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16. Abstract In order to use the cost-optimization procedure of dynamic programming to rank safety improvements, improvement costs and benefits must be input. The benefits are in terms of accident reductions resulting from specific safety improvements. In this study a comprehensive list of accident reduction factors were developed to use in the cost-optimization program. The development of the list of reduction factors was based mainly on a review of literature and survey of states, with limited input from a before-and-after accident analysis.			
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DEVELOPMENT OF ACCIDENT REDUCTION FACTORS

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Lance Gorman, Chairman, Division of Traffic, Kentucky Department of Highways

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## INTRODUCTION

As part of its highway safety improvement program, the Kentucky Transportation Cabinet utilizes the cost-optimization procedure of dynamic programming to rank highway safety improvements. The accuracy of the improvement costs and benefits (in the form of accident reductions) determines the effectiveness of this program. The procedure presently assumes a 100-percent reduction in accidents for any given safety improvement, but this generally does not occur in reality. The objective of this study is to develop a listing of factors that may be used to reasonably predict the reduction (or increase) in accidents expected upon implementation of a given safety improvement.

## PROCEDURE

A review of literature pertaining to past and current studies related to benefits associated with safety improvements was conducted. Information from those sources was compiled to form a list of accident reduction factors for various highway safety improvements.

A survey of states was performed to determine what is being used currently by individual states. A letter was sent to all states to obtain information concerning accident reduction estimates used to rank highway safety improvements and the basis for those percentages (Appendix). The states were asked whether the percent reductions in accidents, if used, were based on before-and-after analysis related to implementation of the improvement, a review of relevant literature, or engineering judgment.

A before-and-after accident analysis of safety improvement projects in Kentucky was performed and a list of reduction factors was compiled for those safety improvements. Accident data for one or two years before implementation of the improvement and one or two years after implementation were obtained from the Accident Surveillance Section of the Division of Traffic. Average annual accidents before and after

implementation of safety improvements were compared to obtain the estimated percent reduction in all accidents related to implementation.

## RESULTS

An attempt was made to compile a comprehensive list of all types of safety improvements from current literature and from other states. Although some safety improvements may have been excluded from the literature sources or returned survey responses, a large number of safety improvements and associated accident reduction factors was collected. Those safety improvements were grouped into the general categories listed in Table 1. Subsequent tables were based on all or part of those categories. All categories having characteristics in common, such as signs, were placed in the same category. Subdivisions by type of improvement within each category were made to provide clarity and organization. For example, the category "Signs" was subdivided by type of sign: Warning Signs, Regulatory Signs, Guidance Signs, Other.

## REVIEW OF LITERATURE

From the review of literature pertaining to past and present studies, 42 sources relating to accident reductions from highway safety improvements were obtained and are listed in the "References" section of this report. The majority of the sources described the effects of highway safety improvements in terms of percentage reductions in accidents. These are listed in Table 2. The remaining references related highway safety improvements to percentage reductions in accident rates and are listed in Table 3.

Some of the references listed reductions in accidents or accident rates by severity of accident -- fatal, injury, fatal and injury, and property damage only -- as well as reductions in total accidents or accident rates for a given safety improvement. Others listed only a total reduction in all accidents or rates for a given safety

improvement. Reductions for specific types of accidents such as wet pavement or nighttime accidents were listed by some of the references. Reductions in accidents or accident rates for some types of safety improvements varied widely among sources. For example, in the safety improvement category for signals in Table 2, the percentage reduction in all accidents corresponding to new signal installation ranged from 10 to 80 percent.

The source of the information given in Tables 2 and 3 is identified by the reference number as given in the listing of references. Some references were based upon findings of several previous studies and contained more than one list of reduction factors. Additional lists of reduction factors by the same reference are denoted by a lower case letter. For example, Reference 6, a 1966 report by Roy Jorgensen & Associates, contains three separate lists of accident reduction factors: a summary of before-and-after-results from a previous study, a list of forecasted reductions from the same study, and a list of reduction factors based on the Jorgensen study itself. These three lists are designated in Table 2 as References 6, 6a, and 6b, respectively.

#### SURVEY OF STATES

Table 4 summarizes the origin of reduction factors obtained from the survey of states. At the time of the survey, 22 states replied they did not use reduction factors in ranking highway safety improvements. Eleven states reported they developed their own factors through before-and-after studies, review of literature, engineering judgment, or a combination of the three. Twelve states adopted factors either from current literature or factors developed by other states. Five states -- Kansas, New Jersey, New York, Texas, and Utah -- used a combination of adopted factors and factors developed from their own studies. The expected percentage reductions in accidents for highway safety improvements according to reduction factors used by states are given in

Table 5, while percentage reductions in accident rates corresponding to highway safety improvements expected by states are given in Table 6.

The reduction factors listed in Tables 5 and 6 were either developed by the states listed or have been adopted from other sources. The source shown in these tables is either the state (noted by the state abbreviation) or the literature source from which the state adopted its factors (as noted in Table 4). Review of Tables 4, 5, and 6 reveals that Minnesota has developed its own reduction factors, but those factors are not listed in Table 5 or Table 6. Minnesota does not have a set of statewide reduction factors. Instead, individual highway districts are responsible for developing their own reduction factors. Two districts listed accident reduction factors for highway safety improvements. Those factors were given by type of accident (e.g. rear end, angle, head-on, right turn, etc.) and were incompatible with factors submitted by other states. Thus, they were not included in the tables.

#### BEFORE-AND-AFTER ANALYSIS IN KENTUCKY

A before-and-after accident analysis of highway safety improvements in Kentucky was performed. Accident data were obtained for one-year or two-year periods before and after implementation of safety improvements. Average annual accidents before and after implementation were compared to determine the percentage reductions in total accidents for various types of safety improvements. Those results are given in Table 7.

#### CONCLUSION

Through a review of current literature and a survey of states, it was concluded that there is no commonly accepted list of factors that may be used to predict the percentage reduction in accidents corresponding to implementation of different types of highway safety improvements. Some states utilized developed or adopted factors for the

purpose of ranking safety improvements, while others preferred alternative methods. Nearly all states expressed an interest in such a set of factors.

#### DEVELOPMENT OF REDUCTION FACTORS

It was the objective of this study to derive a comprehensive list of accident reduction factors for the purpose of optimizing the priority ranking procedure of highway safety improvements in Kentucky. The development of a list of these reduction factors was based mainly on the review of literature and survey of states, with limited input from the before-and-after accident analysis in Kentucky.

Table 8 lists a set of recommended accident reduction factors for highway safety improvements. Some of those factors are based on before-and-after studies, others are based solely on engineering judgment, and some entail a combination of both. While many of these factors are judgmental, a step has been made toward developing a set of commonly accepted accident reduction factors. It is hopeful that this list will be continually improved and upgraded through before-and-after accident analyses so that in the future a reliable prediction of accident reductions associated with highway safety improvements may be utilized by all agencies.

#### IMPLEMENTATION

The Division of Traffic of the Kentucky Transportation Cabinet uses a dynamic programming procedure as a means to priority rank safety improvements. To use this program, the user must provide certain vital information that includes expected reductions in accidents for each safety improvement. The accident reduction factors developed in this report (given in Table 8) can be used to provide that information.

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TABLE 1. SAFETY IMPROVEMENT CATEGORIES

- I. SIGNS
  - A. Warning Signs
  - B. Regulatory Signs
  - C. Guidance Signs
  - D. Other
  
- II. SIGNALS
  - A. New Signal Installation
  - B. Signal Modernization, Modification  
or Upgrading
  - C. Warning Signal/Flashing Beacons
  - D. Signal Phasing
  - E. Other
  
- III. DELINEATION
  - A. General
  - B. Delineators
  - C. Other Delineation
  
- IV. PAVEMENT MARKING
  - A. Paint Stripes
  - B. Other Pavement Marking
  
- V. CHANNELIZATION
  - A. General Intersection
  - B. Left-Turn Channelization
  
- VI. CONSTRUCTION/RECONSTRUCTION
  - A. Lane Addition
  - B. Lane/Shoulder Widening
  - C. Alignment
  - D. Curve Reconstruction
  - E. Intersection/Interchange
  - F. Bridges
  - G. General Reconstruction and Miscellaneous
  - H. Other
  
- VII. PAVEMENT TREATMENT
  - A. Resurfacing
  - B. Skid Resistance
  - C. Other
  
- VIII. SAFETY BARRIERS
  - A. Median Barriers
  - B. Crash Cushions
  - C. Guardrails
  - D. Bridge-Underpass Locations

TABLE 1. SAFETY IMPROVEMENT CATEGORIES (Cont.)

- IX. SAFETY LIGHTING
  - A. General
  - B. Intersections
  - C. Sections
  - D. Railroad Crossings
  - E. Bridge Approaches
  - F. Underpasses
  - G. Other Lighting
  
- X. SAFETY POLES AND POSTS
  - A. Signs and Supports
  - B. Utility Poles
  
- XI. RAILROAD CROSSINGS
  - A. At-Grade Crossings
  - B. Other
  
- XII. REMOVAL/RELOCATION OF ROADSIDE OBJECTS
  - A. Removal
  - B. Relocation
  - C. Other
  
- XIII. OTHER
  - A. Fencing
  - B. Miscellaneous
  - C. Other Combination Improvements

TABLE 2. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENTS

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
<b>I. SIGNS</b>						
<b>A. WARNING SIGNS</b>						
1. Intersections						
a. Urban: 2 lanes	5,6b,10,14		51			29
2+ lanes				47	26	41
Rural: 2 lanes/4 leg			19			37
2+ lanes/4 leg			-7			9
2 lanes/T-int.			43			61
2+ lanes/T-int.		67			65	
b. Stop ahead	5,6b,10,14					
Rural: 2 lanes				96		47
c. Prepare for sudden stop	3					25
2. Sections						
a. Urban: 2 lanes	5,6b,7a,10,14		14			14
2+ lanes			26			20
Rural: 2 lanes			32			36
2+ lanes			3			18
b. Deer crossing sign	1	5	5		5	
c. Vehicle activated sign	1	20	20		20	
d. Ice on bridge sign	2	80	80		80	
e. Ice on bridge sign sensor	1	50	50		50	
f. Side road sign	3					27
	5					19
g. Advisory speed	5					38
	7,10b					36
3. Curves	1	20	20		20	
a. Rural: 2 lanes	5,6b,7a,10,14			71	23	57
2+ lanes				40		52
b. Arrows	5,7,7a,11					20
c. Advance warning with advisory speed	7,11					20
d. Special w/stated speed	7,11					75
e. Special (other)	5					75
	12					20
f. Combination curve warning and advisory speed	7					75
g. Curve warning signs with delineation	6b,10,14					
Urban: 2+ lanes				-27		20
Rural: 2 lanes				41		22
<b>B. REGULATORY SIGNS</b>						
1. Intersection						
a. 4-way stop	5					48
Urban: 2 lanes	5		68		70	70
	6b,10,14			67		68

TABLE 2. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
b. Stop control, minor leg	5,6b,10,14					
Urban: 2 lanes			71			48
2+ lanes				18	22	38
Rural: 2 lanes			89			65
c. Change from 2-way to 4-way stop	5					56
d. Install yield sign	5,6b,10,14					
Urban: 2 lanes			80			59
2+ lanes						-46
2. General	5 15					22 38
3. Overhead lane	10a					15
C. GUIDANCE SIGNS						
1. General	5					14
2. Diagrammatic exit signs	2	25	25		25	
3. Overhead	10a					20
D. OTHER						
1. Fasten seat belts at entrance ramps & int.	1,2	2				
2. Variable message signs	2	10	10		10	
3. Upgrade signing	12					10
4. Traffic signs (general)	39			1		0
5. Install or upgrade	41					23
II. SIGNALS						
A. NEW SIGNAL INSTALLATION						
1. General	5 6 6a 7,11 6b,7a,10,14 10a 10b 15 16 18 39					19 32 25 15 29 80 27 14 18 30 10
				50		
					43	26
				8		
2. With channelization	5,7,11 6 18 39					20 27 42 6
				53	39	
				21		

TABLE 2. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL INJURY	F&I**	PDO***	TOTAL
<b>B. SIGNAL MODERNIZATION, MODIFICATION, OR UPGRADING</b>					
1. General	5				12
	6				17
	7,11,12				10
	15				14
	10b				27
	16				18
	17				12
	19				40
2. Urban, 2 lanes	6b,10,14			35	31
2+ lanes				10	-2
2+ lanes, T-int.				57	
Rural, 2+ lanes				45	42
3. Signal modernization, modification, or upgrading w/channelization	5,7,11 6				35 41
4. Remove signal	10a,12				90
<b>C. WARNING SIGNALS/FLASHING BEACONS</b>					
1. New Installation	1	10	10	10	
	6				30
a. Intersections	7,7a,10b,11				
4-leg, red-yellow					50
3-leg, red-yellow					50
4-way, red					75
b. Red-yellow	5	71	39	27	34
4-leg		62	34	35	31
3-leg		100	56	36	53
c. 4-way red	5	100	81	53	68
d. Advance warning	5	100	-4	41	31
intersection		100	-50	41	24
curve		100	50	54	54
school		0	63	-10	3
curve/int.					30
e. Advance warning curve and intersection	7,11 12 15				30 20 21
f. Urban, 2+ lanes	6b,10,14		73		-27
g. Rural, 2 lanes			29		56
2+ lanes					21
h. At curves & intersections	6a 7a 10b	94	59		25 37 30
i. RR Crossing	7,7a,10b,11 16				80 94
j. Pedestrian signals	5,6b,10,14				
Urban, 2 lanes			56		13
2+ lanes			42		3
	12				30
<b>D. SIGNAL PHASING</b>					
1. Add RTOR phase	5	30	3		5
2. Add left-turn phase	12				30

TABLE 2. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL INJURY	F&I**	PDO***	TOTAL
3. Add left-turn phase w/illumination	5,6b,10,14	76			46
4. Add left-turn phase (no channelization)	5,6b,10,14	57			39 40
5. Timing	10a				10
6. Improve timing and interconnect	12				10
7. Add pedestrian phase	10a 12				60 30
E. OTHER					
1. Prohibit RTOR	12				25
2. Pretimed to actuated	5 10a 12				41 14 10
3. 12-inch lens	10a,12				10
4. Install or improve signals	41				18
III. DELINEATION					
A. GENERAL					
	6 6a 7a 16	100	39		36 45 19 13
B. DELINEATORS					
1. Raised pavement markers	5,7,10b,11 12				5 15
2. Install delineators					
a. At horizontal curves	5,7,7a,10b,11 6b			41	30 22
b. At bridge approaches	1 2	10 5	10 5	5 5	
c. Rural, 2 lanes 2+ lanes	5		16 -10	61	2 46
d. At bridge underpass 2 lanes 2+ lanes	5,6b,10,14		-8	62 89	50 47 53
3. Reflectorized traffic buttons	5 18				20 25
4. Curve delineation	7a	16	16	16	16
5. Install posts where none present	3				25
6. Replace and upgrade posts and lenses	1	2	2	1	
C. OTHER DELINEATION					
1. Delineation for wrong-way accidents	1,2	20	20	20	

TABLE 2. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL INJURY	F&I**	PDO***		
<b>IV. PAVEMENT MARKING</b>						
<b>A. PAINT STRIPES</b>						
1. Install/improve edge marking, rural	5					15
2. Right edgelines	5,7,10b,11 7a 12			17		2 14 15
3. Edgeline striping	5					11
a. 22-26'						7
b. 28-34'						13
c. 36-40'						14
4. Centerline striping	5 12					60 25
a. Rural, crest curve	6b,10,14					64
5. Centerlines & edgelines	5			-4		4
6. Median double yellow	5,7,10b,11					5
7. No passing striping	5,7,10b,11 12					65 30
8. Transverse stripes	1,2					15
9. Line striping	5	-2	4		-4	-1
10. Add painted line only	5					25
All sections						40
Tangent sections						28
Winding sections						28
11. Add any centerline	5					28
Winding sections						40
Horizontal curves						2
12. Improve centerline striping	5					-25
13. Improve center and edgelines	5					12
14. Other striping	10a					13
15. Striping and/or delineators	41					15
<b>V. CHANNELIZATION</b>						
<b>A. GENERAL INTERSECTION</b>						
1. Channelization	5	34	6	7	18	15
a. W/storage lane						15
b. W/signs						37
c. W/left turn bay	5 6 6a 39 41	40	22		22	22 51 30 11 23
d. Right turn & acc. lane	12			5		15
e. Continuous left-turn lane	12 16					30 23



TABLE 2. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
2. Channelization & signals	5			31	15	20
Rural primary		-20	-1		6	3
Urban, primary		67	34		23	26
Urban, primary, undivided 4 lanes		58	41		24	31
Rural, secondary			-27		30	18
Urban, secondary		-732	-13		9	0
<b>B. LEFT-TURN CHANNELIZATION</b>						
1. At signalized intersections	7,11					15
a. Left-turn phase	7a,10b 12					36 30
b. No left-turn phase	7a,10b 12					15 20
2. At non-signalized intersections	7,7a,11					
a. W/curbs and/or raised bars						65
urban areas						70
rural areas						60
b. Painted channelization						30
urban areas						15
rural areas						50
<b>VI. CONSTRUCTION/RECONSTRUCTION</b>						
<b>A. LANE ADDITION</b>						
1. Left-Turn lane						
a. Without signal						
Urban:	5					25
2 lanes			30			19
2+ lanes				54	18	6
2 lanes, T-int.			79			79
2+ lanes, T-int.			62			51
Rural:	5					
2+ lanes			-1			-6
2+ lanes, Y-int.				5	-15	33
Urban, 2 lanes	6b,10			80		19
2+ lanes				54	18	6
2 lanes, T-int.				79		79
2+ lanes, T-int.				62		51
Rural, 2+ lanes				-1		-6
2 lanes, Y-int.				5	-15	33
Urban, 2 lanes	7a					19
2+ lanes						6
Rural, 2 lanes						-6
b. With signal	5,6b,7,10,11,14					
Urban				1	-7	27
Rural, +-int.			58			43
Rural, T-int.			-28			-42
c. Two-way left-turn lanes	5					30
2. Add Acc./Decel. lanes	5					10
3. Add right-turn lanes and and decel. lane	12					15
4. Add passing lane	12					30

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
5. Add shoulder	5	12	12		20	17
6. Extend acc. lane to 1,000' at ramp	2	75	75		75	
7. Extend lane drop and add acc. lane	12					20
8. Add climbing lane	5					14
9. Lane added without new median	16 39 41				-20	17 -14 17
<b>B. LANE/SHOULDER WIDENING</b>						
1. Pavement & shoulder widening	5 7a 39	-13	32	26	18	21 27 22
2. Passing lane	5					
a. Widen to 36'						11
Widen to 46'		37	24		24	25
Widen to 42-44'		58	-10		40	27
b. 2 lane highways	17					
widen to 40'		37	24	24	24	25
widen to 42-44'		58			40	27
c. 2 lane highways	17					
AADT <3000, widened to 28'			30			16
AADT <5000, widened to 32'			18		45	35
AADT >5000, widened to 40'			28		30	29
3. Shoulder stabilization	5,6b,10,14		46			38
4. Shoulder improvement	3 5 16					23 28 29
5. Shoulder widening						
a. No dimensions	6b,10,14 12 16				7	-2 15 29
b. To 28' road width	5	69	30			16
32' road width		53	17		44	35
40' road width		-29	29		31	29
6. Shoulder widening or improvement	41					29
7. Widen travelled way						
a. No dimensions, rural 2 lane	6b,7a,10,14 12,16				30	38 25
b. From 9-ft. lanes	6b,10,14				16	38
c. From 10-ft. lanes	6b,10,14				-65	-37
8. Pavement widening	39 41				-2	8 25

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
<b>C. ALIGNMENT</b>						
1. Change horizontal alignment	5 7a 12 39	80	22	27 -56	29	28 40 20 29
2. Change vertical alignment	5 12 39			50 18	56	54 15 32
3. Change horizontal & vertical alignment	5 10b 39		46	62 47	46	52 50
<b>D. CURVE RECONSTRUCTION</b>						
	5 6b,7a,10,14			89	96	60 88
<b>E. BRIDGES</b>						
1. Widen existing bridge or other major structure	2 7a 12 16 17 39 41	50 50	50 62		50 44	40 65 44 30 65
2. Replace bridge or other major structure	7a 16 39 41	100	66		62 27	44 27 44
<b>F. GENERAL RECONSTRUCTION AND MISCELLANEOUS</b>						
	6 6a 7,11 10a 10b 15					42 40 20 15 25 43
<b>G. OTHER</b>						
1. Improve sight distance	3 5 10a 16 39 41	57	20	21	26	28 24 20 31 22 31
a. At intersections	12					15
2. Improve median crossover	1	50	50		50	
3. Close median openings	2 3,5 10a	50	50		50	29 80
4. New median	5	19	2		14	11
5. Add median and barrier	12					40
6. Correct/improve superelevation	10b 12					50 20

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL INJURY	F&I**	PDO***	TOTAL
7. Increase turning radii at intersections	12				11
8. Frontage road, new construction	5				40
9. Ramp modification Entrance Exit	5				30 20
10. Widening, correct superelevation, etc.	5				20
11. Flatten side slope	5		10	20	16
12. Construct pedestrian crossover	5		100	20	95
13. Grade separated interchange (replace at-grade)	1	100	75	75	
<b>VII. PAVEMENT TREATMENT</b>					
<b>A. RESURFACING</b>					
1. Urban, 2+ lanes	5,6b,7a,10,14			46	42
2. Rural, 2 lanes 2+ lanes				21 59	12 44
3. Overall resurfacing	12				10
4. ACP	5 17 19				21(42 <sup>w</sup> ) 42 <sup>w</sup> 49 <sup>w</sup>
5. Overlay	5 16 39 41			13 24 10	21 17 22 17
<b>B. SKID RESISTANCE</b>					
1. Deslicking	1	50	50	50	
a. Urban, 2 lanes	5,6b,10,14		15	20	
b. Rural	5 10a 12		37		50 13
2. Pavement grooving	5 16 41	12(67 <sup>w</sup> )	91 <sup>w</sup>	9(30 <sup>w</sup> )	10(75 <sup>w</sup> ) 48 48
a. Length < 0.5 Mile	7				75 <sup>w</sup>
b. Length > 0.5 Mile					75 <sup>w</sup>
3. Grooving or resurfacing	5 15	80 <sup>w</sup>	76 <sup>w</sup>	67 <sup>w</sup>	70 <sup>w</sup> 43
4. Pavement anti-skid treatment	5,7a	21		-8 16	
5. Asphalt seal coat	5 17 19				21(42 <sup>w</sup> ) 42 <sup>w</sup> 40 <sup>w</sup>
6. Saw concrete/rural	5				20

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL INJURY	F&I**	PDO***	TOTAL
7. Treated with resin/bauxite	5				40
<b>C. OTHER</b>					
1. Rumble strips	3 5				29 28
a. Rural, 2 lanes	5,6b,10,14		26	24	27
<b>VIII. SAFETY BARRIERS</b>					
<b>A. MEDIAN BARRIERS</b>					
	5 6a 39	30		-1	-25 8
1. Cable barrier >2 lanes	5 6b,7a,10,14	36	-20	4 -40	-31 -33
2. Beam barrier >2 lanes	5 6b,7a,10,14	15	-30	-22 -10	-20 -20
3. Add painted/raised median	5 6b,10,14				10 12
4. Concrete barrier 1-12' (median width) 13-30' (median width)	5,7a	90 85	-3 10 5	-10 -25	-26
5. CMB replacing barrels	1	50	50	-50	
6. Install type barrier >2 lanes	6b,10,14			-11	-44
7. Install center barrier 4-lane, median width 0-5'	6b,10,14			-61	-53
8. Installation or improvement of median barrier	7a 41	18	-9		-36 3
9. Double-faced guardrail 1-12' (median width) 13-30' (median width) 31-60' (median width)	5	75 85 85	2 5 5	-28 -30 -30	
10. Antiglare screen	5 2	0 15	20 15	-50 15	-14
11. CMB w/end treatment	5	60	40	-150	
12. Add median & median barrier	12				40
13. Retrofit curbs w/New Jersey barrier @ bridges	1	75	75	50	
<b>B. CRASH CUSHIONS</b>					
1. General	5 7a	75 70 50	50 9 50	-100 -7 -20	-1
2. Water-filled cushion	5	75	60	-300	
3. Sand-filled cell	5	75	60	-300	
4. Steel barrel	5	75	60	-300	

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL INJURY	F&I**	PDO***		
<b>C. GUARDRAILS</b>						
1. General	6 6a					71 65
2. End treatments						
a. BCT	1 2 5,7a	90 75 55	60 50 25	-180 -40 -15		
b. Texas Turned Down	5,7a	55	25	-15		
3. Thrie-beam guardrail and Hi-dri guardrail blockouts	1	50	50	-10		
4. Road edge guardrail	5 12 39	67	-4	-2 -5		-2 40 -4
a. Install or improve	41			-2		13
5. At bridge rail ends	5 7,10b,11	90	45	-110		61 50
6. At culvert	5	61	45	-61		
7. At ditch	5			26 -19		
8. At embankment	5 7,11	47	42	-47		50
a. curve	5,10b					50
b. outside curves						65
c. inside curves						30
9. At overpass siderail	5	34				
10. At rocks	5			31 -45		
11. At tree	5	65	51	-90		
12. At tree & bush	5			16 -9		
13. At wood utility pole	5	-40	37	-31		
<b>D. BRIDGE/UNDERPASS LOCATIONS</b>						
1. Guardrail transition to bridge end	1 2 7a	75 75 55	50 50 20	-170 -75 -50		
2. Guardrail & shrubs in gaps between bridges	1 2	90 90	60 60	-100 -60		
3. Energy attenuators	7a 39	75	60	-300	22	14
4. Improve substandard bridge rail	7a	15	5	-3		
5. Median & shoulder bridge pier protection	1 2	90 90	60 60	-100 -300		

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL INJURY	F&I**	PDO***	TOTAL
<b>IX. SAFETY LIGHTING</b>					
A. GENERAL	5	36	18	2	12(50 <sup>n</sup> )
	6				70(86 <sup>n</sup> )
	6a				45
	10a				50
	12				10
	15				-18
	16				9
	18				30
	39			-15	-9
	41				9
B. INTERSECTIONS	5				70 <sup>n</sup>
1. New	5,7,7a,10b,11				75 <sup>n</sup>
2. 3-leg	5				51(70 <sup>n</sup> )
3. 2-leg on major leg	5				28(60 <sup>n</sup> )
4. 4-leg on major leg	5				30(62 <sup>n</sup> )
5. Upgrading	5				24(65 <sup>n</sup> )
	10b				50
C. SECTIONS					
1. Urban freeway	5				20(50 <sup>n</sup> )
	7a	50 <sup>n</sup>	20 <sup>n</sup>	14 <sup>n</sup>	
D. RAILROAD CROSSINGS	5				52(60 <sup>n</sup> )
	7,7a,10b,11				60 <sup>n</sup>
E. BRIDGE APPROACHES	5				28(50 <sup>n</sup> )
	7,7a,10b,11				50 <sup>n</sup>
F. UNDERPASSES	5				-2(10 <sup>n</sup> )
	7,7a,10b,11				10 <sup>n</sup>
G. OTHER LIGHTING					
1. Urban interstate interchanges and rural primary sections	7a	50 <sup>n</sup>	50 <sup>n</sup>	50 <sup>n</sup>	50 <sup>n</sup>
<b>X. SAFETY POLES &amp; POSTS</b>					
<b>A. SIGNS &amp; SUPPORTS</b>					
1. Make signs breakaway	1	75	75	-70	
	2	50	50	-10	
	41				35
a. small signs	5,7a	70	25	-12	
b. large metal supports	5,7a	60	20	-20	
c. all supports combined	5,7a	68	24	-14	
	39			-15	-15
2. Breakaway (all)	5			-5	12
	16				-20
					35
3. Safety treat sign support	5				25

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL	INJURY	F&I**	PDO***
<b>B. UTILITY POLES</b>					
1. Make utility poles breakaway	5,7a 1 2	30 75 50	-1 75 50	0 -500 -35	
<b>XI. RAILROAD CROSSING</b>					
<b>A. AT-GRADE</b>					
1. New flashing beacons	5				81
2. Replace signs with:					
a. Flashing beacons	5 39 41			83 90	52 70 75 94
b. Automatic gates	5 39 12 41			94 90	73 83 80 60 99
3. Replace active device:					
a. With automatic gates	5 39 41			82 87	79 80 79 81
b. With grade separation	5		100	88	95
4. Protection prior to installation of:					
a. Flashing light signals	5				
Urban:					
none - new crossing		67	64		57 99
crossbucks		75	71		57
wigwag					48
misc.		100	43		42
Rural:					
crossbucks		83	86		67
wigwag		86	91		74
misc.		57	73		50 48
b. Automatic gates	5				
Urban:					
crossbucks		100	80		71
wigwag		100	94		79
flashing lights		75	89		67
misc.		80	75		68
Rural:					
crossbucks		100	80		74
wigwag		90	88		72
flashing lights		100	93		87
misc.		83	88		66
flashing lights		86	81		63
misc.			100		100
5. Automatic protective devices at RR grade crossings	7a		-16		28
6. Railroad highway grade crossings upgraded from passive to active status:	7a				
Urban					12
Rural					20



TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
7. Crossing surface improvement	39			23		23
B. OTHER	39			62		50
<b>XII. REMOVAL/RELOCATION OF ROADSIDE OBJECTS</b>						
<b>A. REMOVAL</b>						
1. Remove utility poles	5,7a	35	-2		0	
2. Remove trees		50	25		-20	
3. Remove obstacles from:						
a. existing steep slope	5	14	10		-18	
b. existing gentle slope	5	73	23		-40	
c. cut slopes	5	35	15		-30	
4. Remove rock outcroppings	1 2	100 65	100 25		50 5	
5. Fixed object	12 17					80 64
<b>B. RELOCATION</b>						
1. Fixed objects	10a					60
	17					64
2. Utility poles - 30 ft. from pavement edge	5,7a	32	-2		0	
<b>C. OTHER</b>						
1. Clear gore area	1 2	75 50	50 50		25 0	
2. Shield rock cuts	1	90	60		-60	
<b>XIII. OTHER</b>						
<b>A. FENCING</b>						
1. Deer fencing	1	100	100		100	
2. Fencing, livestock	5,6b,10,14					
Rural, interstate		-36	-9		0	-3
Rural, divided		100	63		57	61
Rural, undivided, <4 lanes		100	100		55	74
<b>B. MISCELLANEOUS</b>						
1. Ramp metering	2	75	75		75	
2. Culvert/headwall improvements	1 18	90	60		0	30
3. Eliminate parking	5,6b,10,14 12		3			32 30

TABLE 2. REVIEW OF LITERATURE - PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL INJURY	F&I**	PDO***	TOTAL
4. Modernize to design standards Rural, 2 lanes 2+ lanes	6b,10,14		-6 22	40	10 15
5. Curtail turning movements	6b,10,14		39		40
6. Install curbing	12			50	
7. Pavement approach	12				12
8. Revise driveways	12				13
9. Prohibit left turns	12				30
10. Modernize drainage	18				30
11. Relocate driveways	10a				13
C. OTHER COMBINATION IMPROVEMENTS					
1. Delineators, Markings, Signs, Maintenance General Curve	5				22 24
2. Resurfacing, Patching, Drainage, Deslick, Culvert General Curve & guardrail	5				16 33
3. Marking & Delineation	5 39	10	-5	-9 -15	-12 -11
4. Signs, Markings & Delineation at Narrow Bridges	39			5	15
5. Marking, Maintenance & Signing (intersection)	5				35
6. Marking & Signs General Intersection	5				36 24
7. Rumble Strips & Beacon	5				32
8. Rumble Strips & Lighting	5				17
9. Warning Signs, Installment and Delineators Urban, 2+ lanes	5		-27 41		20 22
10. Intersection directional & warning signs	12				14
11. Signs/striping	16 41				24 24
12. Signs/striping & breakaway signs or supports	16				31
13. Improve drainage structures	39			0	8

\* - Negative value indicates an increase in accidents

\*\* - F&I - Fatal and Injury Accidents

\*\*\* - PDO - Property Damage only Accidents

w - wet pavement accidents

n - nighttime accidents

TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES				
		FATAL	INJURY	F&I	PDO	TOTAL
<b>I. SIGNS</b>						
<b>A. WARNING AND REGULATORY SIGNS</b>						
1. Warning & regulatory signs in urban areas	29	19	9	9	4	5
2. All combinations	24 40	66 30	41 9	42 10	33	36
3. Regulatory Signs (General)	13	100	24		40	34
<b>II. SIGNALS</b>						
<b>A. SIGNAL MODERNIZATION, MODIFICATION, OR UPGRADING</b>						
1. General	13 22 23 24 25 26 27 28 29	100 61 41	63 19 19 20 23 24 17 36	20 29 20	44 16 23 23 24 17 30 22	48 17 39 22 22 24 19 26 24
2. Rural, 2 lanes 4 lanes, undivided 4 lanes, divided >4 lanes, divided All	24	74 48	25 37 33 22	27 38 33 23	27 29 18 39 24	27 32 14 37 23
3. Urban, 2 lanes 4 lanes, undivided 4 lanes, divided >4 lanes, undivided >4 lanes, divided All	24	35 42	13 14 19 20 30 19	14 14 19 20 30 19	27 21 23 22 35 26	23 19 22 21 33 24
<b>B. NEW SIGNALS</b>	13 40	62 44	47 20	21	16	23
<b>C. WARNING SIGNALS/FLASHING BEACON</b>						
Flashing beacon	13	96	51		23	32
<b>III. PAVEMENT MARKING</b>						
<b>A. PAINT STRIPES</b>						
1. Edgeline Striping	24				8	4
22-26'	30					37
28-34'	30					32
36-40'	30					28
All widths	30					32
2. Centerline striping	24				4	1
3. Centerlines & edgelines	24 32 31 33	10	6 42 22	6 39 12 27	6 40 45	6 40 40
4. Other pavement marking	24				26	21

TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

RATES SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES				
		FATAL	INJURY	F&I	PDO	TOTAL
B. PAVEMENT MARKINGS AND/OR DELINEATORS	40	1	-6	-5		
IV. CHANNELIZATION						
GENERAL INTERSECTION						
1. Channelization						
And/or turning lanes	22		12		18	16
	23			19		24
	24	29	15		22	20
	40	49	24	25		
a. Rural, 2 lanes	24		33	33	30	31
4 lanes, undivided			24	25	22	23
4 lanes, divided		53	12	13	22	19
>4 lanes, divided					56	49
All		41	22	23	26	25
b. Urban, 2 lanes	24		40	40	18	26
4 lanes, undivided			21	21	21	21
4 lanes, divided					17	10
>4 lanes, divided			16	16	24	22
All			13	13	19	18
2. Continuous left-turn lane	20		18		18	18
V. CONSTRUCTION/RECONSTRUCTION						
A. LANE ADDITION						
General	24				7	5
	22		29	28	36	33
	40	-25	5	5		
a. Rural, 4 lanes, undivided	24		44	45	19	29
b. Urban, 4 lanes, undivided	24				4	
4 lanes, divided					6	
>4 lanes, undivided			75	75	85	80
>4 lanes, divided			35	34		16
All urban					7	3
B. LANE/SHOULDER WIDENING						
1. Pavement & shoulder widening	24		14	16	20	19
a. Rural areas	24					
4 lanes, divided			37	40		
b. Urban areas	24					
2 lanes			56	56	52	53
4 lanes, undivided			63	63	62	63
4 lanes, divided			26	27		19
All urban			43	43	39	41
2. Shoulder widening or improvement	40	21	6	7		
	24	28			12	8
a. Rural areas	24					
2 lanes		48	8	10	23	18
All rural		41			12	9
b. Urban areas	24					
2 lanes					40	26
4 lanes, undivided			32	30		
All urban					14	9

TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

RATES SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES				
		FATAL	INJURY	F&I	PDO	TOTAL
3. Pavement widening	24 40	40 9	15 10	16 10	25	22
a. Rural areas	24					
2 lanes		47	17	18	28	24
4 lanes, undivided			33	38	41	40
All rural		51	18	19	27	24
b. Urban areas:						
4 lanes, undivided			27	27	51	45
>4 lanes, divided			55	54	66	63
All urban			11	10	20	17
C. ALIGNMENT						
1. Change horizontal alignment	23 24			1 33		10 38
a. Rural areas:	24					
2 lanes			52	56	49	52
4 lanes, undivided			34	33	52	44
4 lanes, divided			32	38		27
All rural		85	44	48	45	46
b. Urban areas:	24					
2 lanes			27	30	35	32
4 lanes, undivided					59	36
>4 lanes, undivided			24	23	34	30
All urban					26	17
2. Change vertical alignment	24		45	49	59	57
a. Rural areas:	24					
2 lanes			59	59	66	63
All rural			57	60	66	63
3. Change horizontal & vertical alignment	24 40	55 66	37 33	38 35	36	37
a. Rural areas:	24					
2 lanes			39	38	49	45
All rural			36	37	29	32
b. Urban areas:	24					
>4 lanes, undivided			54	54	61	59
All urban			51	51	54	53
D. BRIDGES						
1. Widen existing bridge or other major structure	24 40		39 18	40 19	35	37
a. Rural areas:	24					
2 lanes			42	41	51	47
4 lanes, undivided			37	37	32	33
4 lanes, divided			41	48	63	56
All rural			49	49	47	48
b. Urban areas:	24					
>4 lanes, divided					42	40
All urban			36	39	37	37
2. Replace bridge or other major structure	24 40	81 66	33 41	37 43	33	34
a. Rural areas:	24					
2 lanes			37	39	40	40
All rural			38	40	47	44

TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES				
		FATAL	INJURY F&I	PDO	TOTAL	
3. Minor structure replaced or improved	40	24	23	24		
<b>E. OTHER</b>						
1. Improve Sight Distance	40	24	31	30		
a. At intersections	24		29	31	37	35
Rural areas:						
2 lanes			28	29	29	29
4 lanes, divided					60	47
All rural			25	27	38	35
2. New median	24 40	73 69	15	18	11	7
a. Rural areas:	24					
4 lanes, divided					21	18
All rural					16	13
b. Urban areas:	24					
4 lanes, undivided					28	24
4 lanes, divided					16	
All urban			13	12	14	13
3. Flatten side slopes	40	-1	7	7		
4. Upgrade bridge/guardrail transition	40	52	24	27		
<b>VI. PAVEMENT TREATMENT</b>						
<b>A. RESURFACING</b>						
	23					1
	24	29	16	16	32	27
	20	40	33		38	36
	20		57		58	58
	38		24	24	73	55
1. Rural areas:	20		60 <sup>W</sup>		36 <sup>W</sup>	46 <sup>W</sup>
2 lanes	24	48	22	24	34	30
4 lanes, undivided			27	27	43	37
4 lanes, divided			17	15	8	11
All rural		35	20	20	28	25
2. Urban areas:	20		56 <sup>W</sup>		64 <sup>W</sup>	61 <sup>W</sup>
2 lanes	24		19	19	27	25
4 lanes, undivided					28	20
4 lanes, divided			10	10	20	17
>4 lanes, undivided			48	47	53	52
>4 lanes, divided			16	16	39	32
All urban		22	13	13	31	26
<b>B. SKID RESISTANCE</b>						
<b>1. Pavement grooving</b>						
	23			30		
	24		12	13	15	14
	38		15	17	61	40
	40	32	15	15		
a. Rural areas:	24					
2 lanes			43	43	30	37
4 lanes, divided			26	29		
All rural			31	33		12
b. Urban areas:	24					
4 lanes, divided			37	38	59	52
All urban					9	7

TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES				
		FATAL	INJURY	F&I	PDO	TOTAL
2. Skid resistant overlay	40	32	20	20		
<b>C. OTHER</b>						
Rumble Strips	13 35	100 94	33 43		16 33	20 44
<b>VII. SAFETY BARRIERS</b>						
A. MEDIAN BARRIERS	24 40	75 59		1	4	17 11
1. Rural areas:	24					
4 lanes, divided		93				
All rural		75				
2. Urban areas:	24					
4 lanes, undivided			63		65	32
4 lanes, divided		84			15	14
>4 lanes, divided						28
All urban		72			22	16
<b>B. GUARDRAILS</b>						
1. General						
2. New and/or improved	24 38 20 23	35	4 15 23	6 16	7 61	6 42 9 4
a. Rural areas:	24					
2 lanes		50	12	14	18	16
4 lanes, undivided		44	23	24	44	37
4 lanes, divided		46	13	15		6
All rural		43	12	14	14	14
b. Urban areas:	24					
2 lanes					32	23
4 lanes, divided					7	6
All urban					3	2
3. Upgrade guardrails	40	40	7	9		
<b>C. IMPACT ATTENUATORS</b>						
	40	34	29	29		
<b>VIII. SAFETY LIGHTING</b>						
A. GENERAL	13 24 40	100 40 54	53 4		38 10 6	37 6
B. INTERSECTIONS	24		11	14	23	20
C. RAILROAD CROSSINGS	24			49	66	62
<b>IX. RAILROAD CROSSING</b>						
A. AT-GRADE						
1. New flashing beacons	24 40	80 87	82 77	82 79	59	70

TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES				
		FATAL	INJURY	F&I	PDO	TOTAL
a.Rural crossings	24					
2 lanes			76	72	42	54
All rural			75	66	38	50
b.Urban crossings	24					
2 lanes					61	70
All urban			81	85	69	76
2. Upgraded flashing beacons	24		54	54	63	61
3. Automatic gates and new flashing lights	24	98	81	84	62	72
	20	95	96	87	87	91
	40	97	85	87		
a.Rural crossings	24					
2 lanes			47	55	36	44
All rural			51	61	43	50
b.Urban crossings	24					
All urban			67	72	55	62
4. Automatic gates only	24	89	70	74	38	55
	40	88	79	81		
a.Rural crossings	24					
2 lanes				72		46
All rural			57	60		34
b.Urban crossings	24					
2 lanes				43		
All urban			59	64		37
5. Grade separation structures to eliminate existing crossings	24		41	43	37	39
6. Signs & markings at crossings	24			20	31	27
7. Surface improvements at crossings	24				39	34
<b>X. OTHER</b>						
<b>A. COMBINATION IMPROVEMENTS</b>						
1. Channelization, Turning Lanes and/or Traffic Signals (any combination)	22		17	17	9	12
	24	64	25	26	24	25
a.Rural areas:	24					
2 lanes			26	27	51	44
4 lanes, undivided			33	35	35	35
All rural			24	25	36	32
b.Urban areas:	24					
2 lanes			19	21	31	28
4 lanes, undivided			30	30	21	24
4 lanes, divided			18	19	31	27
>4 lanes, divided					32	25
All urban		64	22	23	23	25
2. Marking & Delineation	24				9	4
3. Signs, Markings & Delineation at Narrow Bridges	34		49		42	44



TABLE 3. REVIEW OF LITERATURE -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	REFERENCE	PERCENTAGE REDUCTION IN ACCIDENT RATES			
		FATAL	INJURY	F&I	PDO
B. MISCELLANEOUS					
1. Fencing	40	-158	-11	-15	
2. Obstacle removal	40	57	17	19	

w - wet pavement accidents

TABLE 4. ORIGIN OF ACCIDENT REDUCTION FACTORS USED IN VARIOUS STATES

STATE	NONE USED	DEVELOPED* FACTORS	ADOPTED FACTORS	SOURCE OF ADOPTED FACTORS
Alabama			x	FHWA Handbook (Ref 41)
Alaska		x		
Arizona		x		
Arkansas	x			
California		x		
Colorado	x			
Connecticut			x	1. NCHRP 162 (Ref 10-Primary) 2. Jorgensen (Ref 6) 3. FHWA Memo (Ref 20)
Delaware	x			
Florida	x			
Georgia	x			
Hawaii	x			
Idaho	x			
Illinois	x			
Indiana			x	Missouri
Iowa			x	FHWA Memo (Ref 20)
Kansas		x	x	Missouri
Kentucky	x			
Louisiana		x		
Maine			x	FHWA Memo (Ref 20)
Maryland			x	NCHRP 162 (Ref 10)
Massachusetts			x	Jorgensen (Ref 6)
Michigan	x			
Minnesota		x		
Mississippi	x			
Missouri		x		
Montana		x		
Nebraska			x	Jorgensen (Ref 6), et al
Nevada			x	FHWA Memo (Ref 20)
New Hampshire	x			
New Jersey		x	x	FHWA Report DOT-FH 11-91-29**
New Mexico	x			
New York		x	x	1. Jorgensen (Ref 6) 2. HRR 332 (Ref 11)
North Carolina	x			
North Dakota	x			
Ohio				
Oklahoma				
Oregon	x			
Pennsylvania				
Rhode Island	x			
South Carolina			x	1. Jorgensen (Ref 6) 2. Missouri
South Dakota	x			
Tennessee			x	1982 Highway Safety Stewardship Report, FHWA
Texas		x	x	California DOT
Utah		x	x	Original Caltrans List
Vermont	x			
Virginia	x			
Washington		x		
West Virginia	x			
Wisconsin			x	FHWA Memo (Ref 20)
Wyoming	x			

\* Combination of before and after studies, review of literature, and engineering judgment.

\*\*"Evaluation of Highway Safety Program Standards within the Purview of the FHWA," Report DOT-FH 11-91-29, Federal Highway Administration, 1977.

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
<b>I. SIGNS</b>						
<b>A. WARNING SIGNS</b>						
1. Intersections	KS PA TX		25			23 10 35
a. Urban: 2 lanes	KS MO Jorgensen		51	59 51		29 29 29
2+ lanes	KS, Jorgensen MO			47 47	26	41 41
Rural: 2 lanes/4 leg	KS MO OH Jorgensen		19	59 25 19		37 29 20 37
2+ lanes/4 leg	KS MO OH Jorgensen		-7	47 25 -7		9 41 20 9
2 lanes/T-int.	KS OH Jorgensen		43	25 43		61 20 61
2+ lanes/T-int.	KS OH Jorgensen		67	25 67		65 20 65
b. Stop ahead Rural: 2 lanes	NY KS WA Jorgensen			80 96	45	40 47 47
c. Stop ahead or yield ahead	AK					47
2. Sections	KS PA					35 18
a. Urban: 2 lanes	KS MO, OH, Jorgensen WA		14	14 15	15	14 14
2+ lanes	KS MO, Jorgensen OH WA		26	26 20 20	20	20 20 26
Rural: 2 lanes	KS MO OH, Jorgensen WA		32	14 32 30	35	36 14 36
2+ lanes	KS MO OH, Jorgensen WA		3	26 3 5	20	18 20 18
b. Side road sign	KS					19
c. Advisory speed	KS MT, HRR 332, NCHRP 162					38 36
d. Overhead warning signs	MO, NCHRP 162					20

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
3. Curves	KS	100	50		75	43
	NY					25
a. Rural: 2 lanes	KS, Jorgensen			71	23	57
	OH					20
2+ lanes	KS		40			52
	OH					20
	Jorgensen			40		52
b. Arrows	KS, HRR 332					20
	MT					19
c. Advance warning with advisory speed	MT					29
	HRR 332, NCHRP 162					20
d. Special w/stated speed	HRR 332					75
e. Special (other)	KS, MO, NCHRP 162					75
f. Combination curve warning and advisory speed	LA					22
g. Curve warning signs with delineation	AK					22
Urban: 2+ lanes	Jorgensen				-27	20
Rural: 2 lanes	Jorgensen			41		22
B. REGULATORY SIGNS						
1. Intersection	KS					48
a. Install stop signs	AK					68
b. 4-way stop	KS		68			70
	MO			67		70
	MT					59
	NY					40
	OK					68
	HRR 332,					70
	NCHRP 162					
Urban: 2 lanes	WA			65	70	
	Jorgensen			67		68
c. Stop control, minor leg	NY				25	
Urban: 2 lanes	KS		71			48
	MO, Jorgensen			71		48
	WA			70	50	
2+ lanes	KS			18	22	38
	MO, Jorgensen			18		38
	WA			20		40
Rural: 2 lanes	KS		89			65
	MO			71		48
	WA			80	65	
	Jorgensen			89		65
d. Change from 2-way to 4-way stop	KS					56
e. Install yield sign	AK					59
	NY					25
Urban: 2 lanes	KS		80			59
	MO, Jorgensen			80		
	WA			80	60	
2+ lanes	KS, Jorgensen					-46
	MO					46
2. General	KS					22
	OK					30

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
<b>C. GUIDANCE SIGNS</b>						
1. General	KS					14
2. Overhead	MO,NCHRP 162					5 <sup>s</sup>
<b>D. OTHER</b>						
1. Intersection: regulatory & warning	KS					16
2. Variable message signs	OK					5
3. Upgrade signing	MO					13
	OH					5
	OK					18
	Handbook					23
	NCHRP 162					15
4. Traffic signs (general)	NJ,Handbook					23
	NY					10
5. All combinations	HSS	21	2			2
	KS					20
6. Warning sign-mounted flasher	OH					30
<b>II. SIGNALS</b>						
<b>A. NEW SIGNAL INSTALLATION</b>						
	AK,LA,OK					29
	KS					19
	MT	31	24			23
	NJ,TX,Handbook					18
	NY					32
	OH					20
	WA			50	30	
	HRR 332					5
	NCHRP 162					7
	Jorgensen			50		29
	HSS	36	10			12
1. Rural	PA					32
2. Urban	PA					21
3. With left turn lane	TX					35
4. With right turn lane	TX					35
5. With continuous turn lane	TX					35
6. With channelization	KS,HRR 332					0
<b>B. SIGNAL MODERNIZATION, MODIFICATION OR UPGRADING</b>						
	AK,NJ					18
	KS					12
	MO,NCHRP 162					7
	NY					26
	OH,PA					20
	WA			30	30	20
	HRR					10
1. Urban	KS					18
2 lanes	KS		35			31
2+ lanes	Jorgensen			35		31
2+ lanes	KS		10			-2
2+ lanes, T-int.	Jorgensen			10		-2
	KS		57			
2. Rural	KS		45			42
	Jorgensen			45		42

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
3. With channelization	KS,HRR 332					35
4. Use green extension	KS	100	58		50	46
5. Correspond to MUTCD	MO,NCHRP 162					18
6. Improve and interconnect	MO OK WA			30	30	10 42
7. Other	NY					20
<b>C. WARNING SIGNALS/FLASHING BEACONS</b>						
1. New Installation	KS,TX MO			73		20
a. Intersection						
Red-yellow	KS MO NY	71	39		27	34 50 25
4-leg	KS MT HRR 332,NCHRP 162	62	34		25	31 31 50
3-leg	KS MT HRR 332,NCHRP 162	100	56		36	53 37 50
4-way red	KS MO,MT,HRR 332, NCHRP 162	100	81		53	68 75
b. Advance warning						
intersection	KS KS MT HRR 332	100 100	-4 -50		41 41	31 24 25 30
curve	KS MT NY HRR 332	100	50		54	54 25 30 30
school	KS KS,MO,NCHRP 162	0	63		-10	3 30
curve and intersection						
c. Urban, 2+ lanes	KS WA Jorgensen		73		30 73	-27 50 -27
d. Rural, 2 lanes	KS WA Jorgensen		29		30 29	56 56 21
2+ lanes	KS,Jorgensen WA				15 20	
e. 4-way red replacing:						
2-way 12" stop sign	KS	100	71		57	68
4-way 8" stop sign	KS	100	65		-70	26
f. RR Crossing	MO,HRR 332					80
g. Pedestrian signals	AK,TX KS MO NY OH KS WA Jorgensen					13 40 13 10 50 <sup>P</sup> 13 13 13
Urban, 2 lanes	KS WA Jorgensen		56		55 56	15 13
2+ lanes	KS WA Jorgensen		42		40 42	5 3 3

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
2. Upgrade beacons	KS OH					5 20
D. SIGNAL PHASING	OK					36
1. Add RTOR phase	KS	30	3			5
2. Add left-turn phase	MT					36
Urban, 2+ lanes	NY					25
	LA					22
	TX					15
3. Timing	OH,NCHRP 162					10
4. Improve timing and interconnect	MO OK WA			30	30	10 42
5. Optically programmed signals	MO,NCHRP 162					13
6. Add pedestrian phase	MO,NCHRP 162					60 <sup>P</sup>
7. Add left-turn phase w/illumination	KS		76			46
8. Add left-turn signal w/out turn lane	KS		57 55			39
Urban, 2+ lanes				40		
E. OTHER						
1. Pretimed to actuated	KS MO,NCHRP 162 NY					41 14 20
2. 12-inch lens	MO,NCHRP 162					10 <sup>r</sup>
III. DELINEATION						
DELINEATORS						
1. New installation	Handbook					
	AK,NJ,Handbook					13
	KS					28
	MT	35	8			18
	TX					25
	HSS	-9	-14			-9
a. Rural: 2 lanes	KS		16			2
	OK					22
	Jorgensen			16		2
2+ lanes	KS		-10			46
	OK					22
	Jorgensen			-10	61	46
b. Urban	OK					20
c. Bridge/underpass	KS,TX					50
	MT					45
	OK					21
2 lanes	KS		-8			47
	Jorgensen			-8		47
2+ lanes	KS			62	89	53
	Jorgensen			62		53
d. Tangent sections	MT					23

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
2. Raised pavement markers	AK					20
At intersections	KS, MO, HRR 332, NCHRP 162					5
	OH					9
	OK					2
	PA					19
	WA			5	5	
a. At intersections	OK					10
3. Reflectorized guide markers						
a. At horizontal curves	KS, HRR 332, NCHRP 162					30
b. At bridge approaches	KS, HRR 332, NCHRP 162					40
4. Reflectorized traffic buttons	KS					20
	TX					25
5. Curve delineation	MT					30
	OH					16
	PA					15
	WA			25	25	
6. Shoulder delineation	NY					15
7. Post mounted chevrons (rural)	OK					35
8. Guardrail mounted delineators	OK					21
IV. PAVEMENT MARKING						
A. PAINT STRIPES						
1. Install/improve edge marking	AK					25
a. Rural	KS					15
	WA			15	15	
	Jorgensen			17		14
2. Right edgelines	KS, MO, MT, OK, HRR 332, NCHRP 162					2
3. Edgeline striping	CA					18
	KS				17	11
	TX					25
a. 22-26'	KS					7
	MT					36
	NY					15
b. 28-34'	KS					13
c. 36-40'	KS					14
4. Centerline striping	AK, TX					65
	KS		-12		5	60
	NY					60
a. Rural, crest curve	Jorgensen					64
b. Tangent sections	KS					40
c. Winding sections	KS					28
d. Improve striping	KS		-25			2



TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
<b>5. Add centerlines &amp; edgelines</b>						
a. Rural	KS MT OK				-4	4 12 20
b. Urban	OK					2
6. Median double yellow	KS,MO,HRR 332 NCHRP 162 WA				5	5
7. No passing striping	KS,MO,MT, HRR 332,NCHRP 162					65
8. Line striping	KS NJ,Handbook	-2	4		-4	-1 13
<b>9. Add painted line only</b>						
a. All sections						25
b. Tangent sections						40
c. Winding sections						28
d. Epoxy centerline and edgeline	OK					5
<b>B. OTHER PAVEMENT MARKING</b>						
1. General pavement marking	MO,NCHRP 162 PA TX HSS					12 25 20 -9
2. Intersection/thermoplastic	OK					10
3. Install/improve pavement markings	AK					20
4. Thermoplastic pavement marking	NY  OH OK					47  10 2
5. Upgrade pavement marking	OH					10
6. School zones	TX					20
7. Pedestrian crossing	TX					60
<b>V. CHANNELIZATION</b>						
<b>A. GENERAL INTERSECTION</b>						
1. Channelization	AK,LA,TX CA KS PA KS					30 34 15 10 15
a. W/storage lane	KS	34	6	7	18	15
b. W/signs	KS					37
c. W/left turn bay	CA KS MO NJ,Handbook OK HSS	40	22		22	40 22 20 <sup>r</sup> 23 19 14

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
d. With right turn bay	TX					20 <sup>F</sup>
e. Add painted/raised median	MO,OH,Jorgensen					12
f. Install median barrier	AK MO			61		36
<b>B. LEFT-TURN CHANNELIZATION</b>						
1. At signalized intersections	HRR 332					15
a. Left-turn phase	CA KS,MO,NCHRP 162					35 36
b. No left-turn phase	CA,MO,NCHRP 162 KS					15 16
2. At non-signalized intersections	CA					35
a. W/curbs and/or raised bars	KS,HRR 332					65
	MO					70
	NY					60
urban areas	KS,HRR 332, NCHRP 162					70
suburban areas	KS,NCHRP 162					65
rural areas	KS,HRR332, NCHRP 162					60
b. Painted channelization:	KS					32
	MO					15
	NY					23
	HRR 332					30
urban areas	KS,HRR 332, NCHRP 162					15
suburban areas	KS,NCHRP 162					30
rural areas	KS,HRR 332, NCHRP 162					50
	KS	54	20			22
3. Continuous left-turn lane	CA KS LA MO MT PA					25 30 20 35 33 19
<b>VI. CONSTRUCTION/RECONSTRUCTION</b>						
<b>A. LANE ADDITION</b>						
1. General	NY OK Handbook					30 25 17
a. Lane and Shoulder	OK					25
b. Turning lane	TX					25
2. Left-Turn lane						
a. Without signal:	MO			80		19
	PA					40
Urban:	KS					25
	MO			54		6
2 lanes	KS		80			19
	LA					19
	WA			80	20	19
	Jorgensen			80		19

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
2+ lanes	KS, Jorgensen			54	18	6
	LA					6
	WA			55	5	
2 lanes, T-int.	KS		79			79
	WA			80	80	
	Jorgensen			79		79
2+ lanes, T-int.	KS		62			51
	WA			60	50	
	Jorgensen			62		51
Rural:	LA					32
2 lanes	MO			54		6
	WA			80	20	
2+ lanes	KS		-1			-6
	Jorgensen			-1		-6
2 lanes, Y-int.	WA			5	35	
	Jorgensen			5	-15	33
b. With signal:	MO			1		27
	PA					25
Urban	KA, Jorgensen			1	-7	27
Rural, 2+ lanes	KA		58			43
	Jorgensen			58		43
Rural, T-int.	KA		-28			-42
	Jorgensen			-28		-42
c. Two-way left-turn lanes	LA					14
	WA			50	50	
d. Without signal turn phase	MO			80	18	19
3. Add Acc./Decel. lanes	AK, KS, TX					10
4. Add right-turn lane	LA					2
	WA			40	10	
5. Add passing lane	PA					10
6. Add shoulder	KA	12	12		20	17
7. Extend lane drop and add acceleration lane	WA			40	40	
8. Add climbing lane	KS, PA					14
	Jorgensen					0
9. Add fifth lane	OK					20
10. Lane added without new median	AK, NJ					17
	MT	32	20			26
11. Add turn lane	AK					23
	NCHRP 162					20r
12. Add turn lane and signal	AK					31
13. Add left turn lane w/signal (physical)	NY					50
14. Add left turn lane w/signal (painted)	NY					23
15. Add left and right turning lanes w/signal	NY					40
<b>B. LANE/SHOULDER WIDENING</b>						
1. Pavement & shoulder widening	KS			26	18	21
	PA					22
a. Rural areas:	OK					40
b. Urban areas:	OK					40

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
<b>2. Passing lane</b>						
a. Widen to 36'	KS					11
b. Widen to 46'	KS	37	24		24	25
c. Widen to 42-44'	KS	58	-10		40	27
d. 2 lane highways (to add center passing lane):						
widen to 36'	CA					10
widen to 40'	CA					25
widen to 42-44'	CA					30
<b>3. Shoulder widening or improvement</b>						
	NJ, Handbook PA HSS	35	-10			29 17 -5
a. Rural areas: 2 lanes	WA			5	0	
b. 2 lane highways:						
AADT <3000, widened to 28	CA					15
AADT <5000, widened to 32	KS	69	30			16
AADT >5000, widened to 40	CA				44	35
	KS	53	17			35
	CA					30
	KS	-29	29		31	29
c. Shoulder widening, no dimensions	AK LA MT NY TX Jorgensen		6		7	29 2 12 5 15 -2
d. Shoulder improvement	KS					28
e. Shoulder stabilization	AK, LA, TX KS NJ Jorgensen		46		46	28 38 35 28
<b>4. Widen travelled way</b>						
	AK KS, LA					13 28
a. No dimensions, rural 2 lane	KS OH NY TX WA Jorgensen	30	30			28 38 20 28 38
			30	40	30	38
b. From 9-ft. lanes	KS NY Jorgensen		16		16	38 30 38
c. From 10-ft. lanes	KS NY Jorgensen AK			-65	-37	5 5 5 42
<b>5. Improve median and/or shoulders on divided highway</b>						
<b>6. Pavement widening</b>						
	MT NJ, Handbook PA HSS	84	14			28 25 6 0
a. Rural areas:	OK					38
b. Urban areas:	OK					38

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
C. ALIGNMENT	OK					50
1. Change horizontal alignment	KS	80	22	27	29	28
	NY					45
	PA					32
	TX					40
	HSS	80	26			33
2. Change vertical alignment	KS			50	56	54
	OK					88
	PA					41
	TX					40
	HSS	29	21			27
3. Change horizontal & vertical alignment	AK					21
	KS		46	62	46	52
	MT	40	15			21
	OH, TX					40
	PA					46
	HSS	54	44			44
4. Realignment	LA					40
	MO, NCHRP 162					50
	MT	26	29			37
D. CURVE RECONSTRUCTION	AK					42
	CA					50
	KS					60
	LA					42
	OH, TX					88
	WA			80	80	88
	Jorgensen			89		88
E. INTERSECTION/INTERCHANGE						
1. Install grade separation	AK, TX					55
	WA			60	60	55
2. Construct interchange	AK					55
	WA			30	30	55
3. Reconstruct intersection	AK					40
4. Widen intersection						
a. Urban: signalized						21
unsignalized						20
5. Relocate intersection	OH					25
6. Widen intersection approach	OK					3
7. Pave shoulder (for right turns)	PA					10
F. BRIDGES						
1. Widen existing bridge or other major structure	KS		25	26	14	18
	MT	66	49			41
	NJ, Handbook					65 <sup>f</sup>
	OH					43 <sup>f</sup>
	OK					5
	PA					30
	TX					44
	WA			60	60	44
	HSS	58	34			34

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
2. Replace bridge or other major structure	AK,NJ,Handbook					44
	KS	25	48	52	36	41
	MT	47	39			23
	NY					10 <sup>f</sup>
	OH					62 <sup>f</sup>
	OK					5
	PA					30
	TX					62
	HSS	78	29			31
3. Widen small structure	KS, TX					40
G. GENERAL RECONSTRUCTION AND MISCELLANEOUS	MT					26
1. Reconstruction	LA					40
	MO					25
	HRR 332 NCHRP 162					20 18
a. Road & shoulders	WA			35	35	
b. Reconstruct intersection	TX					40
H. OTHER						
1. Improve sight distance	AK,NJ					31
	KS	57	20	21	26	24
	MT	68	33			32
	NY					30
a. At intersections:	PA					27
b. At horizontal curves	PA					5
2. New median	KS	19	2			11
	HSS	72	-13			1
With left-turn lanes	NY					24
3. Correct/improve superelevation	KS, PA					42
	MO, OH, NCHRP 162					50
4. Widen culvert	MT					46
	OH					25 <sup>f</sup>
5. Replace culvert	OH					60 <sup>f</sup>
	OK					5
6. Increase turning radii at intersections	WA			25	25	
7. Frontage road, new construction	AK, KS, TX					40
	OK					15
8. Ramp modification						
a. Entrance	AK, KS, TX					30
b. Exit	AK, KS, TX					20
9. Widening, correct superelevation, etc.	KS					20
10. Flatten side slope	AK, LA, TX					46
	KS			10	20	16
	WA			20	20	
	HSS	-3	15			9

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
11. Construct pedestrian crossover	AK KS TX HSS			0	20	5 95P 95P 25
12. Construct pedestrian walkway	AK HSS					60 25
13. Construct turn-arounds	AK, TX					40
14. Construct emergency truck deceleration beds/escape ramps or lanes	AK, TX KS PA					20 60 <sup>t</sup> 20 1
15. Stabilize berms--rural section	OH			30		38
<b>VII. PAVEMENT TREATMENT</b>						
<b>A. RESURFACING</b>						
	AK KS MO NY PA TX			55 75 <sup>w</sup> 36	27 83 <sup>w</sup>	21 <sup>w</sup> 26 64 <sup>w</sup> 42 20 57 <sup>w</sup> 15 21
1. Urban, 2+ lanes	KS OH, Jorgensen		46	46		42 <sup>w</sup> 42 42
2. Rural, 2 lanes	KS OH, Jorgensen		21	21		12 12
2+ lanes	KS OH, Jorgensen		59	59		44 44
3. ACP	KS, TX KS					21 42 <sup>w</sup>
4. Overlay	KS MT NJ, Handbook NY HSS	17	21	13	29 <sup>w</sup>	21 22 41 <sup>w</sup> 17 15 21
a. Rural areas:	OK					12
b. Urban areas:	OK					42
c. Intersection, urban	OK					29
<b>B. SKID RESISTANCE</b>						
1. Deslicking	MS OH OH, NCHRP 162					20 20 50 <sup>w</sup>
a. Urban	KS Jorgensen		15	15		20 20
b. Rural	KS		37			

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL	
		FATAL	INJURY	F&I**	PDO***		
2. Pavement grooving	KS	12			9	1	
		67 <sup>w</sup>	91 <sup>w</sup>		30 <sup>w</sup>	75 <sup>w</sup>	
	LA					42 <sup>w</sup>	
	NJ, Handbook					48	
	NY					21	
						55 <sup>w</sup>	
	PA					15	
	TX					42	
	HSS	27	8			11	
	a. Length < 0.5 Mile	KS, Jorgensen					75 <sup>w</sup>
b. Length > 0.5 Mile	KS, Jorgensen					75 <sup>w</sup>	
c. Rural areas: 2 lanes	WA			15	25		
d. Urban areas: 4 lanes, divided	WA			15	25		
3. Grooving or resurfacing	KS	80	76		67	70	
4. Pavement anti-skid treatment	KS	21		-8	16		
	PA					15	
5. Planer	OK					10	
6. Asphalt seal coat	KS					21	
						42 <sup>w</sup>	
7. Saw concrete/rural	KS					20	
8. Treated with resin/bauxite	KS					40	
C. OTHER							
1. Rumble strips	LA, OK, TX					2	
	a. Rural, 2 lanes	KS, Jorgensen			26	24	27
		PA					25
		WA			25	25	
VIII. SAFETY BARRIERS							
A. MEDIAN BARRIERS							
1. Median barriers	MT						
	MT	69	11			14	
	NY					15	
	PA					13	
	TX					36	
	Handbook					75	
	HSS	67	-1			13	
2. Cable barrier >2 lanes	KS	36	-20		-40	-31	
	Jorgensen			4		-33	
3. Beam barrier >2 lanes	KS	15	-30		-10	-20	
				-22		-20	
4. Add painted/raised median	AK, TX					8	
	KS					10	
	WA			10	10		
5. Concrete barrier	KS		-3			-26	
	OH					61 <sup>m</sup>	
	OK					44	
	WA			60	60		



TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
a. 1-12' (median width)	KS	90	10		-10	
b. 13-30' (median width)	KS	85	5		-25	
c. with end treatment	KS	60	40		-150	
6. Install type barrier >2 lanes	Jorgensen				-11	-44
7. Install center barrier 4-lane, median width 0-5'	Jorgensen				-61	-53
8. Installation or improvement of median barrier	NJ Handbook					-3 3
9. Double-faced guardrail						
a. 1-12' (median width)	KS	75	2		-28	
b. 13-30' (median width)	KS	85	5		-30	
c. 31-60' (median width)	KS	85	5		-30	
10. Antiglare screen	KS	0	20		-50	-14
<b>B. CRASH CUSHIONS</b>						
1. General impact attenuator	KS OH PA TX WA HSS	70	9		-7	-1 50 <sup>f</sup>
				34		80
		30	20	50	20	17
2. Water-filled cushion	KS OK	75	60			-300 5
3. Sand-filled cell	KS OK	75	60			-300 5
4. Steel barrel	KS OK	75	60			-300 5
5. G.R.E.A.T.	OK					5
<b>C. GUARDRAILS</b>						
1. General	AK					13
2. New and/or improved	NJ, Handbook NY OH PA TX					13 20 20 <sup>f</sup> 10 30
3. End treatments						
a. BCT	KS OK	55	25		-15	10
b. Texas Turned Down	KS OK	55	25		-15	10
4. Road edge guardrail	KS MT NY OK HSS	67 38	-4 16	-1	-5	-2 4 1 10 -1

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
a. At bridge rail ends	KS MT OH OK WA HRR 332,NCHRP 162	90	45		-110	61 45 <sup>f</sup> 20 <sup>f</sup> 10 50
b. At culvert	KS	61	45		-61	
c. At ditch	KS			26	-19	
d. At embankment	KS HRR 332	47	42		-47	50
e. At embankment curve	KS,NCHRP 162					50
outside curves	MT					55
inside curves	KS,MT,NCHRP 162					65
	KS,NCHRP 162					30
	MT					27
f. At overpass siderail	KS	34				
g. At rocks	KS			31	-45	
h. At tree	KS	65	51		-90	
i. At tree & bush	KS			16		-9
j. At wood utility pole	KS	-40	37			-31
k. Any fixed object	NY					12
l. Fixed object in gore	NY					11
m. At bridge approach	OK TX					33 50
n. Improve to design standards	TX					5
D. BRIDGE/UNDERPASS						
1. Improve substandard bridge rail	AK					5
2. Safety treat concrete headwalls	AK					30
3. Protection at twin-bridge median opening	AK,TX					50
4. Install culvert and bridge railing	NY					15
5. Safety treat concrete headwalls	TX					30
6. Modernize bridge rail to design standards	TX					5
IX. SAFETY LIGHTING						
A. GENERAL LIGHTING						
	AK KS KS,NCHRP 162 LA,OK TX HSS	36	18	2		25 12 50 <sup>n</sup> 25 25 <sup>n</sup> 1
		46	-15			

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
New lighting	CA					15
	MO					50 <sup>n</sup>
	MT					65
	NY, Handbook					9
	PA					10
B. INTERSECTIONS	KS					70 <sup>n</sup>
	WA			15	20	
	HRR 332					75 <sup>n</sup>
1. New	AK					
	KS, LA, MO, OH,					
	TX, NCHRP 162					75 <sup>n</sup>
2. Improvement	AK					19
	KS					24
						65 <sup>n</sup>
	OH, TX, NCHRP 162					50 <sup>n</sup>
3. 3-leg	KS					51
						70 <sup>n</sup>
4. 2-leg on major leg						28
						60 <sup>n</sup>
5. 4-leg on major leg						30
						62 <sup>n</sup>
C. SECTIONS	OH					50 <sup>n</sup>
1. Urban freeway	KS	30	9	19		20
2. Isolated locations (rural)						
D. RAILROAD CROSSINGS	KS					52
	KS, MO, HRR 332,					60 <sup>n</sup>
	NCHRP 162					
	WA			15	20	
	HSS	100	43			63
E. BRIDGE APPROACHES	AK					19
	KS					28
	KS, MO, TX,					
	HRR 332, NCHRP 162					50 <sup>n</sup>
F. UNDERPASSES	AK					10
	KS					-2
	KS, MO, TX,					
	HRR 332, NCHRP 162					10 <sup>n</sup>
G. OTHER LIGHTING						
1. Illuminate terminal nosing	WA			25	25	
2. High most (interchange)	OK					25
X. SAFETY POLES & POSTS						
A. SIGNS AND SUPPORTS						
1. Make signs breakaway	AK, NJ, Handbook					35
	MT		15			10
	PA			25		
a. small signs	KS	70	25		-12	
b. large metal supports	KS	60	20		-20	

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
c. all supports combined	NY OH TX WA HSS			50	0	40 24 <sup>f</sup> 25 4
2. Breakaway all	KS					-20
3. Safety treat sign support	KS			-5	12	25
<b>B. UTILITY POLES</b>						
1. Make utility poles breakaway	KS OH	30	-1		0 <sup>f</sup> 30 <sup>f</sup>	
<b>XI. RAILROAD CROSSING</b>						
<b>A. AT-GRADE CROSSING</b>						
1. New flashing beacons	KS NCHRP 162					81 <sup>t</sup> 80
a. Rural crossings	WA			50	80	
b. Urban crossings	WA			50	80	
2. Cantilever flashing beacons	OK					22 <sup>t</sup>
3. Post mounted flashing beacons	OK					90 <sup>t</sup>
4. Replace signs with:						
a. Flashing beacons	AK,NJ,Handbook KS HSS	93	83	83 <sup>t</sup>	52 <sup>t</sup>	94 <sup>t</sup> 70 <sup>t</sup> 74
b. Automatic gates	AK,NJ,Handbook KS NY HSS	96	86	94 <sup>t</sup>	73 <sup>t</sup>	99 <sup>t</sup> 83 <sup>t</sup> 59 <sup>t</sup> 80
5. Automatic gates and new flashing lights (replacing passive devices)	OK					90 <sup>t</sup>
a. Rural crossings 2 lanes All rural						
b. Urban crossings 2 lanes All urban						
6. Replace active device:						
a. With automatic gates	KS NJ,Handbook NY					
b. With grade separation	KS	100 <sup>t</sup>				
c. With flashing lights	HSS	48	36			

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS			
		FATAL	INJURY	F&I**	PDO***
7. Protection prior to installation of:					
a. Flashing light signals					
Urban:	KS	67 <sup>t</sup>	64 <sup>t</sup>		57 <sup>t</sup>
none-new cross	KS				99 <sup>t</sup>
crossbucks	KS	75 <sup>t</sup>	71 <sup>t</sup>		57 <sup>t</sup>
wigwag	KS		53 <sup>t</sup>		48 <sup>t</sup>
misc.	KS	100 <sup>t</sup>	43 <sup>t</sup>		42 <sup>t</sup>
Rural:	KS	83 <sup>t</sup>	86 <sup>t</sup>		67 <sup>t</sup>
crossbucks	KS	86 <sup>t</sup>	91 <sup>t</sup>		74 <sup>t</sup>
wigwag	KS		60 <sup>t</sup>		50 <sup>t</sup>
misc.	KS	57 <sup>t</sup>	73 <sup>t</sup>		48 <sup>t</sup>
b. Automatic gates					
Urban:	KS	100 <sup>t</sup>	80 <sup>t</sup>		71 <sup>t</sup>
crossbucks	KS	100 <sup>t</sup>	94 <sup>t</sup>		79 <sup>t</sup>
wigwag	KS	75 <sup>t</sup>	89 <sup>t</sup>		67 <sup>t</sup>
flashing lights	KS	80 <sup>t</sup>	75 <sup>t</sup>		68 <sup>t</sup>
misc.	KS	100 <sup>t</sup>	80 <sup>t</sup>		74 <sup>t</sup>
Rural:	KS	90 <sup>t</sup>	88 <sup>t</sup>		72 <sup>t</sup>
crossbucks	KS	100 <sup>t</sup>	93 <sup>t</sup>		87 <sup>t</sup>
wigwag	KS	83 <sup>t</sup>	88 <sup>t</sup>		66 <sup>t</sup>
flashing lights	KS	86 <sup>t</sup>	81 <sup>t</sup>		63 <sup>t</sup>
misc.	KS	100 <sup>t</sup>			100 <sup>t</sup>
8. Automatic protective devices at RR grade crossings	OH				28 <sup>t</sup>
9. Signs & markings at crossings	HSS	-1	-34		-22
a. Urban	OK				10
b. Rural	OK				5
10. Surface improvements at crossings	NY				-7
	OK				5
	HSS	26	25		26
11. Replace flashing lights w/automatic gates	AK				81 <sup>t</sup>
12. Reflectorized cross-bucks					
a. Urban	OK				5
b. Rural	OK				20
B. OTHER	HSS	50	56		44
1. Painted RR symbols	OK				11
2. Thermoplastic RR symbols	OK				11
3. Grade separation structure to eliminate existing crossings	HSS	100	51		49
XII. REMOVAL/RELOCATION OF ROADSIDE OBJECTS					
A. REMOVAL	KS	60	20	20	20
	PA				25

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
1. Remove utility poles	KS OH	35	-2		0	38 <sup>f</sup>
2. Remove trees	KS OH	50	25		-20	25 <sup>f</sup>
3. Remove obstacles from:						
a. existing steep slope	KS	14	10			-18
b. existing gentle slope	KS	73	23			-40
c. cut slopes	KS	35	16			-30
4. Remove curb and/or riprap	AK, TX					20
5. Fixed objects	AK, TX OH					85 <sup>f</sup> 100 <sup>f</sup>
<b>B. RELOCATION</b>						
1. Fixed objects	AK LA, MO, OH, NCHRP 162					85 <sup>f</sup> 60 <sup>f</sup> 99
2. Signs	KS	55	30		-5	
3. Utility poles - 30 ft. from pavement edge	KS OH	32	-2		0	32 <sup>f</sup>
4. Relocate signs behind guardrail	KS	55	30		-5	
<b>C. OTHER</b>	HSS	27	8			12
<b>XIII. OTHER</b>						
<b>A. FENCING</b>						
1. Fencing, livestock	AK, KS, TX, Jorgensen					90 <sup>a</sup>
a. Rural, interstate	KS	-36	-9		0	-3
b. Rural, divided	KS	100	63		57	61
c. Rural, undivided, <4 lanes	KS	100	100		55	74
2. General fencing	MT HSS	-52	5			50 <sup>a</sup> 6
<b>B. MISCELLANEOUS</b>						
1. Close median openings	LA MO, NCHRP 162					100 80
2. Eliminate parking	AK, OK, TX KS MO, Jorgensen NY		3		3	32 32 32 30
3. Remove signal	MO					90 <sup>f</sup>

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				
		FATAL	INJURY	F&I**	PDO***	TOTAL
4. Modernize to design standards	LA					15
a. Rural, 2 lanes	Jorgensen			-6	40	10
2+ lanes	Jorgensen			22		15
5. Curtail turning movements	AK					40
	MO		89			40
a. Urban, 2+ lanes	KS		39			40
	Jorgensen			39		40
6. Revise driveways	MO					13
7. Relocate driveways	OH,NCHRP 162					14
8. Prohibit turns (general)	LA,NY,OH					40
	MO			39		40
9. Modernize drainage	AK,TX					30
	NY					40
10. Improve drainage structures	KS			32	27	29
	PA					22
	HSS	9	-13			-6
11. Change 2-way streets to 1-way	MO					25
C. OTHER COMBINATION IMPROVEMENTS						
1. Flashing beacons & 4-way stop signs (rural)	OK					88
2. Channelization, Turning Lanes and/or Traffic Signals (any combination)	AK,NJ,Handbook					31
	MT	62	34			30
	NY					30
	OK					50
	TX					21
3. Delineators, Markings, Signs, Maintenance						
a. General	KS					22
b. Curve	KS					24
4. Resurfacing, Patching, Drainage, Deslick, Culvert						
a. General	KS					16
b. Curve & guardrail	KS					33
5. Pavement Marking and Delineation	KS	10	-5	-9	-12	-11
6. Striping and Delineation	NJ,Handbook					13
	NY					50
7. Marking, Maintenance and Signing (intersection)	KS					35

TABLE 5. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENTS (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENTS				TOTAL
		FATAL	INJURY	F&I**	PDO***	
8. Marking & Signs						
a. General	KS					36
b. Intersection	KS					24
9. Rumble Strips & Beacon	KS					32
10. Rumble Strips & Lighting	KS					17
11. Warning Signs, Installment and Delineators						
a. Urban, 2+ lanes	KS		-27			20
b. Rural, 2 lanes	KS		41			22
12. Signs/stripping	NJ, Handbook					24
13. Signs & Maintenance--Curve	KS					47
14. Intersection warning signs and delineators	MO			27		20
15. Add turn lane, signal and illumination	MO			57		39
16. New signal and new safety lighting	TX					35
17. New signal and improve safety lighting	TX					30
18. Improve signals and safety lighting	TX					25
19. Lighting, signals, and reflectorized traffic buttons	TX					36

\* - Negative value indicates an increase in accidents  
 \*\* - F&I - Fatal and Injury Accidents  
 \*\*\* - PDO - Property Damage only Accidents  
 s - Rear-end and sideswipe accidents  
 r - Run-off road accidents  
 f - Fatal accidents  
 t - Train accidents  
 w - Wet pavement accidents  
 m - Median and cross-median accidents  
 n - Nighttime accidents  
 a - Angle accidents



TABLE 6. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENT RATES

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENT RATES				
		FATAL	INJURY	F&I**	PDO***	TOTAL
<b>I. SIGNS</b>						
<b>A. WARNING SIGNS</b>						
1. Curves	AZ	-1	67	61	27	47(59 <sup>r</sup> )
<b>B. REGULATORY SIGNS</b>						
	Memo	19	9	9	4	5
<b>C. GUIDANCE SIGNS</b>						
	AZ		100	100	-93	22
<b>D. OTHER</b>						
1. Traffic signs (general)	AZ	100		-81	9	-36
2. All combinations	AZ Memo	0 66	11 41	10 42	11 33	10(27 <sup>r</sup> ) 36
<b>II. SIGNALS</b>						
<b>A. NEW SIGNAL INSTALLATION</b>						
	AZ	82	-7	1	9	6
<b>B. SIGNAL MODERNIZATION, MODIFICATION OR UPGRADING</b>						
	AZ		20	26	-3	7
1. Urban	Memo	42	19	19	26	24
2. Rural	Memo	48	22	23	24	23
3. Left turn signal	AZ		0	0	17	12(78 <sup>l</sup> )
<b>III. PAVEMENT MARKING</b>						
<b>A. PAINT STRIPES</b>						
1. Edgeline striping	Memo				8	4
a. 22-26'						37
b. 28-34'						32
c. 36-40'						28
d. All widths						32
2. Centerline striping	Memo				4	1
3. Add centerlines & edgelines	Memo					
a. Rural		10	6	6	6	6
b. Urban		10	6	6	6	6
<b>B. OTHER PAVEMENT MARKING</b>						
	Memo				26	21
<b>IV. CHANNELIZATION</b>						
<b>A. GENERAL INTERSECTION</b>						
1. Channelization	Memo					
And/or turning lanes		29	12-15	15-17	18-22	16-24
Rural, 2 lanes			33	33	30	31
4 lanes, undivided			24	25	22	23
4 lanes, divided		53	12	13	22	19
>4 lanes, divided					56	49
All		41	22	23	26	25

TABLE 6. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENT RATES				TOTAL
		FATAL	INJURY	F&I**	PDO***	
Urban, 2 lanes			40	40	18	26
4 lanes, undivided			21	21	21	21
4 lanes, divided					17	10
>4 lanes, divided			16	16	24	22
All			13	13	19	18
<b>V. CONSTRUCTION/RECONSTRUCTION</b>						
<b>A. LANE ADDITION</b>						
1. General	Memo		29	28	7-36	5-33
a. Rural, 4 lanes, undivided	Memo		44	45	19	29
b. Urban, 4 lanes, undivided	Memo				4	
4 lanes, divided					6	
>4 lanes, undivided			75	75	85	80
>4 lanes, divided			35	34		16
All urban					7	3
	AZ		25	25	8	13
2. Left-Turn lane	AZ	100	17	28	42	36(92 <sup>1</sup> )
Two-way left-turn lanes	AZ	-4	29	28	26	26
	Memo		18		18	18
3. Add climbing lane	AZ					
<b>B. LANE/SHOULDER WIDENING</b>						
1. Pavement & shoulder widening	Memo		14	16	20	19
a. Rural areas:						
4 lanes, divided			37	40		
b. Urban areas:						
2 lanes			56	56	52	53
4 lanes, undivided			63	63	62	63
4 lanes, divided			26	27		19
All urban			43	43	39	41
2. Passing lane						
2 lane highways(to add center passing lane):	Memo					
widen to 40'		37	24	24	24	25
widen to 42-44'		58			40	27
3. Shoulder widening or improvement	AZ	51	3	9	-59	-21
	Memo	28			12	8
a. Rural areas:						
2 lanes	Memo	48	8	10	23	18
All rural		41			12	9
b. Urban areas:						
2 lanes	Memo				40	26
4 lanes, undivided			32	30		
All urban					14	9
c. 2 lane highways:						
AAADT <3000, widened to 28	Memo		30			16
AAADT <5000, widened to 32			18		45	35
AAADT >5000, widened to 40			28		30	29
4. Pavement widening	AZ		87	80	77	78
	Memo	40	15	16	25	22

TABLE 6. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENT RATES				
		FATAL	INJURY	F&I**	PDO***	TOTAL
a. Rural areas:	Memo					
2 lanes		47	17	18	28	24
4 lanes, undivided			33	38	41	40
All rural		51	18	19	27	24
b. Urban areas:	Memo					
4 lanes, undivided			27	27	51	45
>4 lanes, divided			55	54	66	63
All urban			11	10	20	17
C. ALIGNMENT						
1. Change horizontal alignment	Memo	83	30	33	41	38
a. Rural areas:	Memo					
2 lanes			52	56	49	52
4 lanes, undivided			34	33	52	44
4 lanes, divided			32	38		27
All rural		85	44	48	45	46
b. Urban areas:	Memo					
2 lanes			27	30	35	32
4 lanes, undivided					59	36
>4 lanes, undivided			24	23	34	30
All urban					26	17
2. Change vertical alignment	Memo		45	49	59	57
Rural areas:	Memo					
2 lanes			59	59	66	63
All rural			57	60	66	63
3. Change horizontal & vertical alignment	AZ Memo		100 37	100 38	70 36	80 37
a. Rural areas:	Memo					
2 lanes			39	38	49	45
All rural			36	37	29	32
b. Urban areas:	Memo					
>4 lanes, undivided			54	54	61	59
All urban			51	51	54	53
F. BRIDGES						
1. Widen existing bridge or other major structure	AZ Memo		42 39	42 40	100 35	80 37
a. Rural areas:	Memo					
2 lanes			42	41	51	47
4 lanes, undivided			37	37	32	33
4 lanes, divided			41	48	63	56
All rural			49	49	47	48
b. Urban areas:	Memo					
>4 lanes, divided					42	40
All urban			36	39	37	37
2. Replace bridge or other major structure	AZ Memo		-122 33	-122 37	25 33	-29 34
a. Rural areas:	Memo					
2 lanes			37	39	40	40
All rural			38	40	47	44
G. OTHER						
1. Improve sight distance						

TABLE 6. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENT RATES				
		FATAL	INJURY	F&I**	PDO***	TOTAL
At intersections:	Memo		29	31	37	35
Rural areas:						
2 lanes			28	29	29	29
4 lanes, divided					60	47
All rural			25	27	38	35
2. New median	Memo	73			11	7
a. Rural areas:						
4 lanes, divided	Memo				21	18
All rural	Memo				16	13
AZ	AZ		27	27	32	29
b. Urban areas:						
4 lanes, undivided	Memo				28	24
4 lanes, divided	Memo			16		
All urban	Memo		13	12	14	13
AZ	AZ	19	39	38	16	25
3. Flatten side slope	AZ	76	38	44	24	32
VI. PAVEMENT TREATMENT						
A. RESURFACING						
Overlay	AZ	6	19	18	14	16
Memo	Memo	29-40	16-33	16	32-38	27-36
a. Rural areas:	Memo					
2 lanes		48	22	24	34	30
4 lanes, undivided			27	27	43	37
4 lanes, divided			17	15	8	11
All rural		35	20	20	28	25
Rural (wet pavement accidents)			60		36	46
b. Urban areas:	Memo					
2 lanes			19	19	27	25
4 lanes, undivided					28	20
4 lanes, divided			10	10	20	17
>4 lanes, undivided			48	47	53	52
>4 lanes, divided			16	16	39	32
All urban		22	13	13	31	26
Urban (wet pavement accidents)			56		64	61
B. SKID RESISTANCE						
1. Pavement grooving	Memo		12-15	13-30	15	14-40
a. Rural areas:	Memo					
2 lanes			43	43	30	37
4 lanes, divided			26	29		
All rural			31	33		12
b. Urban areas:	Memo					
4 lanes, divided			37	38	59	52
All urban					9	7
C. OTHER						
Rumble strips	Memo	94	43		33	44
VII. MEDIAN BARRIERS						
A. MEDIAN BARRIERS						
Median barriers	Memo	75			17	11
a. Rural areas:	Memo					
4 lanes, divided		93				
All rural		75				

TABLE 6. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENT RATES				
		FATAL	INJURY	F&I**	PDO***	TOTAL
b. Urban areas:	Memo					
4 lanes undivided			63	65	32	46
4 lanes, divided		84		15	14	14
>4 lanes, divided					28	17
All urban		72			22	16
C. GUARDRAILS						
1. General						
2. New and/or improved	Memo	35	4-23	6-16	7-61	6-42
a. New	AZ	100	100	100	76	88(87 <sup>r</sup> )
b. Improved	AZ					
c. New and improved	AZ					
d. Rural areas:	Memo					
2 lanes		50	12	14	18	16
4 lanes, undivided		44	23	25	44	37
4 lanes, divided		46	13	15		6
All rural		43	12	14	14	14
e. Urban areas:	Memo					
2 lanes					32	23
4 lanes, divided					7	6
All urban					3	2
VIII. SAFETY LIGHTING						
A. GENERAL LIGHTING	Memo	40			10	6
B. INTERSECTIONS	Memo		11	14	23	20
C. RAILROAD CROSSINGS	Memo			49	66	62
IX. RAILROAD CROSSING						
A. AT-GRADE CROSSING						
1. New flashing beacons	Memo	80	82	82	59	70
a. Rural crossings	Memo					
2 lanes			76	72	42	54
All rural			75	66	38	50
b. Urban crossings	Memo					
2 lanes					61	70
All urban			81	85	69	76
2. Upgraded flashing beacons	AZ Memo	100		15 54	15 63	15 61
3. Automatic gates and new flashing lights (replacing passive devices)	Memo	95-98	81-96	84	67-87	72-91
a. Rural crossings	AZ Memo Memo	100	100	100	50	86
2 lanes			47	55	36	44
All rural			51	61	43	50
b. Urban crossings	AZ Memo		100	100	83	86
			67	72	55	62
4. Automatic gates only (replacing passive devices and flashing lights)	Memo	89	70	74	38	55

TABLE 6. SURVEY OF STATES -- PERCENTAGE REDUCTION IN ACCIDENT RATES (Cont.)

SAFETY IMPROVEMENT	SOURCE	PERCENTAGE REDUCTION* IN ACCIDENT RATES				
		FATAL	INJURY	F&I**	PDO***	TOTAL
a. Rural crossings	Memo					
2 lanes				72		46
All rural			57	60		34
b. Urban crossings	Memo					
2 lanes				43		
All urban			59	64		37
5. Signs & markings at crossings	Memo			20	31	27
6. Surface improvements at crossings	Memo				39	34
B. OTHER						
Grade separation structures to eliminate existing crossings	Memo		41	43	37	39
X. OTHER						
A. FENCING						
Fencing, livestock	AZ		100	100	100	100
B. OTHER COMBINATION IMPROVEMENTS						
1. Flashing beacons & 4-way stop signs (rural)						
2. Channelization, Turning Lanes and/or Traffic Signals (any combination)	Memo	64	17-25	17-26	9-24	12-25
a. Rural areas:	Memo					
2 lanes			26	27	51	44
4 lanes, undivided			33	35	35	35
All rural			24	25	36	32
b. Urban areas:	Memo					
2 lanes			19	21	31	28
4 lanes, undivided			30	30	21	24
4 lanes, divided			18	19	31	27
>4 lanes, divided					32	25
All urban		64	22	23	26	25
c. With new signals	AZ	66	53	54	32	43(82 <sup>a</sup> )
d. With improved signals	AZ	-30	51	50	46	48(53 <sup>l</sup> )
3. Pavement Marking & Delineation	Memo				9	4
a. Centerline	AZ		-33	-34	-12	-21
b. Centerline & Edgeline	AZ		69	69	18	46
4. Signs, Markings & Delineation at Narrow Bridges	Memo		49		42	44
5. Marking & Signs at Curves	AZ		86	86	27	65(52 <sup>r</sup> )

\* - Negative value indicates an increase in accidents  
 \*\* - Fatal and injury accidents  
 \*\*\* - PDO - Property damage only accidents  
 a - Angle accidents  
 l - Left-turn accidents  
 r - Run-off-road accidents

TABLE 7. PERCENT REDUCTION IN ACCIDENTS FROM BEFORE AND AFTER ANALYSIS OF SAFETY IMPROVEMENTS IN KENTUCKY.

CATEGORY	SAFETY IMPROVEMENT	LOCATIONS	ANNUAL AVG BEFORE	ANNUAL AVG AFTER	PERCENT REDUCTION
I. SIGNS					
	1. General	9	58	28.5	51
	2. Chevrons and curve signs	1	3.5	5	-43
	3. Chevrons, advisory speed, bridge panels	1	1	2.5	-150
	4. Slippery when wet signs	1	37(16 <sup>w</sup> )	31.5(9.5 <sup>w</sup> )	15(41 <sup>w</sup> )
II. SIGNALS					
	1. Modernization, Modification or Upgrading				
	a. Increase clearance interval	11	122	50.5	59
	b. Add left-turn phase (Ref. 42)	24	480(116 <sup>l</sup> )	409(17 <sup>l</sup> )	15(85 <sup>l</sup> )
	c. Upgrading	5	71	59	17
	2. Warning Signals				
	Add flashing beacons	2	21	22	-5
III. PAVEMENT MARKING					
	Lane use pavement arrows	8	48.5	32.5	33
IV. CONSTRUCTION/RECONSTRUCTION					
	1. Construct acceleration lane	1	2	0	100
	2. Vertical realignment	1	1	1	0
	3. Left-turn lane, median reconstruction	1	15	7	53
	4. Raised median and markings	1	11	2	82
V. OTHER					
	1. Combination improvements				
	a. Pavement marking and signal improvement	3	34	18.5	46
	b. Pavement marking and signing	2	29	25.5	12
	c. Signing and signal improvement	2	27	23	15
	2. Maintenance				
	Trim vegetation	2	13	9	31

l - Left-turn accidents

t - Train accidents

w - Wet pavement accidents

TABLE 8. RECOMMENDED REDUCTION FACTORS FOR SAFETY IMPROVEMENTS

	PERCENTAGE REDUCTION IN TOTAL ACCIDENTS
<b>I. SIGNS</b>	
<b>A. WARNING SIGNS</b>	
1. Intersections	
a. Urban Area	30
b. Rural Area	40
2. Sections	
a. Urban Area	15
b. Rural Area	20
3. Curves	30
<b>B. REGULATORY SIGNS</b>	
1. Intersections	50
2. Other	25
<b>C. GUIDANCE SIGNS</b>	15
<b>D. OTHER</b>	
1. Variable Message Signs	10
2. Upgrade Signing	15
<b>II. SIGNALS</b>	
<b>A. NEW SIGNAL INSTALLATION</b>	20
<b>B. SIGNAL MODERNIZATION, MODIFICATION, OR UPGRADNG</b>	20
<b>C. WARNING SIGNALS/FLASHING BEACONS</b>	
1. Intersections	
a. Red-yellow	30
b. 4-way red	65
c. Advance	25
2. Curves	30
3. RR Crossing	80
4. Pedestrian Signal	15(50P)
<b>D. SIGNAL PHASING</b>	
1. Add protected left-turn phase	25(85 <sup>1</sup> )
2. Add permissive left-turn phase	10(40 <sup>1</sup> )
3. Improve timing	10
4. Add pedestrian phase	30(60P)



TABLE 8. RECOMMENDED REDUCTION FACTORS FOR SAFETY IMPROVEMENTS (Cont.)

	PERCENTAGE REDUCTION IN TOTAL ACCIDENTS
5. Increase clearance internal	30
E. OTHER	
1. Pretimed to actuated	20
2. 12-inch lens	10
III. DELINEATION	
A. POST DELINEATORS	20
B. RAISED PAVEMENT MARKERS	5(20 <sup>wn</sup> )(10 <sup>dn</sup> )
IV. PAVEMENT MARKING	
A. ADD CENTERLINE	30
B. ADD EDGELINE	15
C. ADD NO PASSING STRIPING	40
D. TRANSVERSE STRIPING	15
E. LANE USE/PAVEMENT ARROWS	30
V. CHANNELIZATION	
A. GENERAL INTERSECTION	20
B. LEFT-TURN CHANNELIZATION	
1. Signalized Intersection	
a. Left-turn phase	30
b. No left-turn phase	15
2. Non-Signalized Intersection	
a. With curb	60
b. Painted	30
C. CONTINUOUS LEFT-TURN LANE	30
VI. CONSTRUCTION/RECONSTRUCTION	
A. LANE ADDITION	
1. Left-Turn Lane	
a. Without signal	25
b. With signal	30
c. Two-way left-turn lane	30
2. Acceleration/Deceleration Lane	10

TABLE 8. RECOMMENDED REDUCTION FACTORS FOR SAFETY IMPROVEMENTS (Cont.)

	PERCENTAGE REDUCTION IN TOTAL ACCIDENTS
3. Passing Lane	20
4. Shoulder	20
5. Climbing Lane	10
B. LANE/SHOULDER WIDENING	20
C. ALIGNMENT	
1. Change horizontal alignment	30
2. Change Vertical alignment	45
3. Change horizontal and vertical alignment	50
D. CURVE RECONSTRUCTION	50
E. BRIDGES	
1. Widen Bridge	40
2. Replace Bridge	40
F. INTERSECTION/INTERCHANGE	
1. Construct Interchange	50
2. Reconstruct Intersection	40
G. OTHER	
1. Improve sight distance	30
2. Correct/improve superelevation	40
3. Close median openings	30
4. Increase turning radii at intersections	15
5. Frontage road	40
6. Ramp modification	25
7. Flatten side slope	15
8. Construct pedestrian crossover	95P
VII. PAVEMENT TREATMENT	
A. RESURFACING	20(40 <sup>W</sup> )
B. SKID RESISTANCE	
1. Deslicking	20(40 <sup>W</sup> )
2. Pavement grooving	15(55 <sup>W</sup> )
C. RUMBLE STRIPS	25

TABLE 8. RECOMMENDED REDUCTION FACTORS FOR SAFETY IMPROVEMENTS (Cont.)

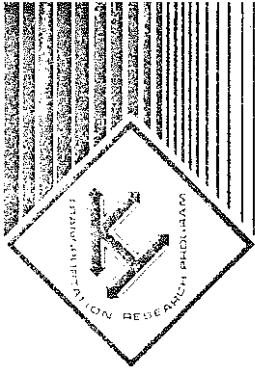
	PERCENTAGE REDUCTION IN TOTAL ACCIDENTS
<b>VIII. SAFETY BARRIERS</b>	
A. MEDIAN BARRIERS	0(60 <sup>f</sup> )(10 <sup>i</sup> )
B. CRASH CUSHION	0(75 <sup>f</sup> )(50 <sup>i</sup> )
C. GUARDRAIL	0(55 <sup>f</sup> )(35 <sup>i</sup> )
<b>IX. SAFETY LIGHTING</b>	
A. GENERAL	25(50 <sup>n</sup> )
B. INTERSECTIONS	25(55 <sup>n</sup> )
C. SECTIONS	25(50 <sup>n</sup> )
D. RAILROAD CROSSINGS	30(60 <sup>n</sup> )
E. INTERCHANGES	25(50 <sup>n</sup> )
<b>X. SAFETY POLES AND POSTS</b>	
A. BREAKAWAY SIGNS	0(60 <sup>f</sup> )(30 <sup>i</sup> )
B. Breakaway Utility Poles	0(40 <sup>f</sup> )(30 <sup>i</sup> )
<b>XI. RAILROAD CROSSING</b>	
A. FLASHING BEACONS	65 <sup>t</sup>
B. AUTOMATIC GATES	75 <sup>t</sup>
C. RR PAVEMENT MARKINGS	10
<b>XII. REMOVAL/RELOCATION OF ROADSIDE OBJECTS</b>	
A. REMOVE FIXED OBJECTS	0(50 <sup>f</sup> )(15 <sup>i</sup> )
B. RELOCATE FIXED OBJECTS	0(40 <sup>f</sup> )(15 <sup>i</sup> )
<b>XIII. OTHER</b>	
A. FENCING	90 <sup>d</sup>
B. ELIMINATE PARKING	30
C. PROHIBIT TURNING MOVEMENTS	40

p - pedestrian accidents  
l - left-turn accidents  
wn - wet-nighttime accidents  
dn - dry-nighttime accidents  
w - wet pavement accidents  
f - fatal accidents  
i - injury accidents  
n - nighttime accidents  
t - train accidents  
d - animal accidents



**APPENDIX**  
**Survey Letter**





# KENTUCKY TRANSPORTATION RESEARCH PROGRAM

UNIVERSITY OF KENTUCKY

College of Engineering  
Transportation Research Building  
533 South Limestone  
Lexington, Kentucky 40506-0043  
Telephone: 606-257-4513

March 1984

Dear

The Kentucky Department of Highways utilizes a cost-optimization procedure (called dynamic programming) to priority rank improvements in its highway safety improvement program. The effectiveness of this program is greatly dependent on the accuracy of the improvement costs and benefits (accident reductions) input into the computer program.

The University of Kentucky Transportation Research Program is performing a study for the Kentucky DOH with the objective of developing a state-of-the-art listing of accident reduction percentages or factors associated with various types of safety improvements. While it is difficult to assign accurate accident reduction factors for specific safety improvements, our objective is to develop a listing which can be used to reasonably predict the consequences of implementing a given safety improvement.

One phase of this study involves a survey of states to determine what is currently being used across the country. We would appreciate any information your office could provide concerning the accident reduction estimates your state used to rank improvements proposed as part of your safety improvement program. We also wish to know the basis for these percentages, that is, whether they are based on studies conducted before and after the installation of safety improvements, a review of relevant literature, or engineering judgment. We will provide you with a summary of the findings of our survey if you so indicate. We appreciate your assistance.

Sincerely,

Kenneth R. Agent, P.E.  
Research Engineer

