30	2.19	2.49
4	3.9	0.42	3.01	3.43
5	5.4	0.55	3.97	4.52
6	7.1	0.69	4.97	5.66
7	9.0	0.83	6.00	6.83
8	11.1	0.98	7.05	8.03
9	13.4	1.12	8.11	9.23
10	15.9	1.27	9.16	10.43
11	18.5	1.41	10.15	11.56
12	21.4	1.55	11.19	12.74
13	24.4	1.68	12.15	13.83
14	27.6	1.81	13.08	14.89
15	30.9	1.93	13.95	15.88
16	34.4	2.05	14.79	16.84
17	38.1	2.16	15.60	17.76
18	41.9	2.26	16.34	18.60
19	45.9	2.36	17.05	19.41
20	50.0	2.45	17.69	20.14
20-Year Total		26.14	188.79	214.93
Equiv. Ann. Total		2.10	15.15	17.25

Table 5. Total Work Zone 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	0.12	0.89	1.01
2	2.0	0.24	1.70	1.94
3	3.5	0.39	2.84	3.23
4	5.4	0.58	4.17	4.75
5	7.6	0.77	5.59	6.36
6	10.2	0.99	7.14	8.13
7	13.0	1.20	8.67	9.87
8	16.2	1.43	10.29	11.72
9	19.7	1.65	11.92	13.57
10	23.5	1.88	13.54	15.42
11	27.5	2.09	15.09	17.18
12	31.8	2.30	16.62	18.92
13	36.3	2.50	18.07	20.57
14	41.1	2.70	19.48	22.18
15	46.2	2.89	20.86	23.75
16	51.5	3.07	22.15	25.22
17	57.0	3.23	23.34	26.57
18	62.8	3.39	24.49	27.88
19	63.8	3.54	25.56	29.10
20	75.0	3.68	26.33	30.01
20-Year Total		38.64	278.74	317.38
Equiv. Ann. Total		3.10	22.38	25.48

Table 6. Total Work Zone 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	0.12	0.89	1.01
2	2.4	0.28	2.04	2.32
3	4.3	0.48	3.49	3.97
4	6.8	0.73	5.25	5.98
5	9.8	1.00	7.21	8.21
6	13.3	1.29	9.32	10.61
7	17.1	1.58	11.41	12.99
8	21.4	1.88	13.60	15.48
9	26.0	2.18	15.73	17.91
10	31.0	2.47	17.86	20.33
11	36.4	2.77	19.98	22.75
12	42.2	3.06	22.06	25.12
13	48.3	3.33	24.04	27.37
14	54.7	3.59	25.93	29.52
15	61.5	3.85	27.77	31.62
16	68.6	4.09	29.50	33.59
17	76.0	4.31	31.12	35.43
18	83.7	4.52	32.65	37.17
19	91.7	4.72	34.06	38.78
20	100.0	4.90	35.38	40.28
20-Year Total		51.15	369.29	420.44
Equiv. Ann. Total		4.10	29.63	33.73

Table 7. Twenty-Year Cost Savings (Million $) and Benefit-Cost Ratio* for SHRP Work Zone Safety Research

	Implementation Rate					
	Slow		Moderate		Fast	
Basis of Cost	Savings (Million $)	Ratio	Savings (Million $)	Ratio	Savings (Million $)	Ratio
Agency Savings	26	0.9	39	1.3	51	1.7
User Savings	189	6.3	279	9.3	369	12.0
Agency Plus User Savings	215	7.2	318	10.6	420	13.7

* Based on an estimated 20-year research, development, and implementation cost of $30 million.

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