Research Report
KTC-96-13

KENTUCKY TRANSPORTATION CENTER

College of Engineering

DEVELOPMENT OF ACCIDENT REDUCTION FACTORS

UNIVERSITY OF KENTUCKY

UNIVERSITY OF KENTUCKY

College of Engineering

Kentucky Transportation Center

Our Mission

We provide services to the transportation community through research, technology transfer and education. We create and participate in partnerships to promote safe and effective transportation systems.

We Value...

Teamwork -- Listening and Communicating, Along with Courtesy and Respect for Others
Honesty and Ethical Behavior
Delivering the Highest Quality Products and Services
Continuous Improvement in All That We Do

For more information or a complete publication list, contact us at:

KENTUCKY TRANSPORTATION CENTER

176 Raymond Building
University of Kentucky
Lexington, Kentucky 40506-0281

(859) 257-4513
(859) 257-1815 (FAX)
1-800-432-0719
www.engr.uky.edu/ktc
ktc@engr.uky.edu

Research Report
KTC-96-13

DEVELOPMENT OF ACCIDENT REDUCTION FACTORS

by

Kenneth R. Agent
Research Engineer

and

Nikiforos Stamatiadis
Associate Professor

and

Samantha Jones
Research Assistant

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with

Kentucky Transportation Cabinet
Commonwealth of Kentucky

June 1996

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

The objective of this project is to develop accident reduction factors associated with various types of highway safety improvements. These factors will be used in the cost-optimization procedure to rank safety improvements.

The basis of the accident reduction factors developed in this study is a survey of states and a review of literature. The recommended reduction factors are presented in a table which lists the percent reduction in all accidents or specific types of accidents for given types of improvements.

1.0 INTRODUCTION

As part of its highway safety improvement program, the Kentucky Transportation Cabinet utilizes a cost-optimization procedure to rank safety improvements (Zegeer 1981) at locations identified as high accident locations using traffic accident data (Agent 1995). The accuracy of the improvement costs and benefits (in the form of accident reduction estimates) determines the effectiveness of this program. Accident reduction factors were last developed for Kentucky in 1985 to use in this procedure (Creasey 1985). There is a need to update and refine these factors to insure that the most accurate results can be obtained. The objective of this project is to develop accident reduction factors associated with various types of highway safety improvements.

2.0 PROCEDURE

The basis of the accident reduction factors developed in this study is a survey of states and a review of literature. A mail survey of states was conducted to determine the information and procedure the various states use to assign accident reduction factors to various types of improvements. A review of the current literature on this subject was also another source used for the development of these factors. Reports which had determined reduction factors in accidents associated with various types of safety improvements were collected and reviewed.

Information from the state surveys and literature review was compiled to develop a general list of safety improvement categories. The general list was then divided into specific types of improvements. Tables were prepared showing the range of reduction estimates used for a given specific safety improvement obtained from both the literature review and the state survey. All of the available information was used to develop a listing of safety improvements and associated reduction factors.

3.0 RESULTS

A general list of safety improvement categories was prepared (Table 1). These categories were selected to include the major broad types of safety improvements. These general types of improvements were then subdivided into numerous specific categories (Table 2). The subdivisions of the general areas were made to provide clarity and organization. For example, the general "traffic signal" category was subdivided into "new signal," "signal upgrade," "remove signal," "signal phasing," "interconnect traffic

signals," "install flashing beacon," and "railroad" subcategories. There were further subdivisions in some of these categories.

The type of accident affected by a specific improvement was considered. In most instances, the reductions applied to all accidents. Specific accident types were identified where possible. For example, reduction factors were given for nighttime accidents when roadway lighting improvements were considered.

3.1 SURVEY OF STATES

A response was obtained from 43 states and the District of Columbia. Of the 44 responses, 37 indicated they used some types of reduction factors in their safety improvement programs. Of those 37, 19 have developed their own tables providing accident reduction factors for their state while the remaining 18 used reduction factors from other sources.

When factors were developed for use in a state, they were based on information from the literature, other states or from before and after accident studies. A brief summary of the response from each state is given in Appendix A. The summary indicates whether or not the states use reduction factors and gives the source of any reduction factors used.

The information regarding specific accident reduction factors obtained from the state survey was summarized in Table 2. For a given safety improvement category, the number of states having a reduction factor for that category was given along with the range in the reduction percentages given and the average of all the factors. Some states used the same source for a given category. The factor was considered for each state even when it was used in more than one state. In some instances, states may not have used the same description for a specific improvement but it was determined that they were similar enough to be placed in the same category.

3.2 REVIEW OF LITERATURE

Reports were obtained which either had results of accident studies showing reductions associated for various safety improvements or made recommendations for accident reduction factors. A list of the reports used in the analysis is given in Appendix B.

A summary of the information obtained from the literature is also given in Table 2. The number of instances in which a factor was found for an improvement category was listed along with the range in the reduction percentages and the average of the factors.

4.0 RECOMMENDATIONS

A list of recommended reduction factors is given in Table 3. Percent reductions for all accidents and/or for specific types of accidents are given for various types of improvements. These factors are to be used as guidelines and not as a substitute for site specific considerations.

When several types of improvements are included in a specific project, the factors for the various improvements must be combined. The percent reductions should not be added. The largest reduction factor should be considered first with a reduction determined and then any other reductions should be applied to the remaining accidents. When appropriate, the number of accidents of a specific type must be used. Following is a formula which can be used to determine a combined reduction factor for several improvements.

$$ARF = 1 - [(1 - AR1)\ (1- AR2)\ (1 - AR3)] \quad (1)$$

where: ARF is the combined accident reduction factor and
AR1, AR2, AR3 are the individual reduction factors.

5.0 REFERENCES

Zegeer, C. V.; Agent, K. R.; and Rizenbergs, R. L.; "Identification, Analysis, and Correction of High-Accident Locations in Kentucky, " Report UKTRP-81-15, August 1981.

Agent, K. R. and Pigman, J. G.;"Analysis of Traffic Accident Data in Kentucky (1990-1994)," Report KTC-95-19, September 1995.

Creasey, T. and Agent, K. R.; "Development of Accident Reduction Factors," University of Kentucky Transportation Research Program, Report UKTRP-85-6, March 1985.

TABLE 1. GENERAL SAFETY IMPROVEMENT CATEGORIES

1 - TRAFFIC SIGNS

2 - TRAFFIC SIGNALS

3 - ROADWAY DELINEATION

4 - LIGHTING

5 - CHANNELIZATION

6 - PAVEMENT TREATMENT

7 - ROADSIDE IMPROVEMENTS (APPURTENANCES/CLEAR ZONE)

8 - CONSTRUCTION/RECONSTRUCTION

9 - REGULATIONS

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY NO.	STATE SURVEY PERCENT REDUCTION RANGE	STATE SURVEY PERCENT REDUCTION AVERAGE	REVIEW OF LITERATURE NO.	REVIEW OF LITERATURE PERCENT REDUCTION RANGE	REVIEW OF LITERATURE PERCENT REDUCTION AVERAGE
TRAFFIC SIGNS	All	7	4-52	23	6	3-36	13
Warning Signs							
General	All	12	5-50	23	11	10-60	30
Curve Warning	All	16	17-55	32	11	20-55	37
	Run-off-Road	2	20-35	28			
Chevron	All	2	39-71	55	3	20-35	30
Intersection Related	All	14	25-47	36	5	15-47	32
Bridge Related	All	2	20-47	34			
Railroad Crossing	Train	5	25-40	29			
Pavement Condition	Wet Weather	2	10-25	18	1	80	80
Pedestrian (General)	Pedestrian	1	15	15			
School Zone	All	3	3-20	14			
Animal	All	2	5-10	8	1	5	5
Advisory Speed	All	2	15-36	26	2	25-36	30
Regulatory Signs							
General	All	1	15	15	2	22-23	22
2-Way Stop	All	19	12-68	39	6	12-50	36
All-Way Stop	All	16	40-73	57	10	35-73	58
Yield	All	17	25-59	45	8	20-59	45
Speed Limit	All	1	40-40	40			
Lane Use	All	2	30-30	30	1	15	15
Guide Signs							
General	All	9	7-15	14	3	14-15	15
Directional	All	2	5-14	10	3	14-50	26
Route/Street	All	1	25	25	1	20	20
Variable Message	All	9	10-40	15	2	10	10
TRAFFIC SIGNALS							
New Signal	All	28	13-68	28	20	13-45	24
	Angle				3	60-75	66
Signal Upgrade							
General	All	21	9-50	24	19	10-45	23
12-Inch Lens	All	11	10-25	12	4	10-10	10
Pretimed to Actuated	All	10	15-27	22	4	10-27	20
Backplates	All	2	15-34	24			
Optical Lenses	All	4	15-25	18	1	15	15
Remove Signal	All	3	30-100	53			
Signal Phasing	All	2	23-30	26			
Exclusive Left Turn Phase	All	15	15-80	29	4	25-43	33
	Left Turn	9	25-85	70	5	40-85	63
P/P Left Turn Phase	All	6	10-10	10	1	10	10
	Left Turn	6	40-40	40	1	40	40
Improve Timing	All	6	10-22	12	4	10-25	15
Pedestrian Phase	All	14	10-60	23	6	8-56	24
	Pedestrian	7	15-60	47	3	60-60	60

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY NO.	STATE SURVEY PERCENT REDUCTION RANGE	STATE SURVEY PERCENT REDUCTION AVERAGE	REVIEW OF LITERATURE NO.	REVIEW OF LITERATURE PERCENT REDUCTION RANGE	REVIEW OF LITERATURE PERCENT REDUCTION AVERAGE
All-Red/ Yellow	All	7	30-31	31	1	30	30
	Angle				3	20-44	32
Interconnect Signals	All	9	10-26	15	3	10-25	17
Install Flashing Beacon	All	8	20-91	38	3	10-37	23
Intersection	All	18	7-50	33	10	2-60	38
	Angle				2	45-46	46
Intersection Advance	All	11	20-42	26	3	25-30	28
General Advance	All	8	15-54	37	4	7-30	19
Railroad							
Flashing Lights	All	11	30-80	58	1	70	70
	Train	4	65-65	65	15	65-94	77
Lights and Gates	Train	11	50-100	74	11	28-87	77
Automatic Gates	Train	9	50-100	76	11	50-99	77
ROADWAY DELINEATION/ PAVEMENT MARKINGS							
General	All	4	13-13	13	6	1-6	4
Edgeline Markings	All	19	2-40	20	12	2-40	15
	Off Road	2	25-25	25	3	25-59	36
Centerline Marking	All	19	5-65	36	14	1-64	24
Wide Markings	All	2	37-60	48	1	5	5
Durable Markings	All	6	15-57	46			
No Passing Zones	All	12	30-65	42	7	30-66	48
	Passing				2	85-85	85
Crosswalks	All	2	10-10	10			
	Pedestrian	2	25-70	48			
Lane Use Arrows	All	6	30-30	30	1	30	30
Raised Pavement Markers	All	15	4-50	13	7	4-15	6
	Wet/Night	7	20-25	21	3	20-46	29
	Night	8	10-26	17	4	10-26	18
Post Delineators/ Curve	All	14	15-40	23	8	2-32	23
	Night	2	30-30	30	1	30	30
Delineators/Tangent	All	17	13-50	28	5	2-25	16
	Night	2	30-30	30	1	30	30
Flexible Delineator Post	All	1	40-40	40			
Bridge Related	All	2	15-39	27	2	15-40	28
Railroad Related	All	11	10-50	19	1	10	10
Animal Reflectors	Animal	1	25-25	25			
LIGHTING							
General	All	6	9-30	25	5	0-17	10
New Roadway	All	10	9-64	28	8	6-37	18
	Night	12	20-90	45	5	15-67	38
Upgrade Roadway	Night	2	23-61	42			
New Intersection	All	8	19-75	31	2	20-25	22
	Night	12	18-70	49	6	50-75	64

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY NO.	STATE SURVEY PERCENT REDUCTION RANGE	STATE SURVEY PERCENT REDUCTION AVERAGE	REVIEW OF LITERATURE NO.	REVIEW OF LITERATURE PERCENT REDUCTION RANGE	REVIEW OF LITERATURE PERCENT REDUCTION AVERAGE
Upgrade Intersection	All	2	25-50	38			
	Night	1	50	50	2	50-50	50
New Interchange	All	5	25-25	25	3	25-50	42
	Night	4	50-50	50	3	43-75	56
Railroad Crossing	All	9	25-50	34	2	30-62	46
	Night	5	60-60	60	6	60-65	61
Bridge	Night	7	19-62	48	5	50-50	52
Illuminate Sign	All				1	15	15
CHANNELIZATION							
General Intersection	All	15	14-50	28	10	17-60	29
Left Turn Lane	All	4	6-31	20	5	18-32	24
Signal/ No Turn Phase	All	16	15-50	22	8	15-50	21
	Left Turn				2	50-57	54
Signalized/ Turn Phase	All	13	15-50	30	9	25-50	36
	Left Turn				2	16-70	43
No Signal	All	13	19-60	41	4	15-45	28
	Rear End	3	62-93	83			
	Left Turn				1	51	51
Right Turn Lane	All	9	2-61	24	5	15-61	30
Increase Turn Lane Length	All	2	15-40	28	2	15-15	15
PAVEMENT TREATMENT							
Resurfacing	All	14	7-59	26	8	7-42	27
	Wet	7	40-42	41	3	40-54	45
Rumble Strips	All	10	18-44	29	7	2-44	25
Skid Resistant Surface	All	14	9-50	27	20	10-60	25
	Wet	7	40-70	45	5	40-55	50
Pavement Grooving	All	13	15-65	26	12	1-48	20
	Wet	10	42-75	61	5	49-75	62
Shoulder Grooving	All	2	14-50	32			
ROADSIDE IMPROVEMENTS (APPURTENANCES/CLEAR ZONE)							
Install Guardrail	All	17	0-63	22	8	0-40	20
	Fatal	6	55-100	64	3	55-90	68
	Injury	6	3-42	31	3	15-45	32
Install Median Barrier	All	10	0-65	28	13	0-75	33
	Fatal	5	60-80	64	3	45-90	65
	Injury	5	5-10	9	3	10-61	27
Upgrade Guardrail	All	11	5-15	8	10	4-30	10
	Fatal	4	9-80	51			
	Injury	5	13-60	37			
Upgraded End Treatment	All	1	10	10	6	10-75	35
Attachment to Structure	All	2	15-15	15			

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY NO.	STATE SURVEY PERCENT REDUCTION RANGE	STATE SURVEY PERCENT REDUCTION AVERAGE	REVIEW OF LITERATURE NO.	REVIEW OF LITERATURE PERCENT REDUCTION RANGE	REVIEW OF LITERATURE PERCENT REDUCTION AVERAGE
Install Impact Attenuator	All	16	0-80	29	10	0-80	31
	Fatal	4	75-75	75	3	50-75	65
	Injury	4	50-50	50	3	9-50	36
Remove Fixed Objects	All	15	0-90	32	10	0-40	22
	Fatal	8	50-53	50	3	50-60	53
	Injury	8	15-28	17	3	15-20	17
	Off Road	2	55-55	55			
Relocate Fixed Objects	All	10	0-90	41	2	0-85	42
	Fatal	4	40-40	40	2	40-40	40
	Injury	4	15-15	15	2	15-15	15
	Off Road	2	55-55	55			
Flatten Side Slopes	All	11	0-46	30	10	7-46	19
	Off Road	2	46-46	46			
Convert to Breakaway	All	15	0-75	28	11	0-75	52
	Fatal	4	60-60	60	1	60	60
	Injury	4	30-30	30	1	30	30
	Off Road	2	45-45	45			
Upgrade Bridge Railing	All	8	5-50	24	8	10-45	28
	Fatal	1	75	75			
	Injury	1	75	75			
Gore Improvements	All	5	17-65	27	3	34-62	49
CONSTRUCTION/RECONSTRUCTION							
Add Median	All	10	10-70	35	8	7-30	14
Mountable	All	4	8-50	20	4	12-44	28
Non-mountable	All	11	8-50	27	8	3-15	10
Glare Shield	All	1	15	15			
Horizontal Realignment	All	20	21-80	44	6	20-60	40
	Off Road	2	50-50	50			
Curve Reconstruction	All	6	50-50	50	11	15-88	54
Vertical Realignment	All	13	21-58	41	5	15-57	40
	Off Road	2	50-50	50			
Hor. and Vert. Align.	All	6	34-80	52	13	30-50	38
Realign Intersection	All	6	30-70	41	1	50	50
Modify Superelevation	All	13	30-65	46	5	10-50	34
Sight Distance Imp.	All	13	7-40	26	1	30	30
Intersection	All	1	30	30	5	10-35	25
General	All	4	30-35	32	11	20-43	34
Widen Shoulder	All	18	5-50	19	17	8-57	20
	Off Road	2	15-15	15	1	13	13
2-4 Feet	All	2	15-32	24	2	15-16	15
Over 4 Feet	All	2	30-55	42	3	15-35	25
Pave Shoulder	All	3	10-25	18	1	20	20
	Off Road	2	15-15	15			
Shld. Stabilization/Dropoff	All	5	6-38	23	3	38-40	39

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY NO.	STATE SURVEY PERCENT REDUCTION RANGE	STATE SURVEY PERCENT REDUCTION AVERAGE	REVIEW OF LITERATURE NO.	REVIEW OF LITERATURE PERCENT REDUCTION RANGE	REVIEW OF LITERATURE PERCENT REDUCTION AVERAGE
Widen Pavement	All	19	5-56	26	16	7-38	22
	Off Road	2	30-30	30			
Additional Lane							
General	All	13	5-56	24	5	5-17	12
Passing/Climbing	All	9	20-30	22	7	20-50	28
Accel/Decel	All	15	10-25	12	4	10-17	13
Left Turn (at Signal)	All	17	20-45	30	3	25-30	27
	LT Rear End	2	60-90	75			
Left Turn (no Signal)	All	16	20-35	28	3	30-30	30
	LT Rear End	2	84-90	87			
Right Turn Lane	All	5	20-45	27			
Two Way Left Turn	All	21	25-45	34	10	15-50	31
Close Median Opening	All	9	30-95	49	6	29-80	52
Bridge Improvements							
Widen Bridge	All	20	23-92	49	18	23-66	43
Replace Bridge	All	17	25-62	42	12	25-70	53
Deck Repair	All				2	10-13	12
Increase Turning Radii	All	12	10-35	18	4	10-35	21
Construct Interchange	All	11	40-75	56	2	50-55	52
	Angle/RE	1	90	90			
Modify Ramp	All	7	25-45	28	1	25	25
	Off Road	2	25-25	25			
Pedestrian-Related							
Grade Separation	Pedestrian	14	60-95	90	1	95	95
Sidewalks	Pedestrian	2	60-75	68			
Truck Escape Ramp	Truck	4	18-75	36			
Brake Check Area	All	1	45	45			
Frontage Road	All	7	30-40	39	1	40	40
Drainage Imp.	All	2	10-30	20			
Animal Fencing	All	3	15-90	55			
	Animal	5	90-90	90	4	90-100	92
REGULATIONS							
Eliminate Parking	All	16	8-90	39	7	8-90	37
Angle to Parallel Parking	All				1	59	59
Prohibit Turns	All	9	40-90	46	8	25-40	35
Prohibit Turns on Red	All	3	20-25	22	1	25	25
Modify Speed Limits	All	3	20-20	20	2	20-20	20
2 way to 1 way	All	3	30-40	33			

TABLE 3. RECOMMENDED REDUCTION FACTORS

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
1 - TRAFFIC SIGNS		
Warning Signs		
1-1	Warning Signs - General	25
1-2	Curve Warning Run-off-road Accidents	30
1-3	Intersection-Related Warning (Side road, stop ahead, etc.)	30
1-4	Railroad Crossing Train Accidents	30
1-5	Pavement Condition Surface Condition-Related Accident	20
1-6	School Zone	15
Regulatory Signs		
1-7	Stop Sign (Two-way)	35
1-8	All-Way Stop	55
1-9	Yield	45
Guide Signs		
1-10	Guide Sign - General	15
1-11	Variable Message Sign	15
2 - TRAFFIC SIGNALS		
2-1	Install Signal Angle Accidents	25 65

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
2-2	Signal Upgrade - General	20
2-2a	12-inch lens	10
2-2b	Backplates	
	Right Angle Accidents	20
2-2c	Optically Programmed Signal Lenses	15
2-3	Remove Unwarranted Signal	50
Signal Phasing		
2-4	Signal Phasing - General	25
2-5	Add Exclusive Left Turn Phase	25
	Left Turn Accidents	70
2-6	Add Protected/Permissive Left Turn Phase	10
	Left Turn Accidents	40
2-7	Improve Timing	10
2-8	Add Pedestrian Phase	25
	Pedestrian Accidents	55
2-9	Add All-Red Interval/Increase Yellow Time	15
	Right-Angle Accidents	30
2-10	Interconnect Traffic Signals	15
Flashing Beacon		
2-11	Flashing Beacon - General	30
2-12	Install Flashing Beacon at Intersection	30
2-13	Intersection Advance Warning Flasher	25

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
2-14	General Advance Warning Flasher	35
Railroad Crossings		
2-15	Railroad Crossings - General	
	Train Accidents	70
2-16	Flashing Lights	
	Train Accidents	65
2-17	Flashing Lights and Automatic Gates	
	Train Accidents	75
2-18	Automatic Gates	
	Train Accidents	75
3 - ROADWAY DELINEATION/PAVEMENT MARKINGS		
3-1	General	15
3-2	Edgeline Markings	15
	Off Road	30
3-3	Centerline Markings	35
3-4	Wide Markings	
	Night Accidents	25
3-5	No Passing Zone	
	Passing Accidents	40
3-6	Crosswalk	
	Pedestrian Accidents	25
3-7	Raised Pavement Markers	10
	Night Accidents	20
	Wet Night	25

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
3-8	Post Delineators	
	Night Accidents	30
3-9	Railroad	
	Train Accidents	15
4 - LIGHTING		
4-1	General	25
	Night Accidents	50
4-2	Roadway Segment	25
	Night Accidents	45
4-3	Intersection	30
	Night Accidents	50
4-4	Interchange	25
	Night Accidents	50
4-5	Railroad Crossing	30
	Train Accidents at Night	60
5 - CHANNELIZATION		
5-1	General Intersection	25
5-2	Left Turn Lane - with Signal	25
	Left Turn Related	45
5-3	Left Turn Lane - without Signal	35
	Left Turn Related	50
5-4	Right Turn Lane	25
	Right Turn Related	50
5-5	Increase Turn Lane Length	15

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
6 - PAVEMENT TREATMENT		
6-1	General	25
	Wet Pavement	50
6-2	Resurfacing	25
	Wet Pavement	45
6-3	Pavement Grooving	25
	Wet Pavement	60
6-4	Rumble Strips	25
6-5	Shoulder Grooving	25
7 - ROADSIDE IMPROVEMENT (APPURTENANCES/CLEAR ZONE)		
7-1	Install Guardrail	5
	Fatal Accidents	65
	Injury Accidents	40
7-2	Install Median Barrier	5
	Fatal Accidents	65
	Injury Accidents	40
7-3	General Guardrail Upgrade	5
	Fatal Accidents	50
	Injury Accidents	35
7-4	Impact Attenuator	5
	Fatal Accidents	75
	Injury Accidents	50
7-5	Remove Fixed Objects	30
	Fatal Accidents	50
	Injury Accidents	30

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
7-6	Relocate Fixed Objects	25
	Fatal Accidents	40
	Injury Accidents	25
7-7	Flatten Side Slopes	30
7-8	Convert Hardware to Breakaway	5
	Fatal Accidents	60
	Injury Accidents	30
7-9	Upgrade Bridge Railing	5
	Fatal Accidents	60
	Injury Accidents	30
7-10	Gore Improvements	25
8 - CONSTRUCTION/RECONSTRUCTION		
	Realignment	
8-1	Horizontal Realignment/Curve Reconstruction	40
8-2	Vertical Realignment	40
8-3	Modify Horizontal and Vertical Realignment	50
8-4	Realign Intersection	40
8-5	Modify Superelevation	40
8-6	Sight Distance Improvement	30
	Pavement Widening	
8-7	Widen Pavement	25

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
8-8	Widen Shoulder	20
	4 Feet or Less	20
	Over 4 Feet	35
8-9	Shoulder Stabilization/Shoulder Dropoff	25
8-10	Pave Shoulder	15
Additional Lanes		
8-11	Add Passing/Climbing Lane	20
8-12	Add Acceleration/Deceleration Lane	10
8-13	Add Left Turn Lane	25
	Left-turn Related Accidents	50
8-14	Add Right-Turn Lane	25
	Right-turn Related Accidents	50
8-15	Add Two Way Left Turn Lane	30
Median		
8-16	Add Mountable Median	15
8-17	Add Non-mountable Median	25
Bridge		
8-18	Widen Bridge	45
8-19	Replace Bridge	45
8-20	Bridge Deck Repair	15

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
Intersection		
8-21	Increase Turning Radii	15
8-22	Sight Distance Improvements	30
Freeway		
8-23	Construct Interchange	55
8-24	Modify Entrance/Exit Ramp	25
8-25	Frontage Road	40
8-26	Glare Screen Night Accidents	15
Pedestrian		
8-27	Construct Pedestrian Grade Separation Pedestrian Accidents	90
8-28	Add Sidewalk Pedestrian Accidents	65
Other		
8-29	Drainage Improvements	20
	Wet Pavement	40
8-30	Install Animal Fencing Animal Related	90
9 - REGULATIONS		
9-1	Eliminate Parking Parking Related	35

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

TYPE OF IMPROVEMENT		PERCENT REDUCTION*
9-2	Prohibit Turns Turning Accidents	45
9-3	Modify Speed Limits	20
9-4	Two-way to One-way Operation	30

* Refers to all accidents unless a specific accident type is noted.

APPENDIX A

SUMMARY OF STATE USE OF REDUCTION FACTORS

STATE	USE OF REDUCTION FACTORS
Alabama	A table of recommended reduction factors is included in the Accident Identification and Surveillance Manual. These factors are based on a combination of literature on the subject and data from safety improvement projects in Alabama.
Alaska	A table of recommended reduction factors is used as input in the hazard elimination priority formula. The numbers used in the current ranking process are normally based upon three-year data studies conducted before the installation of a safety project with the improvement evaluated for three years after its completion. There is a proposed revision that is under review. While the current factors apply to all accidents, the proposed factors would apply only to accidents susceptible to correction by a particular improvement.
Arizona	Accident rate reduction data were obtained for various safety improvements implemented on the Arizona State Highway System. Three-year before and after periods were evaluated for the majority of the improvements. The percent reductions in accident rates obtained using Arizona data are used to determine the expected benefit from safety projects. A table giving accident rate reduction levels which may be attainable from various safety improvements was developed using Arizona data.
Arkansas	Reduction factors from research literature and other states are considered. Also, before and after crash analyses are conducted for safety improvement projects to determine what impact the improvement may have had. No independent table of factors has been developed.
California	A table giving average accident reduction factors was developed from an analysis of before and after reports of past safety improvement projects on California State highways.
Colorado	A table listing factors for Colorado has been developed using several sources. These include NCHRP Report 162, information from New York and California, national averages from FHWA, and research conducted in Colorado.

STATE	USE OF REDUCTION FACTORS (continued)
Connecticut	Various references are used as a basis of reduction factors. These include annual reports on highway safety improvement programs from FHWA, factors used in New York, and a report giving reduction factors from FHWA. No independent table of factors has been developed.
Delaware	Accident experience is used to evaluate the benefits of each highway safety improvement project. Three-year before and after periods are used. The evaluation findings are used as input data to evaluate candidate safety projects. A listing of reduction factors has not been developed.
District of Columbia	A process is underway to develop a predictability model to determine safety improvement costs and benefits. Reduction factors have not been determined.
Florida	A table giving reduction factors has been developed. This table was based primarily on a research study. The study determined that a before and after design was to be used to derive reduction factors for 103 safety improvement types. Other sources (NCHRP 162, HRR 332, and data from nine other states) were also considered.
Georgia	Accident reduction factors developed are those required in the annual improvement report submitted each year to FHWA for the Annual Report on Highway Safety Improvement Programs. A system of analyzing the preventable accidents at a proposed improvement site is used to predict the accident reduction. National accident reduction factors from FHWA are used as guidelines. No specific table of factors was listed.
Idaho	In most cases, the accident reduction factors outlined in the 1985 Kentucky report are used (UKTRP-85-6). The exceptions are actual Idaho reductions based on completed highway projects, by type of improvement, that have a 95 percent or better confidence level.

STATE	USE OF REDUCTION FACTORS (continued)
Iowa	A table listing reduction factors has been developed. These factors are used as a starting point in the analysis process. Accident history is reviewed to determine if accidents are of the type that can be corrected by the proposed improvement. The reduction factors used in the benefit cost analysis may then be adjusted based on the accident history.
Illinois	A table of reduction factors was developed using a combination of factors recommended in the 1985 Kentucky report and past crash experience relating to safety projects completed in Illinois on non-interstate routes.
Indiana	Reduction factors were developed in a research study based on reductions in various project types. A new study in underway to update the factors. A survey was sent to the states and accident histories related to improvements in Indiana will be used.
Kansas	When considering a reduction factor for a specific project, past accident reductions of similar completed projects are used. A few factors have been determined for specific improvements based on Kansas project histories by comparing before and after accidents.
Kentucky	Currently use factors developed in 1985 Kentucky report.
Maryland	The accident reduction factors developed by the New York Department of Transportation are used.
Massachusetts	Reduction factors are not used.
Michigan	A section in the Safety Programs Manual gives safety improvement projects and respective crash reduction factors. Most of the reduction percentages were based on references which are noted in the table. The reduction percentages for each reference are given for each crash type with a recommended percentage also listed. The notation is made that they apply only to those crash types that would be reduced by the proposed improvement.

STATE	USE OF REDUCTION FACTORS (continued)
Minnesota	A combination of the information given in the 1985 Kentucky report and data from before and after accident studies is used to determine appropriate reduction factors. A table listing projected percent reductions for various types of collisions as a result of different improvements was developed using before and after data.
Mississippi	The basis of reduction factors is a combination of data published by FHWA and studies conducted before and after installation of safety improvements in Mississippi.
Missouri	A table of estimated accident reduction factors has been developed based on before and after accident studies and reviews of relevant literature. The table gives estimated accident reduction factors by countermeasure for specific types of accidents.
Montana	A table of accident reduction factors was developed using references from a combination of the literature and other states. Data sources and the corresponding factor for specific improvement types are listed with a recommended reduction factor given.
Nebraska	Factors used are selected from the highway safety literature. A standard list of reduction factors has not been developed. A factor is chosen which is considered the most appropriate for the project under consideration.
New Jersey	A list of reduction factors has not been developed. Data from FHWA are used for reduction estimates.

STATE	USE OF REDUCTION FACTORS (continued)
New York	The accident reduction factors that are most frequently used are percentages showing the percent reduction from the before to the after improvement implementation period accident rate. These factors are updated annually. A table has been developed listing reduction factors for various improvement types. It is noted that the data are not representative of all applications of these improvements under all conditions and are not intended as a substitute for a detailed engineering analysis of actual accident records at a site.
Nevada	Currently, data from the 1985 Kentucky report and from FHWA are used in the cost/benefit analysis. The possibility of using the results of a before and after analysis of safety projects for a database of accident reduction factors is being considered.
North Carolina	Accident reduction factors are not used.
North Dakota	Accident reduction factors are not used.
Oklahoma	Accident reduction factors are not used.
Oregon	Accident reduction factors are not used.
Pennsylvania	Accident reduction factors are not used.
Rhode Island	Factors developed by other states have been used.
South Carolina	The factors recommended in the 1985 Kentucky report are used.
South Dakota	A few factors have been developed but the majority of factors are based on existing sources. Specifically listed as references are a report by Roy Jorgenson and Associates and data from California, New York, and Kentucky.

STATE	USE OF REDUCTION FACTORS (continued)
Tennessee	A table giving reduction factors was developed using before and after studies for safety improvements made in Tennessee. A data base was obtained by accumulating these results by improvement type for several years.
Texas	A table has been developed giving reduction factors for specific preventable accidents for given safety improvements.
Utah	Use the reduction factors developed by Texas.
Vermont	No specific table of factors has been developed. Factors are based on a combination of sources such as New York as well as before and after accident studies conducted in Vermont.
Virginia	The reduction factors currently used are under review. New factors will be developed with those developed by New York to be used in the interim.
Washington	A list of countermeasures with accident reduction rates has been compiled to aid in making accident reduction estimates. Data from a review of research were used in the development of the factors.
West Virginia	Recommendations from a report from Missouri are used as guidance for determining reduction factors. These percentages are modified based on before and after studies conducted in West Virginia.
Wisconsin	A reduction factor used for a specific project is determined based on accident data and experience. A specific table of reduction factors is not used.

APPENDIX B

LIST OF LITERATURE

RELATED TO REDUCTION FACTORS

"Accident Reduction Levels Which May Be Attainable from Various Safety Improvements." Office of Highway Safety, Program Evaluation Division, Effectiveness Evaluation Branch, Federal Highway Administration. August 1982.

Agent, Kenneth R. "Development of Warrants for Left-Turn Phasing." Research Report 456. August 1976.

Barbaresso, James et al. "Selection Process for Local Highway Safety Projects. "Transportation Research Record 847. Transportation Research Board, National Academy of Sciences, Washington, D.C. 1992. Pages 24-29.

Benioff, B. and Rorabaugh, T. "A Study of Clearance Intervals, Flashing Operation, and Left-Turn Phasing as Traffic Signals." Federal Highway Administration, Report Number FHWA-RD-78-46. May 1980.

Box, P. C. "Effect of a Lighting Reduction on an Urban Major Route." Traffic Engineering. Vol. 46, No. 10, October 1976.

Box, P. C. "Relationship Between Illumination and Freeway Accidents." Illuminating Engineering. Vol. 66, No. 5, May/June 1971.

Craus, J. and Mahalel, D. "Analysis of Operation and Safety Characteristics of Left Turn Lanes." ITE Journal. July 1986.

Creasey, Tom; Agent, Kenneth. "Development of Accident Reduction Factors." UKTRP Report 85-6. March 1985.

Cribbins, P. D. and Walton, C. M. "Traffic Signals and Overhead Flashers at Rural Intersections: Their Effectiveness in Reducing Accidents." Highway Research Record 325. Highway Research Board, Washington, D.C. 1970.

David, N. A. and Norman, J. R. "Motor Vehicle Accidents in Relation to Geometric and Traffic Features of Highway Intersections: Vol. II -- Research Report." FHWA-RD-76-129. Federal Highway Administration, Washington, D.C. 1976.

"Designing Safer Roads -- Practices for Resurfacing, Restoration and Rehabilitation." Special Report 214, Transportation Research Board. 1987. Page 264.

Ebbecke, G. M. and Schuster, James J. "Areawide Impact of Traffic Control Devices." Transportation Research Record 644. Transportation Research Board, Washington, D.C. 1975.

Ermer, Daniel; Fricker, John; Sinha, Kumares. "Accident Reduction Factors for Indiana." FHWA-IN-JHRP-91-11. Federal Highway Administration, Washington, D.C. May 1991.

"Evaluation of Minor Improvements: Flashing Beacons, Safety Lighting, Left Turn Channelization." Traffic Department, California Department of Public Works. 1967.

"Evaluation of Shoulder Improvements, Arizona State Highway Systems." Traffic Engineering Section, Safety Project Services, Arizona Department of Transportation. 1978.

Fisher, J. and Camou, R. "The Safety Benefit of Arterial Street Widening." Transportation Engineering. October 1977.

Foody, T. and Long, M. "The Identification of Relationships Between Safety and Roadway Obstructions." Ohio Department of Transportation, Columbus, Ohio. 1974.

Forkenbrock, David; Foster, Norman; Pogue, Thomas. "Safety and Highway Investment." Midwest Transportation Center, Iowa University. Iowa City, Iowa. June 1994.

Gramza, K.; Hall, J. A.; Sampson, W. "Effectiveness of Freeway Lighting." FHWA-RD-79-77. Federal Highway Administration, Washington, D.C. February 1980.

Greiwe, R. "Intersection Management Techniques for the Left Turning Vehicle." ITE Journal. June 1986.

Hall, D. L.; Sinha, K. C.; Michael, H. "Comprehensive Evaluation of Nonsignalized Control at Low Volume Intersections." Transportation Research Record 681.Transportation Research Board, Washington, D.C. 1978.

Hall, Thomas. "Safety Benefits from the Categorical Safety Programs." Transportation Engineering. February 1978.

"Handbook of Highway Safety Design and Operating Practices." Federal Highway Administration, Washington, D.C. 1978.

Heimbach, C.; Hunter, W.; Chao, G. "Paved Highway Shoulders and Accident Experience." ASCE Transportation Engineering Journal. November 1974.Henry, David. "Benefits of Highway Safety Improvements in California."Transportation Engineering. March 1978.

"Highway Safety Improvement Program Annual Report 1990/91." Division of Traffic Operations, California Department of Transportation. Sacramento, California. 1991.

"Highway Safety Improvement Program Annual Report 1994/95." Division of Traffic Operations, California Department of Transportation. Sacramento, California. 1995.

Hoppe, G. H. "The Effect of All Red Signal Phasing on Traffic Accidents." January 1977.

Horne, T. W. and Walton, C. M. "Design Characteristics of Median Turn Lanes." Research Report Number 212-1F. Center for Highway Research, University of Texas, Austin, Texas. October 1977.

"Identification, Analysis and Correction of High-Accident Locations." Technology Transfer Assistance Program, Missouri Highway and Transportation Department. Second Edition, 1990.

Jorgenson, Ray and Associates. "Cost and Safety Effectiveness of Highway Design Elements." National Cooperative Research Program Report 197. Transportation Research Board, Washington, D.C. 1978.

Jorgenson, Ray and Associates. "Evaluation of Highway Criteria for Safety Improvements on the Highway." Westat Research Analysts, Inc. 1980.

Kamel, N. and Gartshore, T. "Ontario's Wet Pavement Accident Reduction Program." MSR-80-001. Ontario Ministry of Transport and Communications. 1980.

Laughland, J. et al. "Methods for Evaluating Highway Safety Improvements." National Cooperative Highway Research Program Report 162. Transportation Research Board. 1975.

Long, George H. and Watson, John E. "Highway Safety Improvement Program, Procedure and Techniques." New York State Department of Transportation, Albany, New York. November 1989.

Long, M.D. "Effect of Pavement Grooving on the Occurrence of Traffic Accidents." Bureau of Traffic, Ohio Department of Highways. 1971

Lovell, J. and Hauer, E. "The Safety Effect of Conversion to All-Way Stop Control." Transportation Research Record 1068. Transportation Research Board, 1986. Page 107.

Lyles, R. "An Evaluation of Warning and Regulatory Signs for Curves on Rural Roads." FHWA-RD-80-008. Federal Highway Administration. 1980.

McFarland, William et al. "Assessment of Techniques for Cost-Effectiveness of Highway Accident Countermeasures." FHWA-RD-79-53. Office of Research and Development, Federal Highway Administration, Washington, D.C. January 1979.

Morrisey, J. "The Effectiveness of Flashing Lights and Flashing Lights with Gates in Reducing Accident Frequency at Public Rail-Highway Crossings 1975-1978." DOT-TSC-FRA-80-19. Federal Railroad Administration. April 1980.

Neuman, T. "Intersection Channelization Design Guide." National Cooperative Highway Research Program Report 279. Transportation Research Board, 1985. Page 48.

"Parking Removal on Business Section Roads Can Reduce Traffic Accidents." American Highways. Michigan State Highway Department. July 1965.

Pigman, Jerry G.; Agent, K.R.; Crabtree, Joseph D. "Safety Improvement Program for Toll Roads KYP-84, HPR-PL-1(15), Part III-B." Research Report 548. July1980.

Pigman, Jerry G.; Agent, K.R.; Mayes, J.G.; Zegeer, C.V. "Optimal Highway Safety Improvement Investments by Dynamic Programming." Bureau of Highways, Department of Transportation. November 1974.

Pigman, Jerry G.; Agent, K.R.; Rizenbergs, R.L. "Evaluation of Raised Pavement Markers in Kentucky: Statewide Installations; 1975-1979." UKTRP Report 81-8. July 1981.

Pigman, Jerry G.; Agent, K.R.; Zegeer, Charles V. "Interstate Safety Improvement Program." Bureau of Highways, Department of Transportation. March 1979.

"Synthesis of Safety Research Related to Traffic Control and Roadway Elements."Volume 1-2, Federal Highway Administration, Report Numbers FHWA-TS-82-232/233. December 1982.

Tamburri, T. N.; Hammer, C. J.; Glennon, J. C.; Lew, A. "Evaluation of Minor Improvements." Highway Research Record 257. Highway Research Board, Washington, D.C. 1968.

Tamburri, Thomas; Smith, Richard. "The Safety Index: A Method of Evaluating and Rating Safety Benefits." Highway Research Record 332. Highway Research Board, National Research Council, Washington, D.C. 1971.

Thakkar, J. "Study of the Effect of Two-Way Left-Turn Lanes on Traffic Accidents." Transportation Research Record 960. Transportation Research Board, 1984. Page 31-32.

Turner, H. J. "The Influence of Road Lighting on Traffic Safety and Service." Australian Road Research Board Proceedings. Vol. 1, 1962.

Walker, F. W. and Roberts, S. E. "Influence of Lighting on Accident Frequency at Highway Intersections." Transportation Research Record 562. Transportation Research Board, Washington, D.C. 1976.

Walters, W. C. and Ashby, J. T. "Investigation of Accident Reduction by Grooved Concrete Pavement." Research Report Number 82, Louisiana Department of Transportation and Development. 1974.

Wattleworth, Joseph A.; Atherly, Ronald J.; Hsu, Ping. "Accident Reduction Factors for Use in Calculating Benefit/Cost." Technical Report Volume 2/3. University of Florida, Gainesville, Florida. November 1988.

Zegeer, C. et al. "Safety Improvements on Horizontal Curves for Two-Lane Rural Roads--Informational Guide." FHWA-RD-90-074. Turner-Fairbank Highway Research Center, Federal Highway Administration, Washington, D.C. October1991.

Zegeer, C.; Deen, R.; Mayes, J. "The Effect of Lane and Shoulder Widths on Accident Reductions on Rural, Two-Lane Roads." Report 561, Kentucky Department of Transportation, 1980. Transportation Research Record 806. Transportation Research Board, 1981.

Zegeer, Charles; Council, Forrest. "Safety Relationships Associated with Cross-Sectional Roadway Elements." Transportation Research Record 1512. Transportation Research Board, Washington, D.C. 1995.

"The 1986 Annual Report on Highway Safety Improvement Programs." Office of Highway Safety, Federal Highway Administration. April 1986.

"The 1989 Annual Report on Highway Safety Improvement Programs." FHWA-SA-89-002. Office of Highway Safety, Federal Highway Administration. April 1989.

"The 1992 Annual Report on Highway Safety Improvement Programs." FHWA-SA-92-013. Office of Highway Safety, Federal Highway Administration. April 1992.

"The 1994 Annual Report on Highway Safety Improvement Programs." FHWA-SA-94-030. Office of Highway Safety, Federal Highway Administration. May 1994.

"The 1995 Annual Report on Highway Safety Improvement Programs." FHWA-SA-95-033. Office of Highway Safety, Federal Highway Administration. April 1995.