

HANDBOOK OF TRAFFIC ENGINEERING PRACTICES
FOR SMALL CITIES

by

SUSAN LYNN GERTH

B.S., University of Wisconsin - Platteville, 1978

A MASTER'S REPORT

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

Approved by:


Major Professor

SPEC
COLL
LD
2668
R4
1982
G47
c.2

111200 188540

TABLE OF CONTENTS

<u>Chapter</u>		<u>Page</u>
1	CONTENTS OF THE HANDBOOK	1
	How to Use the Handbook	1
2	STOP SIGNS	3
	When Should a Stop Sign be Used at an Intersection? .	3
	When is it Necessary to Install a Three or Four-Way Stop?	4
	There is a Stop Sign in Town Which Drivers Either Seem to Miss or Just go on Through it. What Should be Done About it?	4
	Can a Stop Sign be Used to Control Excessive Speed? .	6
	Should a Stop Sign be Placed Next to a Traffic Light in Case the Power Fails?	6
	If the Traffic Volume is Low at an Intersection but the Streets are Crossed Frequently by Pedestrians, Should a Stop Sign be Used?	6
	Should a Stop Sign be Used at a Railroad Crossing? .	7
	Are There Other Uses for Stop Signs?	7
	Are Turnable or Roll Out Stop Signs Permissible? . .	7
	What Should be Done if a Stop Sign is No Longer Needed?	8
	Do Stop Signs Really Provide More Effective Intersection Control Than Yield Signs?	9
	Is There a True Energy Savings Realized When Unneeded Stop Signs are Removed From an Intersection	9
3	SPEED LIMITS	12
	Is There a Maximum Speed Limit Established by the State of Kansas?	12
	How Can a Local Authority Change the Speed Limit for its Jurisdiction?	13
	Are There Limitations Set by the State Under Which the Local Authority is Bound in Altering Speed Limits?	13
	Where Should Speed Limit Signs be Located?	13
	How Far Apart Should Speed Limit Signs be Installed Along the Roadway?	14
	If Residents of a Neighborhood are Reporting that Cars are Speeding on Their Streets, Should the Speed Limits be Lowered to Slow Drivers Down? . . .	14
	What Investigations are Required to Legally Establish a Speed Limit?	15
	Are There Recommended or Prescribed Speed Limits for Specific Locations Such as School Zones? . . .	20
	Are There Other Ways to Control Vehicle Speed? . . .	21
	SCHOOL CROSSINGS	22
	Where Should School Crossings be Located?	22

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH THE ORIGINAL
PRINTING BEING
SKEWED
DIFFERANTLY FROM
THE TOP OF THE
PAGE TO THE
BOTTOM.**

**THIS IS AS RECEIVED
FROM THE
CUSTOMER.**

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH DIAGRAMS
THAT ARE CROOKED
COMPARED TO THE
REST OF THE
INFORMATION ON
THE PAGE.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

TABLE OF CONTENTS (continued)

Chapter		Page
4	Who Should be Involved in Developing a Safe School Crossing Plan?	23
	How Can One Tell if a School Crossing is Unsafe?	24
	What are the Alternatives for Protecting School Crossings?	24
	When is an Overpass (or Underpass) Justified at a School Crossing?	25
	Will a Reduced Speed Limit be Helpful in Safe-guarding Pedestrians at School Crossings?	25
	Are There Situations Where School Speed Limits Should Not be Posted?	25
	When Should Adult Guards or Student Patrols be Used at a School Crossing?	26
	What Standard Signs Should be Used at School Crossings?	27
	Should Pavement Markings be Used for Crossings?	28
	Should a Traffic Signal be Installed at a Busy Intersection if School Children Will Cross There Frequently?	29
5	TRAFFIC SIGNS.	31
	Do New Sign Installations Have to be Approved by Another Authority Before a Local Jurisdiction Can Install Signs?	31
	What Types of Signs are Available for Traffic Control and Management?	32
	Do All Signs Have to Meet Certain Specifications in Size, Shape, and Coloring?	32
	Is There a Specific Mounting Height and Location for Signs?	33
	Where Should Warning Signs be Located?	34
	What Kind of Signing Should be Used to Warn Motorists of a Sharp Curve?	35
	What Signs Should be Used Where a Minor Road T's With a Heavily Traveled Major Road and There is a High Frequency of Accidents?	36
	What Signs Should be Used to Warn Motorists of a Narrow Bridge?	37
	What Sign Should be Used to Alert Motorists of a Change in Speed Limits?	38
	Are There Requirements for Street Name Signs?	39
6	PAVEMENT MARKINGS.	40
	What Types of Pavement Markings are Used?	40
	What Colors Can be Used for Pavement Markings?	40
	What Width and Spacing Requirements are Used for Pavement Markings?	41
	When Should a Broken Line be Used?	41
	What Types of Pavement Markings (Lines) Should be Used on Two-Lane Roads?	42
	Should All Roads Have a Centerline?	42
	Under What Situations are Pavement Edge Lines Used?	44

TABLE OF CONTENTS (continued)

Chapter		Page
6	When Should Stop Lines be Used?	44
	Where are Crosswalk Markings Necessary?	45
	What Color and Width of Lines are Used for Crosswalks?	45
	If the Motorists Fail to Yield to Pedestrians at a Crosswalk, Can the Crosswalk's Visibility be Improved?	45
7	PARKING.	48
	How Can the Number of Parking Spaces Needed in Various Parts of the City be Identified?	48
	What Can be Done if Parking is Inadequate?	49
	How Much Space is Needed for Each Parking Stall?	51
	What are the Advantages and Disadvantages of On-Street Parking?	55
	When Should On-Street Parking be Allowed?	56
	Where Should Parking Always be Prohibited?	56
	What Types of "No Parking" Signs Can be Used?	57
	What Type of Parking is Needed for Special Purpose Vehicles or Areas?	59
8	FLASHING BEACONS	62
	How and Where are Hazard Identification Beacons Used?	62
	How are Intersection Control Beacons Used?	62
	When Should an Intersection Control Beacon be Considered?	64
	Are Intersection Control Beacons Appropriate at Intersections Where Sight Distances on the Approaches are Restricted?	64
	How and When are Stop Sign Beacons Used?	64
	Do Flashing Yellow (Hazard Identification) Beacons Help Control Excessive Speeds?	65
9	SIGNALS.	66
	What Disadvantages do Signal Installations Have?	66
	What Warrants Must be Satisfied for a Traffic Signal Installation?	66
	What Data Should be Collected When Studying an Intersection?	70
	What Size and How Many Lenses per Signal Face are Required?	71
	How Can I Determine if 8 Inch or 12 Inch Indications are Appropriate?	71
	How is the Number and Location of Signal Faces Determined?	71
	An Intersection Within the City Meets Warrants as Established in the MUTCD for Signalization. Should a Pretimed or Traffic Actuated Controller be Used to Operate the Intersection?	72
	Based Upon Cost Estimates for Signalizing an Intersection, it Appears the Cost Would Exceed the Funds Available--Can a Less Costly Instal- lation be Made?	73
	What Signal Cycle Length Should be Selected?	73

TABLE OF CONTENTS (continued)

Chapter		Page
9	How is Signal Phasing Determined?	74
	What is the Desirable Length for the Yellow Clearance Interval?	74
	How Much Time Should be Allocated to the Green Interval?	75
	At an Existing Two-Phase Signalized Intersection, a High Percentage of the Accidents Occurring Involve Left Turning Vehicles. What Solutions are Available?	77
	Rear-End Accidents are Occurring on an Approach to an Existing Signalized Intersection. What Changes Should be Considered?	78
	When is it Necessary to Install Pedestrian Signal Indications?	78
	Where Should the Pedestrian Indications be Mounted?	79
	Is There any Requirement Regarding the Timing of Pedestrian Signals?	79
	Can a Traffic Signal be Used to Stop Motorists at a Fire Station Entrance?	79
	Are the Design Standards for an Emergency Signal the Same as an Intersection Signal?	79
	When Can You Make a "Right Turn on Red" at an Intersection?	80
10	ROADWAY LIGHTING	82
	What Illumination Levels Should be Used in Street Lighting?	82
	How are Lighting Installations Designed?	83
	What is a Typical Set of Calculations to Determine a Lighting Installation?	84
	What is the Difference Between Partial vs. Continuous Lighting?	90
	What is the Most Effective Light Source?	90
	Where Should Street Lighting be Installed?	91
	What Type of Luminaire Spacing Should be Used?	91
	What Mounting Height Should be Used?	93
	What Types of Luminaire Supports Should be Used?	94
	What is a Typical Layout for Intersection Lighting?	94
	What Problems are Caused by Glare?	94
	What Type of Routine Maintenance is Required for Lighting Installations?	95
	An Existing Intersection has Experienced Several Nighttime Accidents. Is Lighting Warranted?	96
	What Types of Accidents May be Correctible by Street Lighting?	96
11	RAILROAD CROSSINGS	98
	What Factors Determine Whether a Railroad Crossing is Safe?	98
	What Signs and Markings Should be Used to Warn Motorists of a Railroad Crossing?	99
	What Control Devices and Signals are Available for Use at a Railroad Crossing?	100
	How Much Distance Does a Motorist Need to Sight an Approaching Train in Order to Either Clear the Tracks or to Stop Safely?	101

TABLE OF CONTENTS (continued)

<u>Chapter</u>		<u>Page</u>
12	DRIVEWAYS.	104
	What Factors Should a Local Authority Take Into Account in Providing Guidelines for Driveway Construction?	104
	What Criteria Should be Used in Determining Where Driveways Can be Safely Located?	105
	What are the Design Standards for a Non-Commercial Driveway?	106
	What are the Design Standards for a Commercial Driveway?	106
	What is the Recommended Grade for a Driveway?	107
	How Closely Can Driveways be Spaced?	107
	Can a Driveway be Shared Jointly by Two Adjacent Property Owners?	108
	Are There Guidelines for Driveways for Special Uses Such as Drive-In Theatres and Service Stations?	108
13	COMMERCIAL DEVELOPMENT	109
	How Much Traffic Will be Generated by a New Commercial Development?	109
	How Many Parking Spaces Are Needed for a New Development?	109
	If a Development Includes a Mix of Offices and Retail Establishments, Won't Some Trips be to Both Offices and Stores?	110
	How Many Access Drives are Needed to Accommodate a Development?	110
	What are the Guidelines to Determine if a Development Will Need Additional Traffic Lanes Along an Adjacent Street?	112
	Are There Guidelines for Street and Area Lighting in Commercial Development?	113
	What Process Must a Developer Follow to Obtain the Necessary Permits?	113
14	TURN RESTRICTIONS AND ONE-WAY STREETS.	115
	When Should Left Turns be Prohibited at an Intersection?	115
	Can Left Turns be Prohibited at an Intersection for Only Part of the Day, for Example, the Peak Hour?	116
	How Should Left-Turn Prohibitions be Signed?	116
	If a Street is Extremely Narrow, Would the Best Approach be to Make it One-Way or to Prohibit Parking?	117
	Under What Conditions is it Desirable to Make a Street One-Way?	118
	What Benefits Can be Achieved for Motorists and Pedestrians by Implementing a One-Way Street System?	118
	Is There Reason for Businessmen to be Concerned if the Streets on Which Their Businesses are Located are Made One-Way?	119

TABLE OF CONTENTS (continued)

<u>Chapter</u>		<u>Page</u>
14	What is the Best Use of Traffic Signs to Advise Motorists of One-Way Travel on a One-Way Street?	121
15	TRAFFIC ACCIDENTS.	124
	How Should Local Accident Records be Filed so That They Can be Used Most Effectively for Accident Analysis?	124
	Are There Special Techniques for Summarizing Traffic Accident Data Which Will Help Identify Those Locations Experiencing an Accident Problem?	125
	How Can the Probable Causes for a High Accident Location be Determined?	126
	What Measures Can be Employed to Lower the Accident Rate at a High Accident Location?	127
16	WORK ZONE PROTECTION	131
	What Types of Construction Signs are Available for Work Zone Traffic Control?	131
	Is There a Specific Mounting Height and Location for These Signs?	131
	Which Warning Signs Should be Used for a Typical Work Zone Situation?	131
	How Far in Advance of the Work Zone Should the Warning Signs be Placed?	135
	What Types of Devices are Most Useful for Channelizing Traffic?	135
	What Types of Warning Lights are Available and How Should They be Used?	136
	What Length of Taper Should be Selected to Channelize Traffic Flows Around a Reduction in Pavement Width?	136
	Is There a Proper Sequence for Installing or Removing Traffic Channelizing Devices and Warning Signs?	137
	What is the Best Procedure for Informing a Contractor as to Which Devices to Use for Traffic Control at a Work Zone?	138
	If Flaggers are Needed, What Signalizing Techniques Should They Employ in Directing Traffic?	138
	Are There Certain Rules of Safety Which a Flagger Should Follow in His Job?	140
	What Types of Records Should be Kept of the Signs and Other Devices Used at a Work Zone? . . .	140
	How Often Should an Inspection be Made of Traffic Controls in Work Zones?	140
	What are the Most Common Deficiencies to be Watchful for During Inspections?	141
17	TRAFFIC SIGN INVENTORY	142
	What Information Should be Included in a Sign Inventory?	142
	How Should the Inventory Information be Recorded and Filed?	143

TABLE OF CONTENTS (continued)

<u>Chapter</u>		<u>Page</u>
17	How Can the City Benefit by Using a Sign Inventory System?	143
	What Type of System is Recommended?	144
	What Preparation is Necessary Prior to Conducting a Sign Inventory?	145
	What are the Field Data Collection Steps to Take? .	147
	How is the Filing Done?	147
	How Can the Inventory be Updated?	148
18	TRAFFIC ORDINANCES	149
	Are There Limits to the Local Control and Regulation of Traffic?	149
	Is an Ordinance Necessary for Each Location in the City Having Some Traffic Control Device? . .	150
	What Types of Traffic Control Signs, Signals, and Devices Require an Ordinance?	150
	Do Warning and Advisory Signs Need to be Covered by Ordinance?	151
	Can a Municipality Regulate Traffic on Private Property?	151
	What Steps Should a Municipality Take to Make Sure Ordinances are Proper and Enforceable? . . .	151
	BIBLIOGRAPHY	152

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Cumulative Speed Distribution Curve.	19
2	Standard School Signs.	27
3	Height and Lateral Location of Sign.	33
4	Curve Warning Signs.	36
5	Stop Ahead Sign.	37
6	Narrow Bridge Sign	38
7	Typical Two-Lane, Two-Way Marking Applications	43
8	Typical Crosswalk Markings	47
9	Curb Parking Configurations.	53
10	No Parking Signs	58
11	Urban No Parking Signs	59
12	Truck Requirements at Loading Points	60
13	Typical Intersection Control Beacon Installation . . .	63
14	Desirable Location of Signal Faces	72
15	Intersections at Which RTOR Should be Prohibited . . .	80
16	Utilization Curve.	88
17	Isofootcandle Curve.	89
18	Typical Luminaire Mounting Arrangements.	93
19	Typical Lighting Plan for Intersections, 30 Foot Mounting Height.	96
20	Typical Pavement Markings at Railroad-Highway Grade Crossing	102
21	Sight Distance Triangle for Railroad Crossings	103
22	Typical One-Way Street Signs	121
23	Typical Signing Along a One-Way Street	122
24	Typical Collision Diagram.	128

LIST OF FIGURES (continued)

<u>Figure</u>		<u>Page</u>
25	Construction Signs	133
26	Typical Work Zone Signing.	134
27	Use of Hand Signaling Devices by Flagger	139
28	Traffic Sign Inventory Card.	145
29	Code for May 11, 1978.	148

LIST TABLES

<u>Table</u>		<u>Page</u>
1	Visibility Requirements for Stop Signs.	5
2	Excess Cost of Speed Change Cycles Above Cost of Continuing at Initial Speed for Passenger Cars.	11
3	Frequency Distribution Table.	20
4	Recommended Distance in Feet for Placement of Advance Signs	35
5	Parking Requirements by Lane Use	50
6	Parking Layout, Dimensions for Varying Degrees of Angle Parking	54
7	Suggested Timing for Vehicle Clearance Interval	75
8	Recommended Luminaire Spacing for Typical Roadways.	95
9	Minimum Sight Distances for Combinations of Highway and Train Vehicle Speeds.	103
10	Summary of Trip Generation Rates.	111
11	Parking Requirements.	112
12	Recommended Widths for One-Way and Two-Way Street Improvements.	120
13	General Countermeasures for Accident Patterns and Their Probable Causes	129

ACKNOWLEDGEMENTS

I wish to express my appreciation to the Kansas Highway Safety Coordinating Office of the Kansas Department of Transportation, as well as the Federal Highway Administration for funding of the Handbook of Traffic Engineering Practices for Small Cities. I would also like to thank my major professor, Dr. Bob L. Smith, for his guidance and encouragement on this project.

In addition, I would like to thank my friend, Debbie Mahaffey, who diligently typed this entire report.

I would also like to express my deep gratitude to my parents, Glenn and Mary Giuliani, for a lifetime of encouragement and opportunities. Most of all, I wish to thank my husband, Alan, whose constant love, support, and inspiration makes everything worthwhile.

Finally, I wish to thank God who has given me the ability to accept and conquer the challenges of life.

INTRODUCTION

The safe and efficient flow of traffic is an objective equally shared by state and local officials. Traffic congestion, vehicular and pedestrian accidents, and motorist delays are usually an indication of deficiencies in the roadway system or in the use of traffic control devices along this system.

Roadway and/or signing defects are often difficult to identify. While the symptom of the problem may be readily apparent, e.g., a large number of traffic accidents, the actual problem may be obscure.

The purpose of this handbook is to assist local officials in pinpointing these problems and to provide them with some insight into the answers to typical traffic engineering questions which arise. This handbook has condensed many of the thoughts and requirements of the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) and the standard edition of the MUTCD should be obtained for additional and more complete references.

Traffic control warrants contained in this handbook do not necessarily represent those used by the Kansas Department of Transportation. All traffic control devices used on the Kansas Department of Transportation right-of-way must comply with the policies of the Department. The District Engineer should be contacted when questions arise involving state routes.

This handbook was adapted from the Illinois Department of Transportation Handbook of Traffic Engineering Practice for Small Cities (published August 1980) and the Missouri Highway Commission handbook of the same name (published April 1979) for Kansas local governmental units. This was a highway safety project sponsored by the Kansas Highway Safety Coordinating Office in cooperation with the Federal Highway Administration, U.S. Department of Transportation.

The Kansas Highway Safety Coordinating Office wishes to thank the Illinois Department of Transportation and the Missouri Highway Commission for the use of the handbooks.

Project Director: Dr. Bob L. Smith, Department of Civil Engineering,
Kansas State University

Assistant: Susan L. Gerth, Department of Civil Engineering, Kansas
State University

Technical Advisory Committee:

Robert Alva, P.E., Project Development Engr., FHWA, Topeka, KS

Don Bassett, Traffic Engr., Salina, KS

Charles Brunson, P.E., Traffic and Safety Engr., Safety Dept.,
KDOT, Topeka, KS

Carol Estes, P.E., Traffic Engr., Olathe, KS

Ed Mulcahy, P.E., President, Johnson, Brickell, Mulcahy & Assoc.,
Kansas City, MO

Thomas Mulinazzi, P.E., Assoc. Professor, Civil Engg. University
Kansas, Lawrence, KS

Jerry Petty, P.E., City Engr., Manhattan, KS

John Rothrock, Traffic Engr., Topeka, KS

William L. Smith, P.E., Van Doren, Hazard, and Stallings, Topeka,
Kansas

Fred Terry, P.E., Urban Traffic Engr., KDOT, Topeka, KS.

CHAPTER 1

CONTENTS OF THE HANDBOOK

The following chapters deal with each of the major subject areas pertaining to the regulation of motorists and pedestrians. Each chapter covers typical problems or questions relating to a specific subject and discusses the techniques needed to analyze the problem and develop its proper solution. Those subjects covered include:

- | | |
|---------------------|--------------------------|
| * Stop Signs | * Railroad Crossings |
| * Speed Limits | * Driveways |
| * School Crossings | * Commercial Development |
| * Traffic Signs | * Turn Restrictions and |
| * Pavement Markings | One-Way Streets |
| * Parking | * Traffic Accidents |
| * Flashing Beacons | * Work Zone Protection |
| * Signals | * Traffic Ordinances |
| * Roadway Lighting | * Traffic Sign Inventory |

How to Use The Handbook

This handbook has been designed to be used in either of two ways. If the particular problem (or question) is apparent, the reader can refer directly to the chapter covering that subject area. For example, if the question is "When Should a Four-Way Stop be Used?" the answer can be found by referring directly to the chapter on Stop Signs.

As an added feature, a cross reference will be placed in the Appendix. This index cross references symptoms to causes (or problems). For example, the symptom might be a large number of right-angle collisions; however, the cause (or problem) may not be readily apparent.

In this instance, the reader would turn to the symptom "right-angle collisions" in the index and be referred to the appropriate subject material in the front of the book, i.e., "Stop Sign Visibility," "Signal Placement," etc.

CHAPTER 2

STOP SIGNS

Stop Signs have generally been used by authorities as a catch all remedy for a host of vehicle management problems. It is not difficult to figure out why they are used so frequently. A Stop Sign is a low-cost device, easy to install and its message is clear and universally understood. This chapter will help you determine when a Stop Sign is the right sign to use, when other signs are more appropriate and how to go about installing a Stop Sign.

WHEN SHOULD A STOP SIGN BE USED AT AN INTERSECTION?

Stopping frequently at intersections can create problems for traffic flow, is irritating to motorists, and in this age of energy problems, causes vehicles to use more fuel. So it is important that Stop Signs only be used where they are clearly needed. The question becomes then, what situations and problems at an intersection are best solved by installing a Stop Sign? Let's start by examining when traffic should be stopped on either one or both streets at an intersection.

1. A Stop Sign is appropriate when a less frequently traveled road intersects with a highly traveled road and traffic crossing this road creates a hazard.
2. A Stop Sign should be used when a street enters a through highway or road with frequent and possibly high speed traffic.
3. In an area where several of the intersections are signalized, an intersection with no signals should have Stop Signs facing the minor street.
4. Stop Signs should be used at other intersections where a combination of high speed traffic, a restricted view and frequent accidents indicates the need for one or more Stop Signs.

WHEN IS IT NECESSARY TO INSTALL A THREE OR FOUR-WAY STOP?

One indication that an intersection may need three or four-way stop control is its accident pattern. If five or more right and left-turn collisions (or right-angle collisions) have occurred during the past 12 months, this type of control may be justified.

A three or four-way stop can also be used as an interim measure to control traffic while a signal is being installed at the intersection.

The volume of traffic which enters an intersection is another guideline to help you determine when to use this control. One of the following criteria should be met.

1. The total number of vehicles entering the intersection from all approaches must average at least 500 vehicles per hour for any eight hours of an average day, and vehicles and pedestrians combined from both approaches of a minor street or highway must average at least 200 units per hour for the same eight hours. (You must also determine that vehicles entering from the minor road are delayed at least 30 seconds on the average during the hour when the traffic volume is highest).
2. If 85 percent of the vehicles are approaching the intersection on the main road at more than 40 miles per hour, a multiway stop can be used when there is an average of 350 vehicles entering the intersection per hour for an eight hour period and combined vehicles and pedestrians on both approaches of the minor road average 140 units per hour for the same eight hours. (Chapter 3 - Speed Limits - explains the technique for measuring the 85th percentile speed).

THERE IS A STOP SIGN IN TOWN WHICH DRIVERS EITHER SEEM TO MISS OR JUST GO ON THROUGH IT. WHAT SHOULD BE DONE ABOUT IT?

Possibly the Stop Sign has been mounted in the wrong location or is of insufficient size to be properly visible. The instructions below are some guidelines to follow in selecting the proper size and location for these signs.

1. The normal Stop Sign is 30" x 30" in size. On low-volume local streets and secondary roads with low approach speeds, a 24" x 24" size may be used. For roads having a speed limit of 40 miles per hour (MPH) or greater, the signs should be increased to 36" x 36".
2. The proper location for a Stop Sign is illustrated in Figure 3 on Page 26. The essential points to remember are:
 - * Lateral distance from edge of pavement is six to twelve feet.
 - * Mounting height from the pavement to the bottom of the sign is five feet (seven feet along roads where vehicles are likely to park or pedestrian activity occurs).
 - * The sign should be placed along the roadway at the point where the vehicle is to stop.

If your signs are of correct size and in the proper location, it is possible that motorists are not being adequately warned of the need to stop. "Stop Ahead" signs should be used where the speed limit exceeds 40 MPH and/or the curvature of the roadway prevents the motorist from seeing the Stop Sign as they approach the intersection. On certain occasions, the sign's visibility may also be obscured by trees or shrubs. Table 1 gives the minimum distance back from the intersection that the sign should be visible for different approach speeds.

TABLE 1
VISIBILITY REQUIREMENTS
FOR STOP SIGNS

<u>Approach Speed</u>	<u>Minimum Distance (Feet) (a)</u>
20 MPH	175
30 MPH	200
40 MPH	275
50 MPH	350
55 MPH	425

(a) For concrete or asphalt pavement having a maximum grade of three percent.

If the Stop Sign is not visible for the minimum distance shown in Table 1, "Stop Ahead" signs should be used. In rural areas, these signs should normally be placed about 750 feet in advance of the Stop Sign. On high-speed roads and particularly on freeways, advance warning distances may have to be as great as 1500 feet or more. Where speeds are relatively low in urban areas, the advance distance should be only about 250 feet.

CAN A STOP SIGN BE USED TO CONTROL EXCESSIVE SPEED?

If the only reason for placing a Stop Sign at an intersection is to control vehicle speed, it should not be used. Where Stop Signs have been used in an attempt to control speeds, it has been observed that speeds downstream are higher than if the Stop Signs were not there. Better options are available including speed control signs, expanded enforcement of the present speed limit and warning signs such as "School Crossing" or "Pedestrian Crossing," depending on what is appropriate.

SHOULD A STOP SIGN BE PLACED NEXT TO A TRAFFIC LIGHT IN CASE THE POWER FAILS?

Stop Signs should never be used in conjunction with traffic signals because when the traffic signal is working, motorists can become confused about which control device to obey. It is important that only one type of traffic control sign (and/or signal) be used at any given installation.

IF THE TRAFFIC VOLUME IS LOW AT AN INTERSECTION BUT THE STREETS ARE CROSSED FREQUENTLY BY PEDESTRIANS, SHOULD A STOP SIGN BE USED?

If traffic volumes are low, adequate traffic gaps should be available for pedestrians to safely cross the roadway without the aid of

Stop Signs. Stop Signs should not be used under such circumstances. More information concerning traffic controls for pedestrians can be found in Chapter 4 - School Crossings.

SHOULD A STOP SIGN BE USED AT A RAILROAD CROSSING?

Stop Signs are permissible at railroad crossings if visibility is insufficient to see trains approaching the crossing and the crossing is not signal controlled. Figure 21 and Table 9 on Page 103 of the Chapter on Railroad Crossings illustrate the minimum sight distance required. If visibility is less than these minimum requirements, Stop Signs may be used.

ARE THERE OTHER USES FOR STOP SIGNS?

Certain other situations may dictate the use of Stop Signs. These include:

1. The "T" intersection of two major roads. At a minimum, the road entering on the leg of the "T" should be stopped.
2. School Crossings - see Chapter 4.
3. Road Construction - Hand Stop Signs may be used to control the flow of traffic at locations where construction has narrowed the roadway to one traffic lane.

ARE TURNABLE OR ROLL OUT STOP SIGNS PERMISSIBLE?

The use of Turnable or Roll Out Stop Signs is not recommended. Turnable Stop Signs are subject to vandalism (being turned at the wrong time or in the wrong direction). Consequently, this method of control can be confusing to motorists and should be avoided.

WHAT SHOULD BE DONE IF A STOP SIGN IS NO LONGER NEEDED?

If it has been determined that a stop sign or stop signs are not necessary and that their absence will not create an unduly hazardous situation, the following procedure should be followed for their removal:

1. Obtain a list of all stop signs to be removed and categorize each by type of intersection (4-way stop going to 2-way stop, 4-way stop going to uncontrolled, 2-way stop going to uncontrolled, etc.).
2. Prearrange a target date for the removal to be completed. Depending upon the total number of intersections affected, either all stop signs are removed at one time or a few are removed on each of several days. If the latter procedure is used, each group of intersections should be converted independently of all other groups.
3. Publicize the data and details for the stop sign removal through the various media (newspaper, radio, television, flyers, etc.). Make sure that the publicity is widespread and is at least a week or two in advance.
4. Several days immediately preceding the target date (the number of days required will depend upon the number of signs to be removed), erect warning signs at the affected intersections as follows:

a. Four-way to two-way stop:

Place warning signs at the approaches which retain stop signs to indicate that cross traffic do not stop.

b. Four-way stop to uncontrolled:

Place warning signs at all approaches to indicate that oncoming and cross traffic do not stop.

c. Two-way stop to uncontrolled:

Place warning signs at all approaches to indicate that oncoming and cross traffic does not stop. These warning signs should be kept covered with burlap sacks or other suitable material until the stop signs are removed on the target date.

5. In the early morning hours of the target date, all designated stop signs should be removed and warning signs exposed. It would be advisable to have law enforcement personnel present during the removal to direct traffic.

6. Leave warning signs in place for 90 days so that local drivers may fully adjust to the new conditions.

7. Conduct follow-up studies on the effects of stop sign removal to include citizens' response and possible increase/decrease in traffic accidents.

DO STOP SIGNS REALLY PROVIDE MORE EFFECTIVE INTERSECTION CONTROL THAN YIELD SIGNS?

No! If there is adequate sight distance at an intersection and stop signs are not warranted by volume, the use of yield signs is more effective as well as more economical and energy efficient.

The use of stop signs where they are not needed causes disrespect for the sign message among drivers. They will not stop unless they feel that there is reason to do so.

IS THERE A TRUE ENERGY SAVINGS REALIZED WHEN UNNEEDED STOP SIGNS ARE REMOVED FROM AN INTERSECTION?

Yes! Each time a vehicle slows, stops, and accelerates it consumes more fuel (at a cost to the driver) than if it had been permitted to maintain its original speed. Table 2 shows the cost (in dollars) per 1000 speed change cycles (i.e., reducing and resuming speed). Therefore, if it is possible for fewer vehicles to slow or to stop, the result will be a true savings in energy and its cost. The following example illustrates the savings that can be realized.

An intersection is controlled by a 4-way stop, where there are volumes of 3000 vehicles per day (VPD) on the major road and 1200 VPD on the minor road and speed limits are 30 mph on both roads. If it was decided that the intersection should be changed so that only minor road traffic was required to stop, the resulting savings could be computed. The 3000 vehicles on the major road would no longer incur the extra expense of the 30-stop-30 speed change cycle. From Table 2: $3000 \text{ VPD} \times \$23.59 \text{ per } 1000 \text{ speed change cycles}$, or \$70.77. This is a savings for just one day at one intersection; however, it should be noted that the minor leg traffic would have somewhat increased delays, resulting in a slight reduction in the actual savings.

Table 2: Excess Cost of Speed Change Cycles Above Cost of Continuing at Initial Speed for Passenger Cars* (dollars per 1000 speed change cycles)

Initial Speed, mph	Speed reduced to and returned from, mph										
	Stop	5	10	15	20	25	30	35	40	45	50
5	1.35										
10	4.13	1.90									
15	8.30	4.83	2.29								
20	12.59	8.48	5.13	2.16							
25	18.30	13.19	9.05	5.30	2.77						
30	23.59	17.96	13.33	9.19	5.99	3.14					
35	28.88	22.88	17.72	13.41	9.66	6.28	2.90				
40	34.17	28.10	22.70	17.90	13.73	9.84	6.05	3.09			
45	39.45	33.66	28.08	23.09	18.21	13.76	9.62	6.30	3.11		
50	44.74	39.11	33.57	28.33	22.78	18.04	13.42	9.57	6.15	3.12	
55	50.03	44.50	38.85	33.50	27.98	22.75	17.62	13.15	9.24	5.84	2.90

Source: "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977," American Association of State Highway and Transportation Officials, Washington, DC, page 132.

*January 1980 price levels and conditions, adapted from January 1975 figures by multiplying by 1.627. This multiplier does not take into account changes which have occurred in fuel consumption rates.¹

¹

"Procedure for Estimating Highway User Costs, Fuel Consumption and Air Pollution," May 1980, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, page 13.

CHAPTER 3

SPEED LIMITS

Speed limits are among the most important tools one can use to create and maintain a safe traffic environment. But as in all regulatory procedures, the limits imposed must be reasonable and appropriate to the situation. Most drivers tend to regulate their own speed according to traffic, road and weather conditions, and as explained in this chapter, it is the normal driver's speed which is used by traffic engineers as a guide in setting speed limits.

Other factors must be taken into account, of course, in setting appropriate speed regulations. School zones, for example, create especially hazardous conditions and require special consideration. The important point to remember is that the speed regulation informs the driver of the limits in which one can safely operate a vehicle under normal circumstances and within which the driver can be expected to react safely to driving problems. Setting speed limits at appropriate levels will create a reasonable flow of traffic, discourage violation of the law and help keep streets and highways safe.

IS THERE A MAXIMUM SPEED LIMIT ESTABLISHED BY THE STATE OF KANSAS?

The state of Kansas Motor Vehicle Laws, Article 13 "Miscellaneous Provisions," sets forth the maximum lawful speed limits described below, and are enforceable with or without posted signs:

1. Twenty (20) miles per hour in any business district.
2. Thirty (30) miles per hour in any residential district.
3. Fifty-five (55) miles per hour in all other locations.

The maximum speed limits for all arterial streets shall be determined by an engineering and traffic investigation. This speed limit may be greater or less than the limits for the business or residential district where the arterial is located. However, under no circumstances shall the speed limit exceed 55 mph.

HOW CAN A LOCAL AUTHORITY CHANGE THE SPEED LIMIT FOR ITS JURISDICTION?

For local authorities to change the speed limit on a highway or street within their jurisdiction, they must first conduct an engineering and traffic study on that roadway. From this study, they may declare a reasonable and safe maximum limit (subject to the statutory limit of 55 mph.) thereon which:

1. Decreases the limit at intersections; or
2. Increases the limit within an urban district; or
3. Decreases the limit outside an urban district to not less than twenty (20) mph; or
4. Decreases the limit within an urban district in a school zone to not less than twenty (20) mph but only during hours students are enroute to or from school.

ARE THERE LIMITATIONS SET BY THE STATE UNDER WHICH THE LOCAL AUTHORITY IS BOUND IN ALTERING SPEED LIMITS?

There are limitations in changes to which a local authority is restricted. See the question (and answer) above for the limitations.

WHERE SHOULD SPEED LIMIT SIGNS BE LOCATED?

Speed limit signs for altered zones shall be erected:

1. At the beginning of each zone where the speed limit changes.

2. At the point of change from one zone to another.
3. At additional locations within a zone where it may be necessary to remind the motorist of the legal limit.

HOW FAR APART SHOULD SPEED LIMIT SIGNS BE INSTALLED ALONG THE ROADWAY?

The following guidelines are recommended for roads and streets under local jurisdictions.

The recommended distances between speed limit sign installations in altered speed zones are:

<u>Speed limit (MPH)</u>	<u>Minimum Distance</u>	<u>Maximum Distance</u>
30 or Less	660 Ft. or 2 Blocks	1320 Ft. or 4 Blocks
35 or 40	990 Ft. or 3 Blocks	1900 Ft. or 6 Blocks
45 or 50	1320 Ft. or 4 Blocks	2640 Ft. or 8 Blocks

The recommended distances between speed limit signs do not apply to the posting of statutory limits.

IF RESIDENTS OF A NEIGHBORHOOD ARE REPORTING THAT CARS ARE SPEEDING ON THEIR STREETS, SHOULD THE SPEED LIMITS BE LOWERED TO SLOW THE DRIVERS DOWN?

For a speed limit regulation to be effective, at least 85 percent of the drivers should voluntarily comply with the law. The first action one should take if speed violations are reported is to undertake a study of vehicle speeds.

The basis for the proper speed on any stretch of highway or street is the nationally recognized "85th percentile speed." This is the speed at or below which 85 percent of the observed free flowing traffic is moving. The experience of traffic engineers has been that posting higher or lower speed limits does not significantly change the 85th percentile speed. Moreover, raising a speed limit to the 85th percentile

should not result in an increase in the frequency or severity of accidents. It may be good practice to monitor streets where the speed limit has been raised to determine if the incidence of accidents has actually increased or decreased.

Adoption of the 85th percentile speed recognizes that a small minority of highway users drive at speeds in excess of that considered safe by the majority of drivers. Obviously, enforcement action should be directed toward that minority.

WHAT INVESTIGATIONS ARE REQUIRED TO LEGALLY ESTABLISH A SPEED LIMIT?

A speed limit can only be changed after an engineering and traffic study has been conducted. The prevailing speed of free-flowing traffic should be used in establishing the speed limit. Three methods for conducting the traffic study may be used:

1. Eighty-fifth percentile speed (the preferred method). This is the speed at or below which 85 percent of the free-flowing vehicles observed on the roadway under study are traveling.
2. Upper limit of the 10 miles per hour pace. Observation of vehicles on the roadway will determine the 10 mile per hour range at which most of the vehicles are traveling.
3. Average Test Run Speed. This method is optional on low-volume roadways and is only applicable for determining the prevailing speed of passenger cars.

In order to use the methods described above in establishing a proper speed limit, let's examine the elements of a traffic study.

To determine either the 85th percentile or the 10 mile pace, a spot speed study must be conducted. A spot speed study is made by measuring the individual speeds of a sample of the vehicles passing a given point

(spot) on a street or highway. These individual speeds are used to estimate the speed distribution of the entire traffic stream at that location. Location of the study at the mid-point of the area characteristics will provide viable data.

Study Location

1. General Location depends upon the purpose of the study. For determining speed trends, stations are usually established at a central location on open stretches of straight, rural highways or at midblock locations on urban streets away from the influence of Stop signs and signals.
2. The specific site is selected within the general location to reduce or eliminate the influence of the observer and measuring equipment on vehicle speed. Equipment should be concealed, the observer and his vehicle should be as inconspicuous as possible and on-lookers must be kept from the area.
3. Variables which might influence the study should be minimized. Do not locate the site on curves, grades, rough stretches of road, or near construction unless the study requires these conditions. Other factors such as environment (weather, visibility) and excess traffic flow should be taken into consideration if these conditions are not normal.

Time of Study

Off-peak hours are normally used in conducting a spot speed study although the purpose of the study should determine the time. It is important that trend studies and "before and after" studies be made during the same hours under comparable conditions. Bad weather and unusual traffic volume conditions should be avoided.

Size and Selection of Sample

The speeds of preferably 100 free flowing vehicles in each direction should be obtained for any one location. On low volume roads where it would be difficult to obtain a sample of 100 vehicles in each direction, the study may be terminated after a study period of three hours in

each direction. Vehicles should be selected at random from the free flow of a traffic stream to avoid bias in the results. The following provides some guidelines for selecting vehicles:

1. Always select the first vehicle in a platoon, because this is an indication of the speed that the first driver wants to travel. Others in the platoon may want to travel faster, but how much faster cannot be determined; therefore, should not be part of the study sample.
2. Do not select too large a portion of trucks--their speeds may not be representative of the rest of the sample. Attempt to obtain about the same proportion of trucks in the sample as exists in the traffic stream.
3. The selection must be made at random of only free flowing vehicles, for example, every fourth vehicle's speed. Do not select too large a proportion of higher speed vehicles or the results will be biased toward the upper range of speeds.

To Determine the 85th Percentile

To make use of the data collected, the next step is the analysis. The best way to summarize the data is to chart the speeds collected on a frequency distribution table. Table 3, used as an example of a frequency distribution table, includes the speeds of 100 vehicles. The speeds are grouped into three-mph increments (groups of 1, 2, 4, or 5 mph are occasionally used) with the second column indicating upper-limits for each three-mph increment. The upper limits are needed later for plotting a curve. All of the speeds collected in the example range from a low of 13.6 miles per hour to a high of 49.5 miles per hour. The third column lists the number of vehicles observed operating within each of the three-mph groups.

The cumulative frequency (column 4) is the total of each of the numbers (frequencies) in column 3 added together row by row from the top down. The last column is a running percentage of the cumulative frequency from the top down.

Once the frequency distribution table has been constructed, the best way to determine the 85th percentile is to plot the speed distribution on a graph. Take the upper-limit of each grouping (column 2) and plot that speed on the graph where it corresponds with the cumulative percent of vehicles observed (column 5). Where the curve intersects the 85th percent line, that speed is the 85th percentile speed. In the example given, the curve intersects at 37 miles per hour (Figure 1).

The actual speed limit posted should be this 85th percentile speed rounded off to the nearest five mile per hour increment; in this case 35 mph.

To Determine the 10 Mile Pace

The same distribution of vehicle speeds in Table 3 can be used to determine the 10 mile pace or the 10 miles per hour range containing the most vehicles. By dividing the vehicle speeds into 10 mile ranges (15 to 25 mph, 26 to 35 mph, etc.), it becomes evident that the largest number of vehicles (approximately 51 vehicles) were traveling at speeds between 25 and 35 miles per hour. The upper limit of this range is 35 mph and this study would, therefore, result in the same speed limit being established as the 85th percentile method: 35 mph.

The Average Test Run Speed

Average test run speeds are determined on the basis of five runs in each direction over the length of the proposed zone. The most important part of the test runs is to determine the maximum permissible speed. Time periods are disregarded and while making the test run, the driver should try to "float" in the traffic stream (drive as an average or typical vehicle in the traffic stream).

Supplementary Investigations

The speed limit may differ from the established prevailing speed (obtained by one of three methods above) by more than three miles per hour when it can be justified through further investigation. The investigation may include a study of any or all of the following conditions:

- * Accident Rate
- * Access Control
- * Pedestrian Activity
- * Parking
- * Road Surface Characteristics
- * Roadside Development
- * Safe Speed Design Driterion

FIGURE 1

CUMULATIVE SPEED DISTRIBUTION CURVE

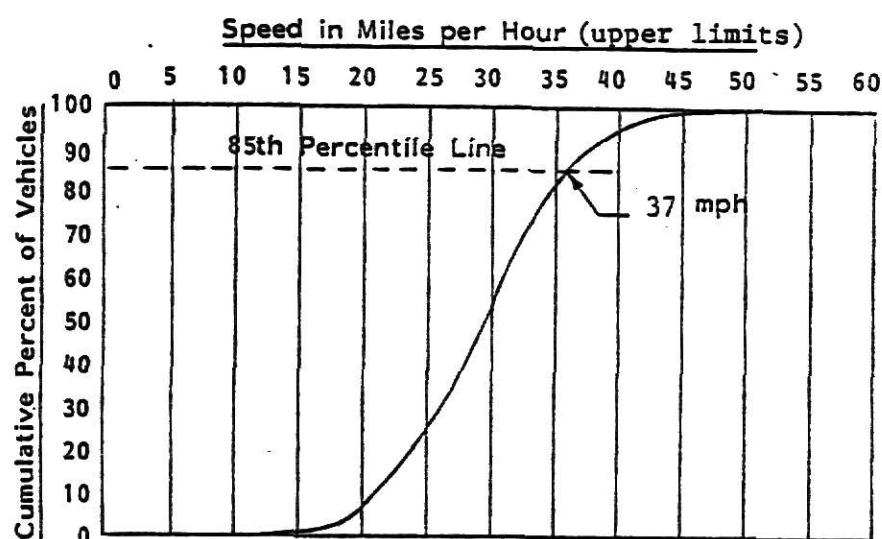


TABLE 3
FREQUENCY DISTRIBUTION TABLE

<u>Row</u>	<u>1</u> <u>Groupings of</u> <u>Speeds</u> <u>Observed</u>	<u>2</u> <u>Upper-</u> <u>Limits</u>	<u>3</u> <u>Frequency</u> <u>of</u> <u>Vehicles</u>	<u>4</u> <u>Cumulative</u> <u>Frequency</u>	<u>5</u> <u>Cumulative</u> <u>Percent*</u>
1	13.6 to 16.5	16.5	1	1	1%
2	16.6 to 19.5	19.5	2	3	3%
3	19.6 to 22.5	22.5	6	9	9%
4	22.6 to 25.5	25.5	12	21	21%
5	25.6 to 28.5	28.5	13	34	34%
6	28.6 to 31.5	31.5	20	54	54%
7	31.6 to 34.5	34.5	18	72	72%
8	34.6 to 37.5	37.5	14	86	86%
9	37.6 to 40.5	40.5	6	92	92%
10	40.6 to 43.5	43.5	6	98	98%
11	43.6 to 46.5	46.5	1	99	99%
12	46.6 to 49.5	49.5	<u>1</u>	100	100%

100 Vehicles

$$\text{*Cumulative Percent} = \frac{\text{Cumulative Frequency}}{\text{Total Number of Vehicles}} \times 100$$

ARE THERE RECOMMENDED OR PRESCRIBED SPEED LIMITS FOR SPECIFIC LOCATIONS SUCH AS SCHOOL ZONES?

Kansas law establishes a maximum 20 mile per hour speed limit while passing a school zone, or while driving along any public thoroughfare on or across which children travel to and from school, on school days when children are present and signs are posted.

ARE THERE OTHER WAYS TO CONTROL VEHICLE SPEED?

1. Coordinated System of Signals should be based on operational speeds of facility. Signals can be timed in progression to have motorists on a given street move at or near a predetermined speed.
2. Advisory Speed Plate. Advisory speed limit plates (in multiples of 5 miles per hour) can be used on curves and at hazardous locations as the advisory maximum speed. These speeds should be determined through accepted traffic engineering procedures and periodically checked and corrected if necessary. They are always posted in conjunction with another warning sign and are not required if the critical speed is less than 5 miles per hour below the posted speed limit.
3. Enforcement. Signals, signs and other warning devices will not be truly effective unless motorists are aware that violation of these rules will result in penalties. Municipalities should draw on local, county and state law enforcement agencies for assistance in regulating traffic. Motorists usually tend to act more lawfully if a law enforcement vehicle is observed on a roadway. Consistent monitoring of a roadway by law enforcement agencies will lead to a reduction in speeding violations and other unsafe driving practices.

CHAPTER 4

SCHOOL CROSSINGS

School areas require special traffic control treatment because of the danger to children who are often less careful than adults. The question facing traffic managers is how to best handle the school safety problem in light of the many issues and factors involved. Parents and school officials will often make demands based on emotions rather than a factual set of circumstances. City officials will be equally concerned with the safety of the children but will be required to work within budget constraints and the demands of the total driver population. What is needed is a program that is acceptable and utilized by educators, enforcement officials, parent-teacher groups, the children and others involved.

WHERE SHOULD SCHOOL CROSSINGS BE LOCATED?

The best approach to locating school crossings is to establish a coordinated school traffic safety program. The first step in the coordinated approach is to set up a school traffic safety committee of governmental and school board officials with the authority to implement the program. The committee's first task is to develop a suggested school route plan for each school serving elementary and kindergarten students. The plan should consist of a simple map showing streets, sidewalks, the school, existing traffic controls and, by arrow markings, the school routes for the children. The school route plan should be designed to provide maximum protection for children at a reasonable cost.

This can be accomplished by selecting routes that take advantage of the protection afforded by existing traffic controls. Some children may also need to walk longer distances to avoid hazardous crossings.

When developing the plan, officials may find the route crosses a major highway or goes through an intersection with particularly heavy traffic. These locations could be particularly hazardous. Each of these locations should be studied to determine if adequate gaps in the traffic stream exist to allow the children to cross safely. If the delay time between adequate gaps is too long, the children may get impatient and attempt to cross under unsafe conditions. The "Traffic Controls for School Areas" publication, published by the Kansas Department of Transportation, which is available from the Urban Highways Department, and the publication "A Program for School Crossing Protection" from the Institute of Transportation Engineers should be referred to for more detailed information on developing a school traffic safety program and crossing plan.

WHO SHOULD BE INVOLVED IN DEVELOPING A SAFE SCHOOL CROSSING PLAN?

For the crossing plan to be effective and acceptable, school administrators, teachers, parents, the local police department and governmental agencies such as the city engineering or traffic department (or the Kansas Department of Transportation for crossings on State routes) should be involved in developing and implementing the plan. The pupils themselves become involved, some on school safety patrols in directing other children at crossings, and all of them in being the recipients of thorough instruction on the purpose and use of the school route plan.

HOW CAN ONE TELL IF A SCHOOL CROSSING IS UNSAFE?

When the delay time between adequate gaps is excessive, or in other words, when safe gaps are less frequent than one per minute, it is an indication that some form of traffic control is needed to create gaps.

The Adequate Gap Time may be computed using the following equation.

Adequate Gap Time = G (in seconds)

$$= \frac{W}{3.5} + 3 + (N-1)2$$

where: W divided by 3.5 = Walking Time, the number of seconds required to walk across the roadway. This value is equal to the width of roadway (W) in feet, divided by the walking speed in feet per second (assumed to be 3.5 ft/sec).

3 = pedestrian perception and reaction time.

(N-1)2 = Pedestrian Clearance Time, additional seconds of time required to clear large groups of children from the roadway. Children are assumed to cross the roadway in rows of five with two-second time intervals between each row. The clearance time interval is equal to (N-1)2 where N is the number of rows, 1 represents the first row, and 2 is the time interval between rows.

For further information on gap studies refer to the ITE handbook, Chapter 3, and Transportation and Traffic Engineering Handbook, Chapter 10, page 441.

WHAT ARE THE ALTERNATIVES FOR PROTECTING SCHOOL CROSSINGS?

There are basically three types of measures available for reducing traffic hazards to children at school crossings: 1) adult crossing guards and student patrols; 2) the use of traffic control devices

including signs, pavement markings and signals, and 3) construction of overpasses and underpasses.

WHEN IS AN OVERPASS (OR UNDERPASS) JUSTIFIED AT A SCHOOL CROSSING?

An overpass or underpass is a major investment. The following conditions should be met before considering this measure.

1. The obstacle the school children must cross is relatively permanent, such as a freeway.
2. The cost of an overpass or underpass is cheaper over the long range than other measures.
3. The location is appropriate for this kind of structure.
4. The funds spent on the structure won't limit money available for other school crossing protection.
5. The structure will serve other pedestrians besides school children.
6. There is no likelihood that replanning the school route will eliminate the need for an overpass or underpass.

WILL A REDUCED SPEED LIMIT BE HELPFUL IN SAFEGUARDING PEDESTRIANS AT SCHOOL CROSSINGS?

The speed of vehicles can be a contributing factor to the incidence of accidents involving vehicles and pedestrians. Local authorities may want to set a speed limit appropriate for school zones.

Other measures which have been found to be effective for pedestrian safety are overpasses and underpasses, one-way streets, and improved signal visibility.

ARE THERE SITUATIONS WHERE SCHOOL SPEED LIMITS SHOULD NOT BE POSTED?

It should be recognized that school speed limit signs are not a "cure-all" because of the difficulty in enforcement--particularly in

rural areas. School speed limit signs would be unnecessary under any of the following conditions:

1. School children are protected by other traffic control devices such as Stop signs and signals, where motorists are required to come to a complete stop. An exception may be made when the speed zone serves to protect children walking on or adjacent to the roadway in the school area.
2. The school or school grounds are completely isolated from the roadway by means of a fence or other barrier, and no access to the roadway is provided.
3. An underpass or overpass has been provided.
4. Entrance to and exit from the school grounds are by school bus or other vehicle only.

WHEN SHOULD ADULT GUARDS OR STUDENT PATROLS BE USED AT A SCHOOL CROSSING?

The use of adult crossing guards and student patrols is an economical and effective method of controlling the movement of students, rather than traffic, at school crossings.

Adult crossing guards should be considered if:

1. Traffic volumes are near the level required to warrant traffic signals and gaps in traffic are so short and infrequent that an adult is required to select adequate gaps and to control waiting children.
2. The costs of a guard are more economical than a pedestrian grade separation structure or a traffic control signal.
3. There are special hazards such as fog, complicated intersections, or high vehicle speeds that can be properly handled only by adult supervision.
4. A change in school routes or districts is imminent and protection is needed only for a limited time.

A student patrol is most useful at locations where some supervision of children using the crossing is desirable but the conditions do not require the actual direction of motor vehicles. They should be assigned to locations adjacent to school grounds only where

adequate gaps in traffic occur frequently enough for safe crossings without stopping traffic. Patrols should not be permitted to halt or direct vehicular traffic.

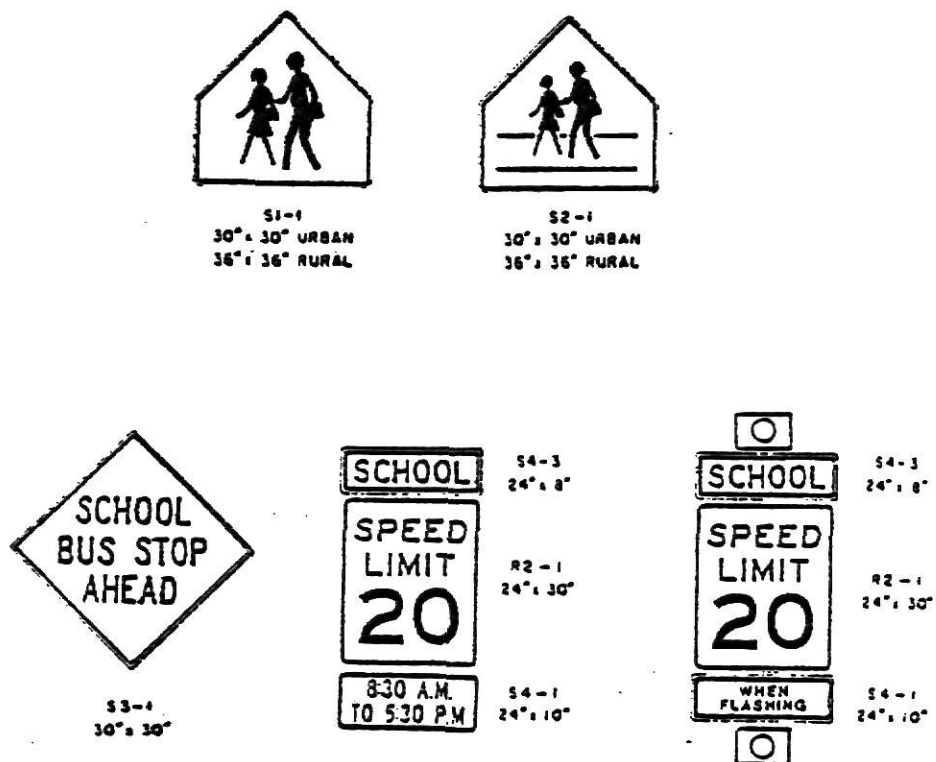
WHAT STANDARD SIGNS SHOULD BE USED AT SCHOOL CROSSINGS?

The signs to be erected at crossings can be found in the Manual on Uniform Traffic Control Devices or Kansas School Crossing Manual (See Figure 2).

1. The School Advance sign (S1-1) is used in advance of locations where school buildings and grounds are adjacent to a highway and where traffic creates a hazard. It is also used in advance of established school crossings that are not near the school to warn motorists that school children may be present.

FIGURE 2

STANDARD SCHOOL SIGNS



2. The School Crossing sign (S2-1) is used at established crossings, including signalized locations, used by pupils going to and from school. Where a crossing is controlled by a Stop sign, the school crossing sign should be omitted. Only crossings adjacent to schools and those on established school pedestrian routes may be signed.
3. The School Bus Stop Ahead is intended for use ahead of locations where a school bus pick-up or drop-off point is not visible for a distance of 500 feet in advance of the point.
4. School Speed Limit signs indicate the speed limit where a reduced speed zone for a school area has been established (in accordance with law) or when a speed limit is specified for such areas by statute.

School Speed Limit signs are used in conjunction with a bottom panel showing the specific time period of the day when the limit applies and a top panel reading School. If desired, a Speed Limit Sign Beacon with a "When Flashing" sign may be used to identify the period the school speed limit is in force (See Figure 2).

5. No Parking and Stopping signs should be used at school crossings to keep them free of vehicles which could block the vision of motorists and pedestrians. Parking signs should display information in the following order:
 - a. Restriction or Prohibition Message.
 - b. Time of Day It is Applicable, If Not All Hours.
 - c. Days of the Week It is Applicable, If Not All Days.
 - d. A Single or Double Headed Arrow Pointing In the Direction(s) the Regulation is in Effect.

SHOULD PAVEMENT MARKINGS BE USED FOR CROSSINGS?

Pavement markings can be used in conjunction with traffic signals and signs or used solely as a crossing safeguard. One should be aware, however, that pavement markings have limitations because they can be hidden by snow and may be worn off by heavy traffic. The following are typical applications of pavement markings at school crossings.

1. Crosswalk Lines are solid white parallel lines marking the edge of the crosswalk. They are a minimum of 8 inches in width, spaced not less than six feet apart and extend from curb to curb. Where no advance stop line is provided, or where vehicle speeds exceed 35 miles per hour, or where crosswalks may be unexpected it is desirable to increase the width of the lines to 24 inches. Crosswalk lines should be limited to only those locations designated on an established school route plan. This ensures that only those crosswalks where there is a significant number of both vehicles and children are marked and encourages children to use only the marked crosswalks. Drivers also become more aware that those crosswalks are used by children and that extra care must be exercised. Crosswalks can be marked either at intersections or at mid-block locations but normally intersection crossings are preferred because motorists are more alert to pedestrians crossings. See Figure 8, on page 47 for typical crosswalk markings.
2. Stop Lines are solid white lines, 12 or 24 inches wide which extend across an approach lane and indicate the point at which vehicles should stop in compliance with a stop sign or traffic signal. Stop lines should ordinarily be placed four feet in advance of and parallel to the nearest crosswalk line. See Figure 8 on page 47 for typical stop line markings.
3. Curb Markings are used to restrict parking near school crossings in order to allow both drivers and pedestrians adequate sight distance. Curb markings are normally yellow and should be used in conjunction with signs.
4. Word Markings on the pavement may be used to supplement standard signs in school areas. The standard messages used are "School" or "School X-ing." They should be white in color and eight feet or more in height.

SHOULD A TRAFFIC SIGNAL BE INSTALLED AT A BUSY INTERSECTION IF SCHOOL CHILDREN WILL CROSS THERE FREQUENTLY?

School signals can be erected at established school crossings in order to create gaps in traffic to allow children to safely cross a roadway. Depending upon conditions, they may be installed either at intersections or at mid-block crossings.

School signals can only be justified if a traffic engineering study is conducted which indicates there are inadequate gaps in traffic

to allow children to safely cross a street. In order to warrant traffic signals at school crossings, each of the following conditions must be met:

1. During each of two daily school crossing periods, the average time between gaps in traffic of sufficient length to permit children to safely cross the highway shall be more than one minute.
2. There is no existing stop or signal control on the street being crossed within 400 feet of the proposed crosswalk.

CHAPTER 5

TRAFFIC SIGNS

Traffic signs are the most commonly used traffic control devices. They provide directional, regulatory, and warning information to motorists. The use of traffic signs should be limited to only those locations where they are warranted or where additional information is required. Signs are not needed to confirm rules of the road.

Local authorities and road district highway officials in their respective maintenance jurisdiction shall place and maintain such traffic control devices upon highways under their maintenance jurisdiction as are required to regulate, warn, or guide traffic. These traffic controls must, by law, conform to the Manual on Uniform Traffic Control Devices. To be effective, a traffic control device should meet five basic requirements.

1. Fulfill a Need.
2. Command Attention.
3. Convey a Clear, Simple Meaning.
4. Command Respect of Road Users.
5. Give Adequate Time for Proper Response.

This chapter will describe some of the more common traffic control signs and their uses, but for more detailed information, always refer to the Manual on Uniform Traffic Control Devices (MUTCD). This manual conforms to the national guidelines on traffic control devices which have been established to promote uniformity throughout the nation.

DO NEW SIGN INSTALLATIONS HAVE TO BE APPROVED BY ANOTHER AUTHORITY BEFORE A LOCAL JURISDICTION CAN INSTALL SIGNS?

According to Kansas statutes, placement of traffic control devices on township or road district roads are subject to written approval of the

County Superintendent of Highways. The Superintendent must be contacted prior to erection of any signs. Signs on a State highway in a city or local jurisdiction must be approved by State authorities. One exception to this rule is that if a municipality maintains parking on a county or city highway or street, parking control signs can be erected without approval of another authority.

WHAT TYPES OF SIGNS ARE AVAILABLE FOR TRAFFIC CONTROL AND MANAGEMENT?

There are three types of signs and they are classified according to their use.

1. Regulatory Signs give the driver notice of traffic laws and regulations that apply at a given place or on a given roadway. To disregard these signs is punishable by law. Examples: Stop Signs, Yield Signs, Speed Limits.
2. Warning Signs call attention to conditions in or around a roadway which are potentially hazardous to traffic operation. Examples are: Curve, Signal Ahead, Stop Ahead, Slippery When Wet.
3. Guide Signs show route destinations, directions, distances, points of interest and other geographical or cultural information including street names and parking areas.

DO ALL SIGNS HAVE TO MEET CERTAIN SPECIFICATIONS IN SIZE, SHAPE, AND COLORING?

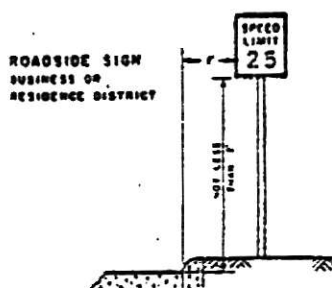
All regulatory and warning signs are required to conform with the Manual on Uniform Traffic Control Devices. These specifications are published by the Federal Highway Administration. There is more flexibility with the design of guide signs and object markers, but where indicated in the Manual, some guide signs must meet certain specifications.

IS THERE A SPECIFIC MOUNTING HEIGHT AND LOCATION FOR SIGNS?

Location - The general rule is to locate signs on the right hand side of the roadway where drivers are in the habit of looking for them. Signs are normally erected individually on separate posts or mountings, except where one sign supplements another or they must be grouped. In rural areas, two signs should not be located closer together than 200 feet along the highway, except at intersections. All signs should be located so motorists can see them without obstruction for a distance of at least 400 feet.

Height - Signs on roadsides in rural areas should be mounted at least five feet above the level of the pavement or roadway edge measured to the bottom of the sign. In an area where parking might occur or where obstructions may block the motorist's view, the height should be a minimum of seven feet. The height to the bottom of a secondary sign mounted below another sign may be one foot less than the appropriate height specified previously. See Figure 3.

FIGURE 3
HEIGHT AND LATERAL LOCATION OF SIGN
TYPICAL INSTALLATION



Lateral Clearance - Signs need to be readily visible to motorists but should not be so close to the roadway that they are a hazard to drivers who leave the road. When there is sufficient right-of-way the near edge of the sign (except for Stop and Yield signs) should be 12 to 18 feet from the edge of the pavement. Stop and Yield signs should not be placed more than 10 feet from the edge of the pavement. The minimum lateral distance is six feet from the pavement in all cases, except for object marking panels. In areas where curbs are in place, a distance of two feet to the edge of the sign is recommended. See Figure 3 above.

Erection Details - Signs are normally mounted at right angles to the direction of, and facing, the traffic they are intended to serve. Should the mirror reflection of the sign reduce its legibility, the sign may be turned slightly away from the road (2 to 5 degrees). On curves, the sign should face approaching traffic rather than be aligned with the road. Sign faces are normally vertical but they can be tilted forward or backward on grades to improve the viewing angle.

WHERE SHOULD WARNING SIGNS BE LOCATED?

Warning signs should be placed at locations on the basis of expected vehicle speed and the action required on the part of the driver. The table below lists the recommended distances these signs should be located in advance of the condition they are warning of (stop, curve, etc.) The two basic criteria to determine the advance sign's placement are the approach speed and the reduction in speed (or stop) required to comply with the sign message.

TABLE 4
RECOMMENDED DISTANCE IN FEET
FOR PLACEMENT OF ADVANCE SIGNS

<u>Speed Reduction Required to Comply with Sign Message</u>				
<u>Approach Speed</u>	<u>Stop*</u>	<u>10-20 MPH</u>	<u>25-40 MPH</u>	<u>45-50 MPH</u>
30 or Less	100'	100'	-----	-----
35-40	225'	275'	175'	-----
45-50	375'	425'	325'	-----
55	450'	500'	400'	225'

* Includes signs for any condition requiring a possible stop, such as a stop sign, crosswalk, railroad crossing, yield sign, etc. The distances recommended can be increased where vehicle backups occur from the stopping point.

WHAT KIND OF SIGNING SHOULD BE USED TO WARN MOTORISTS OF A SHARP CURVE?

Two symbol signs, either Curve or Turn, are used depending on the speed a vehicle should maintain to safely negotiate a curve.

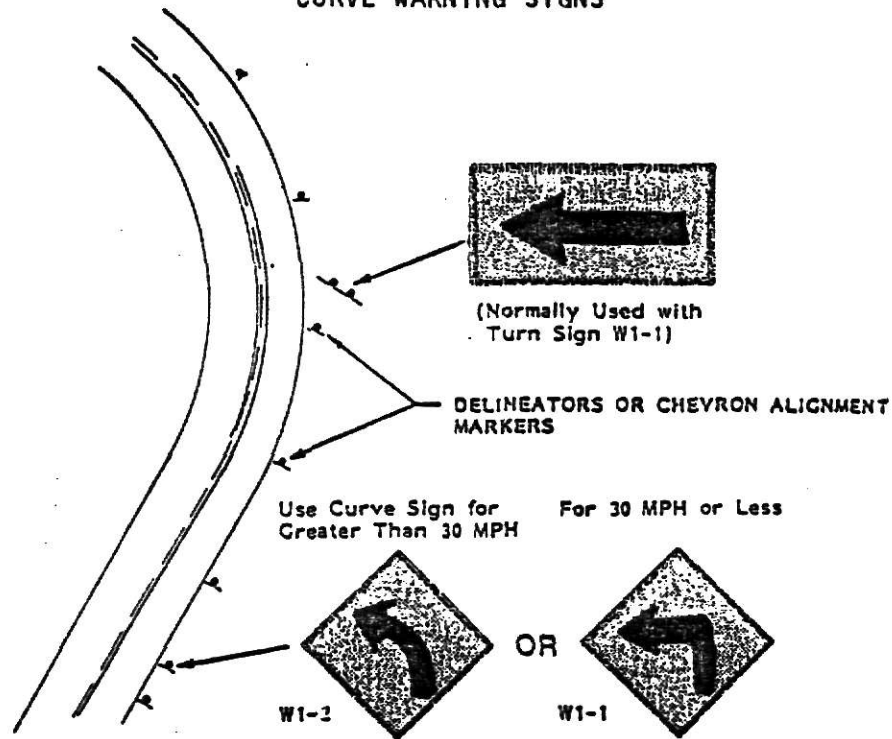
If an investigation of the roadway geometric and operating conditions determines the recommended speed on a curve to be between 30-55 MPH and this speed is equal to or less than the legal speed limit, then a Curve sign (W1-2R or 2L) would be used.

If the investigations indicate that the recommended speed on a turn is 30 MPH or less and the recommended speed is equal to or less than the legal speed limit, the Turn sign (W1-1R or 1L) should be used. When the Turn sign is warranted, a large arrow sign may be used on the outside of the turn. Additional protection may be provided by use of an advisory speed plate mounted below the advance Curve or Turn sign.

For locations which curve sharply and abruptly, Chevron Alignment signs (W1-8) or delineators (see Figure 4) can be used to mark the curve of the road.

FIGURE 4

CURVE WARNING SIGNS

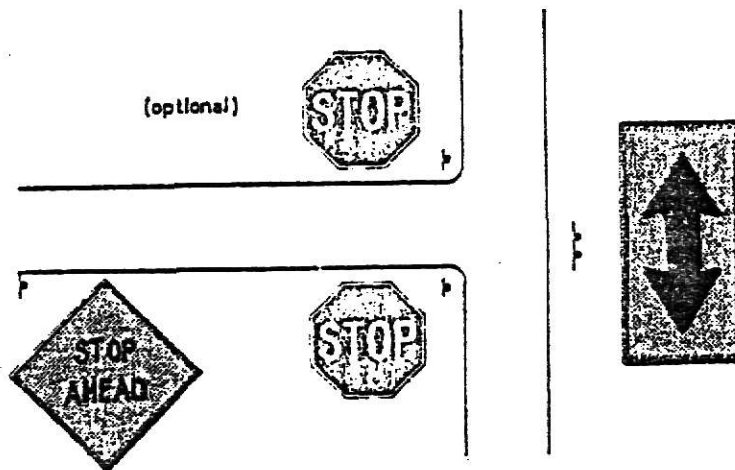


WHAT SIGNS SHOULD BE USED WHERE A MINOR ROAD T'S WITH A HEAVILY TRAVELED MAJOR ROAD AND THERE IS A HIGH FREQUENCY OF ACCIDENTS?

The large number of accidents indicates that the Stop sign is not readily visible to motorists or is unexpected. A Stop Ahead sign (W3-1) should be erected to warn motorists of the upcoming intersection. It may also be helpful to install a double-headed large arrow sign at the head of the "T" directly in line with the leg of the intersection (see Figure 5).

Other measures available are to increase the size of the Stop sign or to install a flashing beacon above the advance warning sign and/or Stop sign. Refer to Chapter 8 for the use of flashing beacons.

FIGURE 5
STOP AHEAD SIGN



WHAT SIGNS SHOULD BE USED TO WARN MOTORISTS OF A NARROW BRIDGE?

A Narrow Bridge sign (W5-2) is used in advance of structures that have a clear roadway that is not at least two feet wider than the pavement approaching the bridge. Additional protection may be provided by the use of bridge-end reflectors at the end of the handrails on both sides of the roadway and/or by a short series of Chevron Alignment Markers (W1-8) or Object Markers (OM-3) in advance of the bridge on both sides of the roadway to indicate the narrowing condition. Bridges or culverts having less than a 20-foot span and a width that is not at

least two feet wider than the pavement approaching the bridge or culvert should be treated as narrow bridges and signed accordingly.

Figure 6 shows these markings.

A One-Lane Bridge sign (W5-3) is used on two-way roads in advance of bridges and culverts.

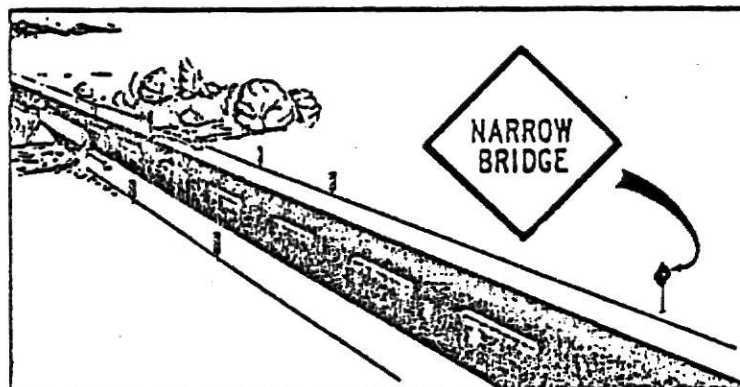
1. Which have a clear roadway width of less than 16 feet.
2. Which have a clear roadway width of less than 18 feet when commercial vehicles constitute a high proportion of the traffic.
3. When the alignment is poor on the approach to the structure which has a clear roadway width of 18 feet or less.

WHAT SIGN SHOULD BE USED TO ALERT MOTORISTS OF A CHANGE IN SPEED LIMITS?

The Speed Zone Ahead sign (R2-5c) should be used in rural areas to inform approaching motorists of a reduced speed zone. The sign is not ordinarily needed in urban areas where speeds are relatively low. This sign shall always be following a Speed Limit sign erected at the beginning of the zone where the altered speed limit applies. Correct placement of the Speed Zone Ahead sign can be determined by referring to Table 3.

FIGURE 6

NARROW BRIDGE SIGN



ARE THERE REQUIREMENTS FOR STREET NAME SIGNS?

Street name signs should be erected to identify street intersections. The lettering on street name signs should be white on green background with the letters at least four inches high. The sign should be reflectorized for nighttime visibility.

Street name signs should be mounted a minimum of seven feet above the pavement. In residential districts at least one cross street sign is recommended at each intersection. In business districts or on major arteries, street name signs should be placed on diagonal corners so that they will be on the near left-hand and far right-hand side of the intersection for traffic on the major street.

CHAPTER 6

PAVEMENT MARKINGS

Pavement markings can provide a very useful function in overall traffic control either as a supplement to other devices or used alone. They serve very effectively in conveying certain regulations and warnings that could not otherwise be made as understandable to the motorist. Moreover, they can be used to advise the motorist without diverting his attention from the roadway. But markings do have significant limitations. They cannot be seen when snowcovered, they are not clearly visible at night when wet, and they may not prove durable under heavy traffic.

WHAT TYPES OF PAVEMENT MARKINGS ARE USED?

Pavement markings are normally used as follows:

1. Yellow Center Lines on Two-Way Roads
2. Roadway Edgelines
3. No Passing Lines on Two-Way Roads
4. Lane Lines on Multi-Lane Roads
5. Stop Lines
6. Crosswalk Lines
7. Railroad Crossing Markings, Arrows, and Other Lane Messages

WHAT COLORS CAN BE USED FOR PAVEMENT MARKINGS?

The colors for pavement markings are yellow and white. Black is permitted in combination with the above colors if the pavement itself does not provide sufficient contrast.

Yellow lines delineate the separation of traffic flows in opposite directions (center lines) or mark the left edge of the pavement of divided highways and one-way roads.

White lines delineate the separation of traffic flows in the same direction (lane lines) or mark the right edge of the pavement.

WHAT WIDTH AND SPACING REQUIREMENTS ARE USED FOR PAVEMENT MARKINGS?

1. A normal line is four to six inches wide.
2. A wide line is at least twice the width of the normal line.
3. A double line consists of two normal width lines separated by a discernible space.
4. A broken line is formed by line segments and gaps, usually in the ratio of one to three. On rural highways, a recommended standard is a 40-foot cycle with 10-foot segments and 30-foot gaps. On urban streets, the cycle length can be less, since speed limits are normally lower and streets are divided into block lengths.
5. A dotted line is formed by short segments, normally two feet in length and gaps of four foot or longer.

WHEN SHOULD A BROKEN LINE BE USED?

Broken lines are permissive in character and constitute a guide for the motorist. For example, a broken white line is used as the lane line on a multi-lane roadway. The motorist is allowed to change lanes and cross the broken line if traffic conditions permit. Other uses for broken lines are:

1. A normal (four to six inches wide) broken yellow line is used as a centerline of a two-lane, two-way road where overtaking and passing is permitted.
2. A double line consisting of a normal broken yellow line and a normal solid yellow line is used as a separation between travel paths in opposite directions to regulate passing. (Note: If both lines are solid, passing is prohibited in both directions).
3. A normal dotted line is used to delineate the extension of a line through an intersection or interchange area.

WHAT TYPES OF PAVEMENT MARKINGS (LINES) SHOULD BE USED ON TWO-LANE ROADS?

The lines referred to here are all longitudinal--run parallel to the direction of the road.

1. Where passing is permitted, a normal broken yellow line.
2. Where passing is permitted in one direction only, a double line consisting of a normal broken yellow center line and a normal solid yellow line in the lane from which passing is prohibited.
3. Where passing is prohibited in both directions, a double line consisting of two normal solid-yellow lines.
4. A normal solid white line used to delineate the edges of the pavement.

Figure 7 depicts the typical center line and edge line markings on a two-lane road.

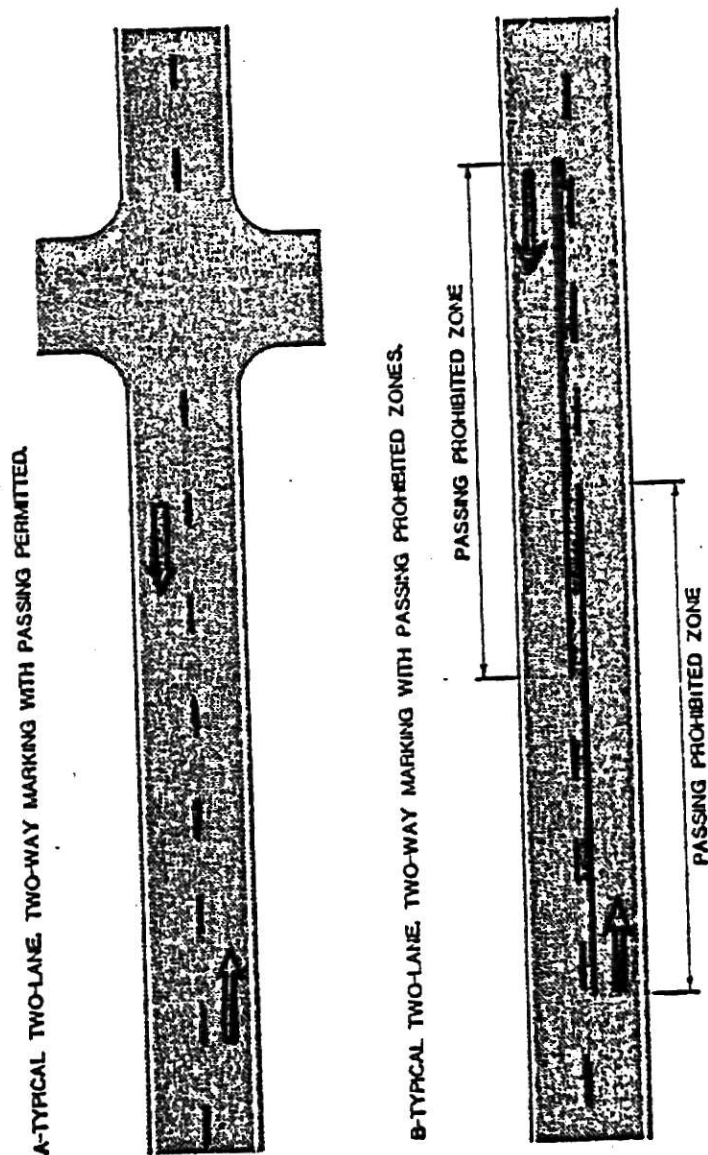
SHOULD ALL ROADS HAVE A CENTERLINE?

Centerlines are desirable on paved highways under the following conditions:

1. In rural areas on two-lane pavements, 16 feet or more in width with prevailing speeds of greater than 35 mph.
2. In residential or business districts, on all through highways, and on other highways where there are significant traffic volumes.
3. On all undivided pavements of four or more lanes.
4. At other locations where an engineering study indicates a need for them.

FIGURE 7

TYPICAL TWO-LANE, TWO-WAY MARKING APPLICATIONS



UNDER WHAT SITUATIONS ARE PAVEMENT EDGE LINES USED?

Pavement edge lines should be used:

1. When it is desirable to mark the edge of pavement as a guide for drivers.
2. When a visual reference for the driver during adverse weather and visibility conditions is deemed necessary.
3. Where it is desirable to reduce driving on paved shoulders or refuge areas of lesser structural strength than adjacent pavements.

Edge lines should not be continued through intersections but should not be broken for driveways.

WHEN SHOULD STOP LINES BE USED?

Stop lines should be used when it is important to indicate the point behind which vehicles are required to stop in a stop controlled intersection or signalized intersection.

Stop lines are solid white and are normally 12 to 24 inches wide extending across all approach lanes. Stop lines should normally be placed at least four feet in advance of and parallel to the nearest crosswalk line.

In the absence of a crosswalk line, the Stop line should be placed at the desired stopping point but no more than 30 feet or less than four feet from the nearest edge of the intersecting roadway. If a Stop line is used along with a Stop sign, it is ordinarily placed in line with the Stop sign.

WHERE ARE CROSSWALK MARKINGS NECESSARY?

Crosswalks should be marked at all intersections where there is substantial conflict between vehicle and pedestrian movements. Marked crosswalks can also be provided at loading islands, school crossings, mid-block pedestrian crossings or where pedestrians may not otherwise recognize the proper place to cross. An engineering study, however, should be required before crosswalks are marked at locations away from traffic signals or stop signs.

WHAT COLOR AND WIDTH OF LINES ARE USED FOR CROSSWALKS?

Crosswalk lines shall be solid white lines, marking both edges of the crosswalk. The lines shall not be less than six inches in width and should not be spaced less than six feet apart. Under some circumstances, such as when a Stop line is not provided, vehicular speeds exceed 35 MPH, or where crosswalks are unexpected (e.g., a non-intersectional location), it may be desirable to increase the width of the crosswalk line up to 24 inches in width.

Lines on both sides of the crosswalk should extend across the full width of the pavement to discourage diagonal walking between crosswalks. (Figure 8a).

IF THE MOTORISTS FAIL TO YIELD TO PEDESTRIANS AT A CROSSWALK, CAN THE CROSSWALK'S VISIBILITY BE IMPROVED?

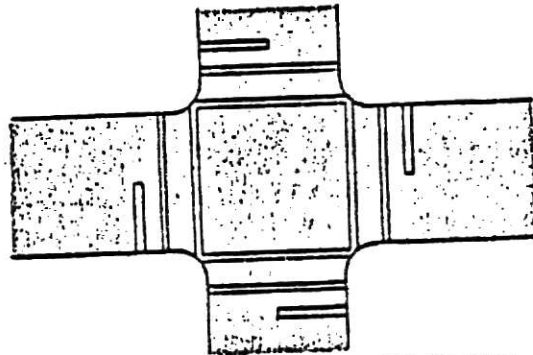
Motorists may be failing to yield to pedestrians at certain crosswalks because the crosswalk is not readily visible or it is unexpected.

This usually occurs when a crosswalk is located in the middle of a block or on a narrow street with parked cars and other physical obstructions blocking the motorist's view.

Several solutions are possible. As mentioned above, the width of the lines could be increased up to 24 inches and the area of the crosswalk marked with diagonal or longitudinal lines to make the walkway more visible (see Figure 8b and 8c). Parking can be prohibited on both sides of the crosswalk for some distance in both directions and warning signs installed to alert motorists to the upcoming crosswalk.

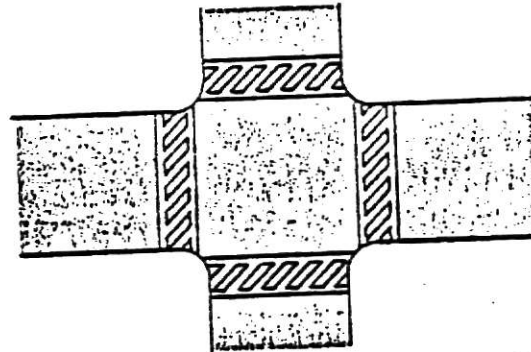
FIGURE 8
TYPICAL CROSSWALK MARKINGS

(a)



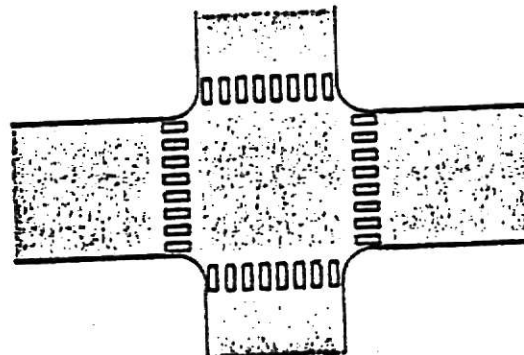
STANDARD CROSSWALK MARKING WITH OPTIONAL STOP LINES

(b)



CROSSWALK MARKING WITH DIAGONAL LINES FOR ADDED VISIBILITY

(c)



CROSSWALK MARKING WITH LONGITUDINAL LINES FOR ADDED VISIBILITY

CHAPTER 7

PARKING

Parking is one of the essential elements of any workable transportation system. Parking characteristics normally are influenced by the size of the city, the other modes of transportation available to commuters and the size and importance of the Central Business District.

This chapter provides basic information on how to determine parking needs, the dimensions of parking spaces and appropriate signs. As with all traffic management questions, one should take advantage of professional advice and utilize proper reference materials for assistance in developing the best possible system for a municipality.

HOW CAN THE NUMBER OF PARKING SPACES NEEDED IN VARIOUS PARTS OF THE CITY BE IDENTIFIED?

Parking space requirements vary by land use. They also vary by city. This variability means that no magic numbers exist to define the amount of parking required for a certain land use in a certain city. Table 5 defines ranges in the amount of parking that has been found adequate in sample locations. A true understanding of the parking needs in a city can only be realized through some basic evaluations. First, it must be realized that parking studies are basically an analysis of demand and supply. The demand results from the necessity to "store" vehicles while the vehicle's occupants complete their trips. This "demand" can vary with the time of day, week and month. The duration and or need to store vehicles, rate of turnover are also important parking demand factors.

The supply of "storage" is basically the amount of on-street and off-street parking that is available to meet demand. This supply can be increased by providing more area for parking use or by reducing the length of time a vehicle may be in a given space, thereby, increasing the use of area. Either of these decisions can have significant impact and must be well thought out.

Among the techniques to examine parking supply and demand characteristics are:

Supply:

1. Parking Inventories - a rather basic comprehensive cataloguing of all public and private parking spaces within a given location and the manner in which these spaces are managed.

Demand:

1. A Parking Usage Studies - an analysis of the number of times a parking space is used in a given time period as well as the average length of stay of a parked vehicle.
2. Parking Accumulation Studies - a determination of which days of the week and hours of the day parking areas are most used.
3. License Plate Checks - a reliable technique for determining parking duration and turnover. It is also used to obtain data on length of stay, illegal parking, and enforcement.
4. Parking Interviews - a method of determining trip origin, destination, purpose, and walking distance through interviews of motorists by mailed questionnaire or personal interview.

WHAT CAN BE DONE IF PARKING IS INADEQUATE?

If these studies indicate that curb parking is inadequate, then a municipality must turn to public or privately financed parking facilities.

Financing of private parking areas is usually through merchant efforts in the immediate vicinity. Public facilities can be financed by general obligation bonds, revenue bonds, or assessment districts. Public-private efforts can include tax incentives, technical advice, or use of city-owned land by the private operator. The parking requirements by land use are listed in Table 5.

Table 5 Parking Requirements by Land Use

Building Type	Range	Mode
<u>Commercial and Industrial</u>	(spaces per 100 sq ft)	
Office Buildings, Banks	0.08 - 1.33	0.25
Business and Professional Services	0.08 - 1.33	0.33
Commercial Recreational Facilities	0.16 - 2.00	1.00
Shopping Goods (Retail)	0.06 - 3.00	0.50
Convenience Goods (Retail)	0.10 - 1.33	0.50
Restaurants	0.06 - 2.00	1.00
Personal Services and Repairs	0.08 - 1.00	0.50
Manufacturing	0.08 - 1.00	0.20
Warehouses	0.02 - 0.67	0.10
Wholesale	0.03 - 1.33	0.15
<u>Residential</u>	(spaces per unit)	
Single Family Dwelling	0.50 - 3.00	1.00
Duplexes	0.50 - 2.00	1.00
Multiple Family Dwellings	0.50 - 2.00	1.00
Apartment Hotels, Rooming Houses	0.25 - 1.50	1.00
Hotels (spaces per bedroom)	0.16 - 2.00	1.00
Motels (spaces per bedroom)	0.25 - 1.25	1.00
<u>Public Buildings</u>	(spaces per 100 sq ft)	
Museums and Libraries	0.10 - 3.33	0.33
Public Utilities	0.10 - 1.00	0.33
Welfare Institutions	0.10 - 0.67	0.25
<u>Medical Buildings</u>	(spaces per 100 sq ft)	
Medical and Dental Offices	0.08 - 1.33	0.50
Hospitals	0.10 - 2.00	1.00
Convalescent Homes	0.08 - 1.00	0.50
<u>Auditoriums</u>	(spaces per seat)	
General Auditoriums and Theaters	0.06 - 0.33	0.25
Stadiums and Arenas	0.05 - 0.33	0.25
School Auditoriums	0.05 - 0.25	0.10
University Auditoriums	0.06 - 0.25	0.10

Source: Gallagher, J. A., "Driver Characteristics in Parallel Parking on One-Way Street," Traffic Engineering, Vol. 20, No. 7, April 1950, pp. 276-279.

HOW MUCH SPACE IS NEEDED FOR EACH PARKING STALL?

Parallel Parking

There are 3 ways to parallel park:

1. Uncontrolled location of vehicle along the curb
2. Designated positions for each vehicle
3. Designated lengths for each vehicle

Three kinds of stalls are used when allocating space for vehicles: end stalls, interior stalls, and paired parking stalls. Since a vehicle can be driven directly into and out of an end stall, only the length of the vehicle, about 18', needs to be accommodated. Interior stalls require room for a car to maneuver and, therefore, should be approximately 23' to 26' in length. The stalls can be delineated by painted lines or meters.

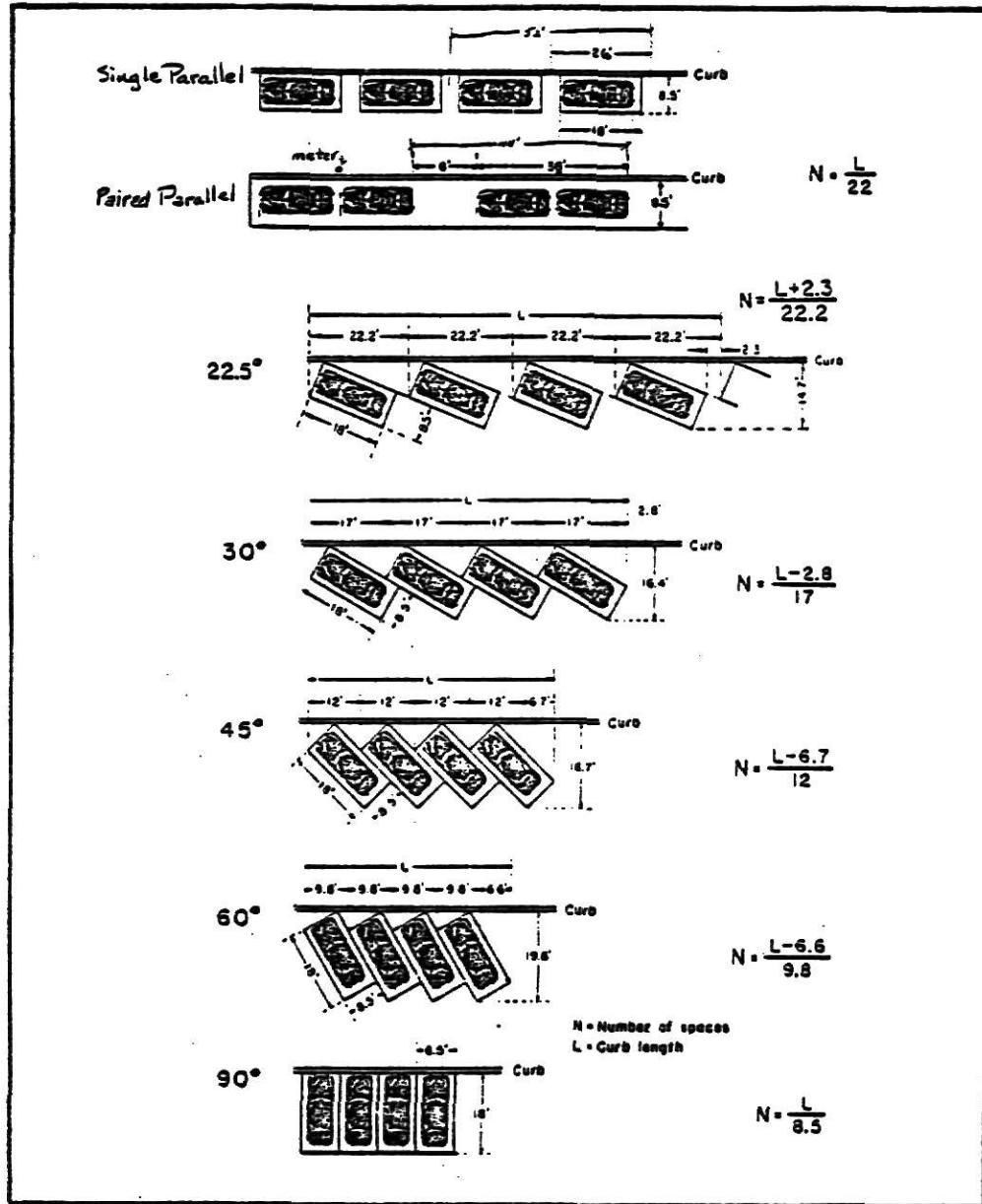
Paired parking stalls are laid out such that two vehicles are parked bumper to bumper with a pair of stalls separated by a maneuver area of approximately 8' - 10'. This method is best when a double parking meter is installed between each pair of vehicles so they do not encroach upon the maneuver area. (See Figure 9).

Angle Parking

Flat angle parking (angles less than 45 degrees) is more commonly used for on-street parking. Angles greater than 45 degrees are more often used in off-street parking lots with the maximum angle, 90 degrees, giving the greatest number of parking spaces per lineal foot of lot (nearly $2\frac{1}{2}$ times more spaces than parallel parking). But as the angle increases, the width of road or lot necessary for the stall length and the additional width for maneuvering into and out of the stall also increases.

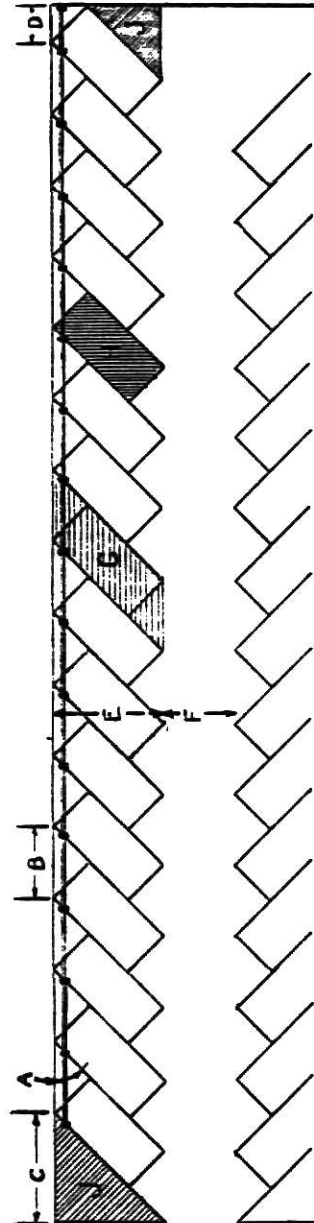
Marking of parking stalls can create additional maintenance costs. However, marking is usually justified where high turnover rates are experienced, when angle parking is used, where parking meters are used, or where absence of markings will create insufficient use of available space. Stall dimensions are usually 9' wide by 19' long; but for high turnover areas, such as shopping centers where shoppers carry large packages, 9' - 10' wide stalls may be more desirable. Attempts to get by with narrower aisles and stalls is not the answer to increasing a parking facility's capacity. Drivers will simply tend to encroach on more than one parking stall which will result in a loss of actual parking spaces. See Figure 9 and Table 6 for stall dimensions at varying degrees of angle parking.

FIGURE 9
CURB PARKING CONFIGURATIONS



Source: adapted from Garwood, F., "Fatal and Serious Accidents Involving Parked Vehicles," Road Research Laboratory, Crow-Thorne, England, September 1958, p. 8.

TABLE 6
PARKING LAYOUT - DIMENSIONS FOR VARYING DEGREES OF ANGLE PARKING



A Parking Angle	B Curb Length	C Starting Loss	D Lost Car Requirement	E Stall Depth	F Aisle Width Minimum	G Gross Car Area	H Net Car Area	J Area Lost Start & Finish of Row
30°	18.0'	29.9'	4.4'	17.3'	10.0'	310	171	205
35	15.6	26.1	5.1	18.2	12.0	286	171	235
40	14.1	22.8	5.8	19.0	12.0	239	171	263
45	12.8	19.8	6.4	19.8	13.0	252	171	286
50	11.8	17.0	6.9	20.4	13.0	239	171	263
55	10.9	14.4	7.4	20.7	15.0	227	171	235
60	10.4	12.1	7.8	21.0	16.0	217	171	205
65	9.9	9.8	8.1	21.1	18.0	209	171	177
70	9.5	7.6	8.4	21.0	20.0	199	171	138
75	9.2	5.4	8.6	20.5	21.0	194	171	103
80	9.1	3.3	8.8	20.2	22.0	184	171	67
85	9.0†	1.6	8.9	19.0†	23.0	177	171	38
90	9.0	0.0	9.0	19.0	24.0	171	171	0

PARKING AREAS

1. All Dimensions are based on parking stall size of 9' x 19'.
2. All Dimensions except "A" and "C" change as stall sizes are changed.
3. Choose the angle and type of parking that best suits your particular needs.
4. Do not skimp on stalls. Each year fewer and fewer cars will fit narrow stalls and more and more will require wider stalls.

WHAT ARE THE ADVANTAGES AND DISADVANTAGES OF ON-STREET PARKING?

There are two types of on-street or curb parking: parallel and angle parking. In parallel parking, the vehicle is parked parallel to the curb; in angle parking, the vehicle forms an angle with the curb ranging from 22.5 degrees minimum to 90 degrees maximum.

On-street parking can increase the number of traffic accidents by as much as 20% for the following reasons:

1. Parking, parked, stopped, and backing vehicles are obstacles for moving traffic.
2. Parking maneuvers often occur with inadequate warning to other traffic.
3. Parked vehicles reduce the sight distance of pedestrians and other traffic.
4. Former occupants of parked vehicles create unexpected mid-block conflicts while near their car.

Parallel parking results in approximately 50% fewer accidents than angle parking. It is preferred when streets are narrow and the volume of traffic is high. However, it takes almost three times as long to parallel park than to angle park (32 seconds versus 12 seconds).

Angle parking, on the other hand, provides more spaces than parallel parking for a given length of curb space. Its main advantage is the ease with which drivers can maneuver into and out of a parking space. The biggest disadvantage is the fact that a driver's vision is impaired when trying to exit a space. Also drivers traveling in through lanes usually keep about two feet more lateral clearance from angle parked vehicles than from parallel parked vehicles.

WHEN SHOULD ON-STREET PARKING BE ALLOWED?

If the need for parking accommodations is greater than the need for traffic movement, such as in residential or shopping areas, on-street parking may be considered. Angle parking should only be used on streets over 70' wide. On streets 34' wide or less, parallel parking may be allowed on one side only. Parking should be prohibited on two-way streets 28' wide or less.

If on-street parking results in a high incidence of accidents, the traffic volume may be too high. In this case, the on-street parking should be restricted during peak hours or moved to an off-street parking lot.

WHERE SHOULD PARKING ALWAYS BE PROHIBITED?

The Uniform Vehicle Code and Model Traffic Ordinance define three terms for use in parking prohibitions:

1. Parking - leaving an unattended vehicle at curbside with motor off.
2. Standing - stopping an attended vehicle at curbside for an extended period with motor running.
3. Stopping - stopping a vehicle momentarily at curbside to pick up or discharge a passenger or package.

Using the previous definitions, parking, standing, or stopping should be prohibited in the following locations:

1. On the street side of any vehicle parked along the edge of a road (commonly referred to as double parking).
2. On a sidewalk.
3. Within an intersection.
4. Within 30' of a Stop sign, Yield sign, or traffic control signal.
5. On or within 20' of a crosswalk.

6. Within 15' of a fire hydrant.
7. Within 20' of a fire station driveway.
8. Between a pedestrian safety zone and the adjacent curb.
9. Alongside or opposite any street excavation or obstruction when it would interfere with traffic.
10. On a bridge or in a tunnel.
11. On any railroad tracks or within 50' of the nearest rail of a railroad crossing.
12. On any controlled access highway.
13. Between roadways of a divided highway.
14. In front of public or private driveways.
15. At all other locations where official signs prohibit parking.

WHAT TYPES OF "NO PARKING" SIGNS CAN BE USED?

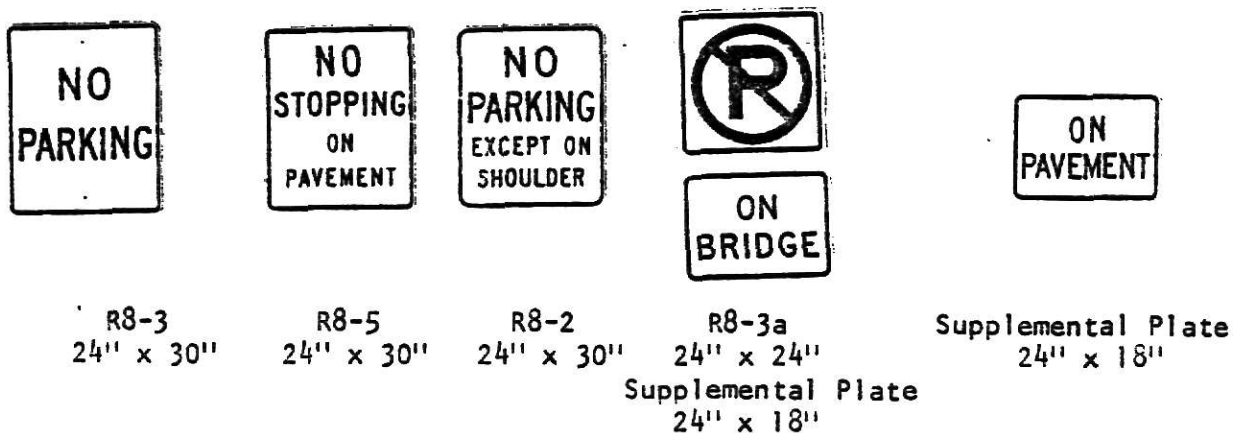
There are a wide variety of no parking situations and each must be analyzed separately as to how it should be treated. All no parking signs must conform to the MUTCD in shape, color, location, and use. The regulations that will be displayed on each sign should be listed from top to bottom in the following order:

1. Restriction or prohibition.
2. Time of day it is applicable, if not at all hours.
3. Days of week applicable, if not every day.

Parking prohibition signs are used where parking is prohibited at all times or at specified times. These signs shall have red letters and border printed on a white background. Parking restriction signs are used where limited time parking or parking in a particular manner is permitted. These signs shall have green letters and border printed on a white background.

In rural districts, special parking prohibition signs may be used to emphasize that no person shall stop, park, or leave standing any vehicle on the paved or traveled part of the highway. (See Figure 10).

FIGURE 10
NO PARKING SIGNS

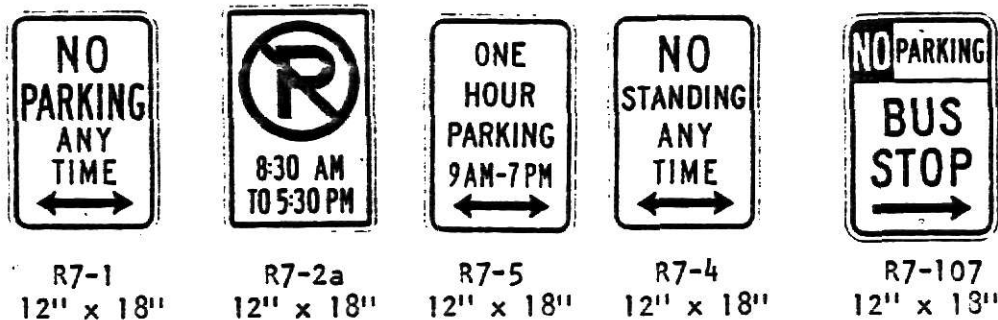


No parking signs in urban areas can be a minimum of 12" x 18". The standard size for rural no parking signs is 24" x 30", although on secondary roads 18" x 24" is permitted.

Parking signs with arrows are used to indicate the restricted zone. The signs should be set at an angle of not less than 30 nor more than 45 degrees with the line of traffic flow so that they are visible to approaching drivers. If the zone is unusually long (a block or longer), signs with a double arrow should be set at intermediate points within the zone. To minimize the number of parking signs, blanket prohibitions and/or restrictions which apply to an entire district, can be posted at municipal boundary lines. (See Figure 11).

FIGURE 11

Urban No - Parking Signs



WHAT TYPE OF PARKING IS NEEDED FOR SPECIAL PURPOSE VEHICLES OR AREAS?

Shopping Areas

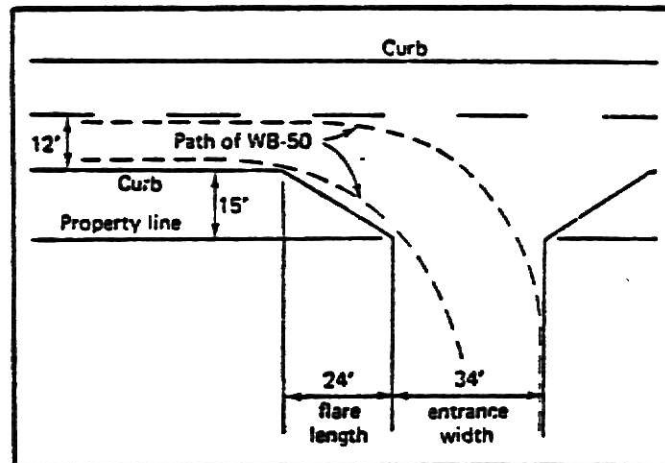
The distance from a parker's destination must be within reason. An average walking distance of 500' - 1000' is tolerated by most shoppers with longer distances acceptable to long-term parkers such as employees. It is recommended that 5.5 parking spaces be allotted per 1000 square feet of leasable floor space. The peak parking demand, which occurs just prior to Christmas, should be taken into consideration when estimating the number of stalls required. In shopping center parking lots, entrance and exit aisles should penetrate far into the parking area to prevent vehicle back-up onto the adjacent street.

Truck Loading Docks

Planning and design of a truck facility and access streets adjacent to the facility calls for slightly different standards than for ordinary automobile movement. Counterclockwise circulation is best for trucks so that the driver can use his left side mirror. The maneuvering length in front of docks should be approximately twice the length of the longest truck using the facility. Berths for trucks should be from 12' - 14' in

width and overhead clearance should be 15'. Dock height should be from 48" - 50". Profile grades approaching loading docks should not exceed 10%. Streets and intersections in the vicinity of truck loading areas should be designed for truck movements (normally using the WB-50 design vehicle) especially as related to corner radii, lane width, placement of street hardware, and design of pavement structure. (See Figure 12).

FIGURE 12
TRUCK REQUIREMENTS AT LOADING POINTS



Source: Berger, W. G. (Vol.1) and Knoblaugh, R. L. (Vol.2), "Urban Pedestrian Accident Countermeasures," Bio Technology, Inc., DOT Report Available NTIS-HS-801-346.

Bus Loading Zones

Intersections and adjacent streets should be designed for the BUS design vehicle using adequate turning radii and lane widths. If the volume of buses stopping at a given point is high, the length of bus bays or bus stops must be increased. Typical sizes range from 50' - 150'

in length depending on the size of the bus, the location of the stop, and the ease of access to the zone.

Taxi Zones

Taxi zones require about 20' for each stall plus an additional 5' on each end for a maneuvering area.

CHAPTER 8

FLASHING BEACONS

There are three general applications of flashing beacons: hazard identification, intersection control, and stop sign beacons. Their purpose is to command the attention of the motorist and they are always used as supplements to warning or regulatory signs or markers. They are standard sections of a traffic signal head, eight inches or 12 inches in diameter, and flash at a rate of 50-60 times per minute.

HOW AND WHERE ARE HAZARD IDENTIFICATION BEACONS USED?

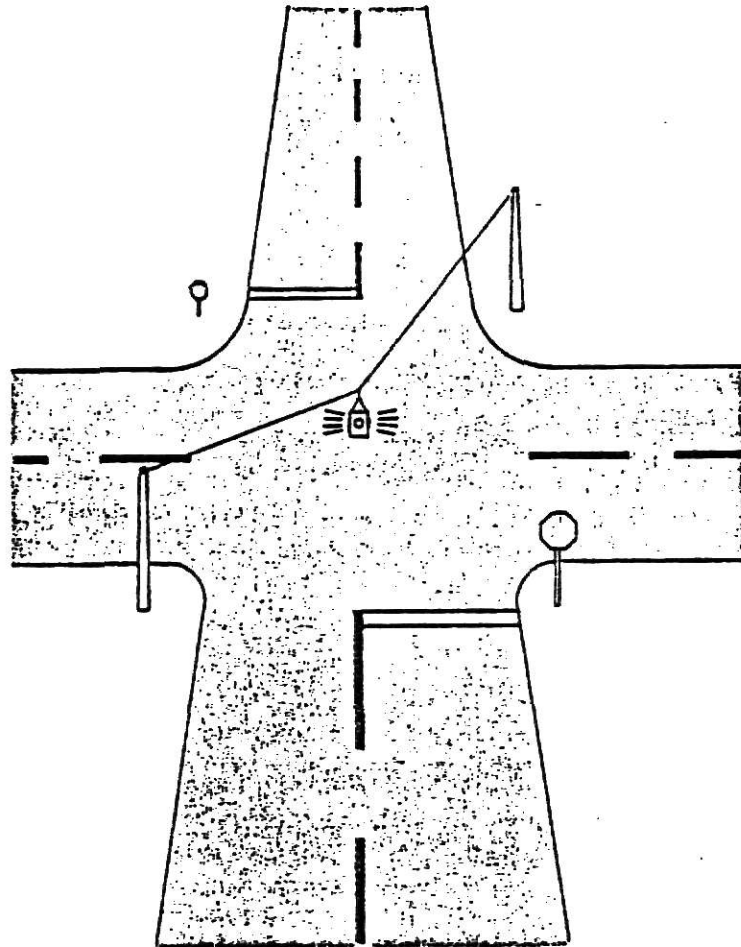
Hazard identification beacons have a yellow lens and are normally mounted above the primary warning sign or marker. Typical applications include:

1. Obstructions in or immediately adjacent to the roadway, such as a center pier in an undivided highway.
2. To supplement advance warning signs, such as the Cross-road Symbol or Stop Ahead signs.
3. At midblock crosswalks (with the Pedestrian Symbol sign).
4. As a supplement to regulatory signs, except Stop, Yield, and Do Not Enter signs.

HOW ARE INTERSECTION CONTROL BEACONS USED?

Intersection control beacons may either flash red in all directions, or yellow for the major route and red for the cross traffic. They should never flash yellow for two conflicting traffic streams at the same time. A stop sign should be used with a flashing red intersection control beacon. Intersection control beacons are normally suspended over the center of the intersection at a height between 15 and 19 feet (see Figure 13).

FIGURE 13
TYPICAL INTERSECTION CONTROL
BEACON INSTALLATION



WHEN SHOULD AN INTERSECTION CONTROL BEACON BE CONSIDERED?

Intersection control beacons are strong attention-getters and should be used sparingly so their effectiveness is not diluted. In urban areas where intersections are closely spaced and therefore expected by the motorist, there is seldom a need for such devices. Their most effective and predominant use is at isolated intersections where motorists may have driven for a considerable distance without encountering other controlled intersections, particularly where accident and enforcement records indicated inadvertent violations of Stop signs or failure to yield the right-of-way. They are more effective and appropriate at all-way stops than at two-way stops because, in the latter case, motorists facing the red indication and Stop sign may assume that cross traffic is also required to stop rather than simply to use caution as called for by the yellow indication.

ARE INTERSECTION CONTROL BEACONS APPROPRIATE AT INTERSECTIONS WHERE SIGHT DISTANCES ON THE APPROACHES ARE RESTRICTED?

Not necessarily. If the intersection itself is not visible, a flasher beacon located there is not likely to give the motorist substantial additional advance warning. Such circumstances are more logically treated by using hazard identification beacons in conjunction with the Stop Ahead and/or Crossroad Symbol signs posted in advance of the intersection.

HOW AND WHEN ARE STOP SIGN BEACONS USED?

As the term implies, the stop sign beacon is a section of a standard

traffic signal head with a flashing circular red indication and is used in conjunction with a Stop sign. They should be mounted between 12 and 24 inches above the top of the Stop sign.

Stop sign beacons should normally be reserved for locations where accident or enforcement records indicate an unusually high or persistent violation rate of the Stop sign. If violations appear to be unintentional, an alternate or supplemental solution of added emphasis on advance warning and higher visibility should be considered. This might be accomplished by using larger signs, by relocating or "doubling up" the advance warning signs on both sides of the roadway, or by the use of hazard identification beacons in conjunction with the advance signs.

DO FLASHING YELLOW (HAZARD IDENTIFICATION) BEACONS HELP CONTROL EXCESSIVE SPEEDS?

Installation of a yellow flashing beacon on a non-regulatory sign will not necessarily cause motorists to reduce their speed. It may be helpful, however, in alleviating the kinds of problems which the public normally (but not necessarily correctly) attributes to excessive speed, such as pedestrian accidents at midblock crosswalks or collisions involving vehicles entering the roadway from abutting developments.

The use of flashing warning lights, which are portable devices similar in operation to flashing beacons, is discussed in Chapter 16, Work Zone Protection.

CHAPTER 9

SIGNALS

This chapter contains information concerning warrants and data for the installation and operation of traffic signals. The main purpose of a traffic signal is to allocate right-of-way at an intersection by alternately directing traffic to stop and to proceed. A well designed and installed traffic signal installation will provide for orderly traffic movement, reduce certain types of accidents, and permit motorists to safely cross or enter the other traffic stream.

A complete discussion on the subject of traffic signals will not be presented in this handbook. Additional information is available in the Manual on Uniform Traffic Control Devices.

WHAT DISADVANTAGES DO SIGNAL INSTALLATIONS HAVE?

An improper or unwarranted signal installation can create excessive delay, encourage disobedience of the signal indications, encourage the use of less desirable routes in an attempt to avoid the signal, and has a tendency to increase rear-end type accidents.

WHAT WARRANTS MUST BE SATISFIED FOR A TRAFFIC SIGNAL INSTALLATION?

Traffic signals should not be installed unless one or more of the following warrants are met. However, the minimum vehicular and pedestrian volumes given in Warrants 1 through 3 can be reduced by 30% when the 85-percentile speed of major street traffic exceeds 40 miles per hour, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000.

Warrant 1 - Minimum Vehicular Volume

The Minimum Vehicular Volume Warrant is satisfied when, for each of any eight hours of an average day, the traffic volumes given in the table below exist on the major street and on the higher-volume, minor-street approach to the intersection. During those eight hours, the direction of the higher volume on the minor street may be on one approach during some hours and on the opposite approach during other hours.

MINIMUM VEHICULAR VOLUMES FOR WARRANT 1

<u>Number of lanes for moving traffic on each approach</u>		<u>Vehicles per hour on major street (total of both approaches)</u>	<u>Vehicles per hour on higher-volume minor-street approach (one direction only)</u>
<u>Major Street</u>	<u>Minor Street</u>		
1-----	1-----	500	150
2 or more	1-----	600	150
2 or more	2 or more	600	200
1-----	2 or more	500	200

Warrant 2 - Interruption of Continuous Traffic

The interruption of a Continuous Traffic Warrant is satisfied when, for each of any eight hours of an average day, the traffic volumes given in the table below exist on the major street and on the higher-volume minor-street approach to the intersection, and the signal installation will not seriously disrupt progressive traffic flow. The eight hours must be the same eight hours for both major and minor street traffic

MINIMUM VEHICULAR VOLUMES FOR WARRANT 2

<u>Number of lanes for moving traffic on each approach</u>		<u>Vehicles per hour on major street (total of both approaches)</u>	<u>Vehicles per hour on higher-volume minor-street approach (one direction only)</u>
<u>Major Street</u>	<u>Minor Street</u>		
1-----	1-----	750	75
2 or more	1-----	900	75
2 or more	2 or more	900	100
1-----	2 or more	750	100

Warrant 3 - Minimum Pedestrian Volume

The minimum Pedestrian Volume Warrant is satisfied when, for each of any eight hours of an average day, the following traffic volumes exist:

1. On the major street, 600 or more vehicles per hour enter the intersection (total of both approaches); or where there is a raised median island four feet or more in width, 1,000 or more vehicles per hour (total both approaches) enter the intersection on the major street; and
2. During the same eight hours as in paragraph (1) there are 150 or more pedestrians per hour on the highest volume crosswalk crossing the major street.

Warrant 4 - School Crossing

A traffic control signal may be warranted at an established school crossing when a traffic engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of school children at the school crossing shows that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period (see Chapter 4).

Warrant 5 - Progressive Movement

Progressive movement control sometimes necessitates traffic signal installations at intersections where they would not otherwise be warranted in order to maintain proper grouping of vehicles and effectively regulate group speed. The Progressive Movement Warrant is satisfied when:

1. On a one-way street or a street which has predominantly unidirectional traffic, the adjacent signals are so far apart that they do not provide the necessary degree of vehicle platooning and speed control, or

2. On a two-way street, adjacent signals do not provide the necessary degree of platooning and speed control and the proposed and adjacent signals could constitute a progressive signal system.

The installation of a signal according to this warrant should be based on the 85-percentile speed unless an engineering study indicates that another speed is more desirable.

The installation of a signal according to this warrant should not be considered where the resultant signal spacing would be less than 1,000 feet.

Warrant 6 - Accident Experience

The Accident Experience Warrant is satisfied when:

1. Adequate trial of less restrictive remedies with satisfactory observance and enforcement has failed to reduce the accident frequency, and
2. Five or more reported accidents, of types susceptible to correction by traffic signal control, have occurred within a 12-month period, each accident involving personal injury or property damage to an apparent extent of \$200 or more; and
3. There exists a volume of vehicular and pedestrian traffic not less than 80% of the requirements specified either in the Minimum Vehicular Volume Warrant, the Interruption of Continuous Traffic Warrant, or the Minimum Pedestrian Volume Warrant; and
4. The signal installation will not seriously disrupt progressive traffic flow.

Warrant 7 - Systems Warrant

A traffic signal installation at some intersections may be warranted to encourage concentration and organization of traffic flow networks.

The Systems Warrant is applicable when the common intersection of two or more major routes has a total existing, or immediately projected, entering volume of at least 800 vehicles during the peak hour

of a typical weekday, or each of any five hours of a Saturday and/or Sunday.

A major route, as used above has one or more of the following characteristics:

1. It serves through traffic flow;
2. It connects areas of principal traffic generation;
3. It includes rural or suburban highways outside of, entering or traversing a city;
4. It has surface street freeway or expressway ramp terminals;
5. It appears as a major route on an official street plan.

Warrant 8 - Combination of Warrants

In exceptional cases, signals occasionally may be justified where no single warrant is satisfied to the extent of 80% or more of the stated values.

WHAT DATA SHOULD BE COLLECTED WHEN STUDYING AN INTERSECTION?

1. Vehicular Volumes
 - a. 24-hour traffic count in one hour increments.
 - b. Peak hour counts in 15-minute increments
2. Pedestrian Volumes.
3. Approach Speed (85th Percentile Speed--See Chapter 3).
4. Safe Approach Speed (Sight Distance).
5. Collision Diagram Showing Accident Experience (Two Year Minimum).
6. Condition Diagram Showing Geometrics, Grades, Parking, Existing Traffic Control Devices, Land Use, and Sight Distance Restrictions.
7. Special Studies.
 - a. Vehicle delay time.
 - b. Gap study.

WHAT SIZE AND HOW MANY LENSES PER SIGNAL FACE ARE REQUIRED?

1. Signal lenses shall be circular and either 8 inch or 12 inch in diameter (see MUTCD, PART IV).
2. Each signal face, except pedestrian signals, shall have at least three lenses but not more than five.

HOW CAN I DETERMINE IF 8 INCH OR 12 INCH INDICATIONS ARE IMPORTANT?

Eight inch lenses are sometimes used. However, the MUTCD and KDOT states that 12 inch lenses should be used:

1. For intersections with 85th percentile speeds exceeding 45 miles per hour.
2. For intersections where signalization might be unexpected.
3. For special problem locations such as those having conflicting or competing background lighting.
4. For intersections where drivers may view both traffic control and lane--direction signs simultaneously.
5. For all arrow indications.

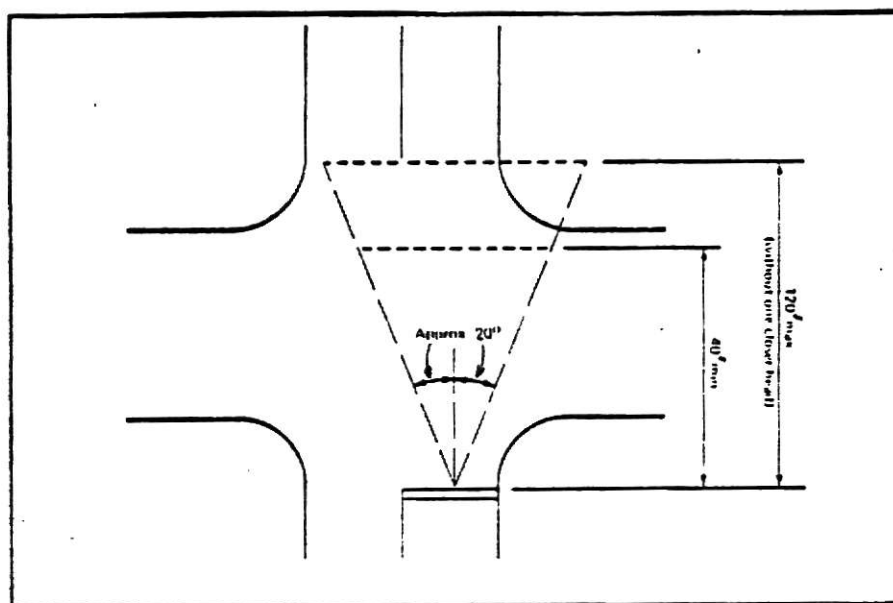
HOW IS THE NUMBER AND LOCATION OF SIGNAL FACES DETERMINED?

1. There shall be a minimum of two signal faces for through traffic.
2. At least one and preferably both signal faces shall be located not less than 40 feet nor more than 120 feet beyond the stop line. (See Figure 14).
3. If both faces are post-mounted then they shall be mounted on the far side of the intersection, unless physical conditions make it impracticable.
4. The two signal faces shall each be within a 40 degrees cone with the sides of the cone extending 20 degrees left and right of the center of the approach extended. (See Figure 14).
5. The mounting height of a post-mounted signal face shall not be less than 8 feet or more than 15 feet above the pavement or sidewalk.

6. The bottom of the signal face housing suspended over a roadway shall not be less than 15 feet nor more than 19 feet above the center of the roadway.

FIGURE 14

DESIRABLE LOCATION OF SIGNAL FACES



AN INTERSECTION WITHIN THE CITY MEETS WARRANTS AS ESTABLISHED IN THE MUTCD FOR SIGNALIZATION. SHOULD A PRETIMED OR TRAFFIC ACTUATED CONTROLLER BE USED TO OPERATE THE INTERSECTION?

This decision should be made using traffic volume data as well as field observations of the traffic patterns at the intersection. A traffic actuated signal should be considered under the following situations:

1. Low, fluctuating or unbalanced traffic volumes.
2. High side-street traffic volumes and vehicle delays during peak hours only.
3. Locations where only a single warrant is satisfied, such as at school crossings.
4. Non-intersection locations (mid-block pedestrian and fire station signals).

Pretimed controllers use a regularly repeated sequence with predetermined timing values based on average traffic volumes. Normally, the cost of pretimed equipment is significantly less than traffic actuated equipment. In addition, pretimed equipment is easier to maintain.

BASED UPON COST ESTIMATES FOR SIGNALIZING AN INTERSECTION, IT APPEARS THE COST WOULD EXCEED THE FUNDS AVAILABLE--CAN A LESS COSTLY INSTALLATION BE MADE?

Many jurisdictions have used what is commonly referred to as a span wire traffic signal installation. This consists of using wood utility service poles and stretching cable between the poles to support the signal heads and electrical cables. The cost of this installation is significantly less than a post or mast arm installation. The effectiveness of this type of signal can be equal to the permanent installation. Some additional maintenance is required such as tightening sagged cables and replacing wiring which is exposed to the elements. This method should definitely be considered if signalization is warranted and funds are not available for a mast arm installation.

WHAT SIGNAL CYCLE LENGTH SHOULD BE SELECTED?

The shortest practicable cycle lengths for pretimed systems are the most desirable. Cycle lengths longer than necessary to accommodate the existing traffic volume produce higher average delays.

The cycle length is the total time required for one complete sequence of signal indications. This time includes the sum of the green phases and yellow clearance intervals. For simple right angle

intersections with moderate traffic volumes, the cycle length will be in the range of 45 to 60 seconds. For a heavier volume intersection, the cycle length may run 60 to 90 seconds. Cycle gears for pretimed controllers are available in 5-second increments.

HOW IS THE SIGNAL PHASING DETERMINED?

The number of traffic phases used depends upon the volume and direction of traffic flow and the number of approaches to the intersection and the number and type of auxiliary lanes. It should be remembered that the number of phases controls the cycle length. When additional traffic phases are used, longer cycle lengths are required.

Types of Phasing

1. Two-Phase--normally used at four-way right angle intersections. Provides for most efficient operation if left turn and pedestrian volumes are not excessive.
2. Three Phase--used at intersections having a concentrated volume of left turns.
3. Exclusive Pedestrian Phase--used at intersections where there is a serious conflict between turning vehicles and heavy pedestrian volumes.
4. Split Phase--leading or lagging green, used where there is an unbalanced direction of traffic flow.

WHAT IS THE DESIRABLE LENGTH FOR THE YELLOW CLEARANCE INTERVAL?

The yellow clearance interval advises the motorist that the red interval is about to commence and the related green interval is about to end. It should be of sufficient length to permit the motorist to bring his vehicle to a safe stop or, if he has already entered the intersection, sufficient time to clear the point of conflict. The yellow interval is a function of approach speed. Excessively short or long

yellow intervals encourage driver disrespect. Normally the yellow interval is in the range of 3 to 5 seconds. When longer yellow intervals are required, it is usually better to use a yellow of 3 to 5 seconds and use an all-red clearance interval of 1 to 3 seconds before the start of green for the opposing traffic (see Table 7).

TABLE 7
SUGGESTED TIMING FOR VEHICLE
CLEARANCE INTERVAL
(Seconds)

Width of Intersecting Street (Feet)	Approach Speed in MPH				
	<u>25</u>	<u>30</u>	<u>35</u>	<u>40</u>	<u>50</u>
30	3.7	3.6	3.7	3.9	4.1
40	4.0	3.9	3.9	4.1	4.3
50	4.2	4.1	4.1	4.2	4.4

HOW MUCH TIME SHOULD BE ALLOCATED TO THE GREEN INTERVAL?

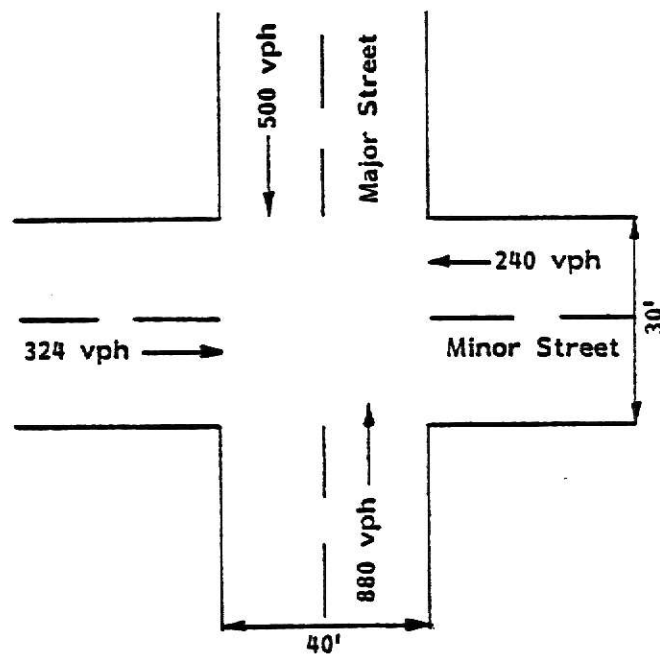
The green time must be proportionately divided between the various phases of the signal cycle to accommodate as many vehicles as possible without causing undue delay on any approach. The minimum green time is normally 12 seconds. In some locations shorter green times (7-8 seconds) have been used successfully.

Studies have shown that when a continuous line of vehicles is waiting for a signal to turn green, there is an initial starting delay for the first few vehicles in the line and then an equal delay for all additional vehicles. It is possible to calculate the necessary green time using the formula, "green time = (2.1)n + 3.7" where n is the

number of vehicles per cycle. This formula indicates an initial delay of 3.7 seconds and 2.1 seconds green time for each vehicle. Commercial vehicles and left turning vehicles will take more time and tend to increase this value.

Even after calculating approximate green and yellow intervals, it is best to field check actual operating conditions periodically and make field adjustments as indicated. The following is an example of a signal timing calculation.

SIGNAL TIMING CALCULATION



85th Percentile Speed -- Major Street 30 MPH
 85th Percentile Speed -- Minor Street 25 MPH

Step 1 -- Determine Yellow Clearance Interval (from Table 7)

The yellow clearance interval for major street is 3.6 seconds.
 The yellow clearance interval for minor street is 4.0 seconds.

Step 2 -- Calculate Minimum Cycle Length

Assume a 50-second cycle

$$\begin{aligned}\text{Cycles per hour} &= 3600 \text{ seconds} \div 50 \text{ seconds} \\ &= 72 \text{ cycles}\end{aligned}$$

Calculate the minimum green time per cycle

$$\begin{aligned}\text{Major Street} & \\ \text{Critical Volume} &= 830 \text{ vehicles/hour} \\ \text{Vehicles/cycle} &= 830 \div 72 = 12.2 \text{ vehicles} \\ \text{Minimum green} &= 2.1 (12.2) + 3.7 = 29.3 \text{ seconds}\end{aligned}$$

$$\begin{aligned}\text{Minor Street} & \\ \text{Critical Volume} &= 324 \text{ vehicles/hour} \\ \text{Vehicles/cycle} &= 324 \div 72 = 4.5 \text{ vehicles} \\ \text{Minimum green} &= 2.1 (4.5) + 3.7 = 13.2 \text{ seconds}\end{aligned}$$

$$\begin{aligned}\text{Minimum Cycle} & \\ \text{Length} &= 29.3 + 13.2 + 3.6 + 4.0 \\ &= 50.1 \text{ seconds}\end{aligned}$$

Step 3 -- Adjust Timing

The calculated minimum cycle length (50.1 seconds) was reasonably close to the assumed cycle length (50 seconds). The phasing should then be adjusted to utilize the entire cycle length, in this instance:

	<u>Green Phase</u>	<u>Yellow Clearance</u>
Major Street	29 Sec.	4 Sec.
Minor Street	13 Sec.	4 Sec.

Had the calculated cycle length been considerably longer or shorter than the assumed cycle length, Step 2 should be repeated using a more appropriate cycle length.

AT AN EXISTING TWO-PHASE SIGNALIZED INTERSECTION, A HIGH PERCENTAGE OF THE ACCIDENTS OCCURRING INVOLVE LEFT TURNING VEHICLES. WHAT SOLUTIONS ARE AVAILABLE?

1. One possibility would be to create a left-turn lane.

Removing these vehicles from the through traffic lane will improve traffic flow.

2. If a left-turn lane exists and the volume of left turning vehicles is high, a separate signal phase should be provided for this direction. A left-turn phase may be desirable when the number of left turning vehicles is 100 or more during the peak hour and is opposed by through vehicles.

REAR-END ACCIDENTS ARE OCCURRING ON AN APPROACH TO AN EXISTING SIGNALIZED INTERSECTION. WHAT CHANGES SHOULD BE CONSIDERED?

There are several possible problems which should be studied:

1. Poor Visibility of Signal Indications:
 - a. Increase size of signal indications.
 - b. Relocate signal faces.
 - c. Install "Signal Ahead" warning sign.
2. Short Clearance Interval:
 - a. Adjust yellow clearance--allowable range is 3 to 5 seconds.
 - b. If longer interval is required, an all-red interval should be considered (normally 1 to 3 seconds).

WHEN IS IT NECESSARY TO INSTALL PEDESTRIAN SIGNAL INDICATIONS?

1. When the traffic signal is installed under the pedestrian volume or school crossing warrant.
2. When pedestrian volume is so substantial an exclusive phase is provided for pedestrian movement during which all conflicting vehicular movements are stopped.
3. When the vehicular indications are not visible or are not positioned to serve pedestrians.
4. At established school crossings (see Chapter 4 - School Crossings).
5. When the volume of pedestrian activity requires use of a pedestrian clearance interval to minimize vehicle pedestrian conflicts.
6. When multi-phase vehicular indications would tend to confuse pedestrians.

WHERE SHOULD THE PEDESTRIAN INDICATIONS BE MOUNTED?

1. Pedestrian indications shall be mounted so that the bottom of the housing is not less than 7 feet nor more than 10 feet above the sidewalk.
2. The pedestrian indications should always be mounted in the line of the pedestrian's vision of the crosswalk being used.

IS THERE ANY REQUIREMENT REGARDING THE TIMING OF PEDESTRIAN SIGNALS?

1. The WALK interval should be at least 4 to 7 seconds. However, the WALK interval does not need to be displayed during the entire time needed to cross the street. Pedestrians can complete their crossing on the FLASHING DON'T WALK.
2. The FLASHING DON'T WALK interval should be long enough for a pedestrian to leave the curb and travel to the center of the farthest traveled lane. This is normally computed based on a walking speed of 4 feet per second (3 for elderly and children).

CAN A TRAFFIC SIGNAL BE USED TO STOP MOTORISTS AT A FIRE STATION ENTRANCE?

A traffic signal may be used when there is direct access to the street from a building housing an emergency vehicle. The use of this type of signal should be considered if adequate gaps in traffic do not exist to permit safe entrance of emergency vehicles or if the sight distance for vehicles approaching the emergency entrance is insufficient.

ARE THE DESIGN STANDARDS FOR AN EMERGENCY SIGNAL THE SAME AS AN INTERSECTION SIGNAL?

Yes, with the following additions:

1. At least one signal face should be located over the roadway.
2. A sign with the legend "Emergency Signal" should be mounted adjacent to each signal face.

WHEN CAN YOU MAKE A "RIGHT TURN ON RED" AT AN INTERSECTION?

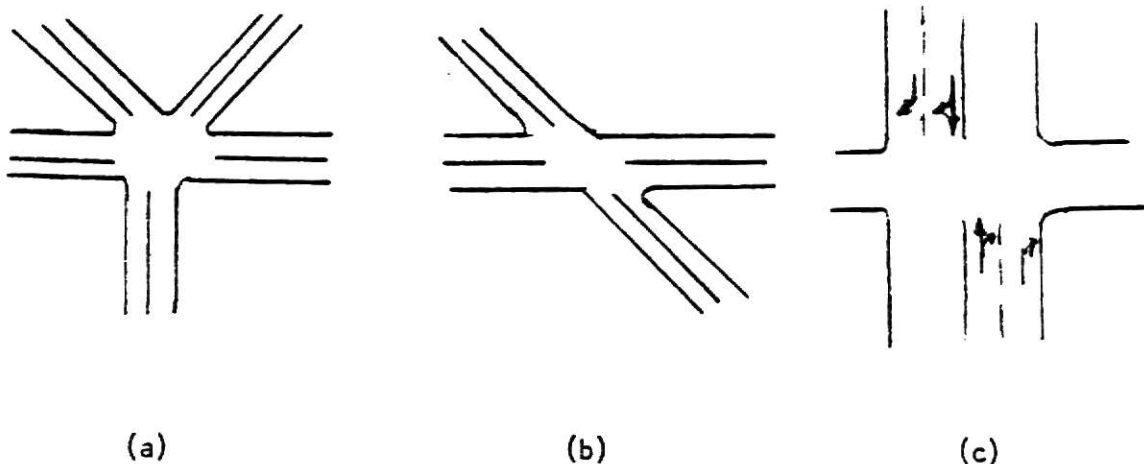
A motorist may make a right turn on red (RTOR) at all signalized intersections throughout the United States (except New York City) unless there is a sign restricting the movement. A RTOR reduces congestion at an intersection, conserves energy, and increases smooth traffic flow. At an actuated intersection where the signal is controlled by a vehicle detector, it has been argued that a motorist making a RTOR will unnecessarily cause cross-traffic to stop; however, actuated detectors are available whereby a vehicle must remain in place a brief period of time before tripping the signal.

To evaluate an intersection as to a potentially hazardous location for a RTOR, the following guidelines are recommended. A RTOR should be prohibited where:

1. An intersection has 5 or more approaches or a restrictive design such as a small turning radius or two right turn lanes (see Figure 15). On a multi-leg intersection, it is necessary to restrict only those approaches at which the driver is unaware which lane of traffic has the right-of-way.

FIGURE 15

INTERSECTIONS AT WHICH RTOR SHOULD BE PROHIBITED



2. The sight distance of vehicles approaching from the left is less than the following minimums:

<u>CROSS STREET SPEED LIMIT (MPH)</u>	<u>MINIMUM SIGHT DISTANCE (FEET)</u>
20	120
25	150
30	190
35	220
40	270
45	320
50	360
55	410

The distances should be measured from the edge of the cross-street pavement or curb line since motorists usually move up to the actual intersection line before making a RTOR. However, if there is heavy pedestrian traffic, the sight distance should be measured from behind the crosswalk line.

3. There is a separate pedestrian signal during which pedestrians can use all crosswalks.
4. The intersection is within 200' of a railroad grade crossing, fire station, ambulance center, or any other intersection where the signal indications from all directions are preempted to allow the train, fire truck, ambulance, etc., to pass safely through the intersection. The RTOR should be prohibited for those approaches that would permit the motorist without knowledge to expose himself to a conflict with the other vehicle.

A RTOR may be prohibited where:

1. Hazardous conflicts between pedestrians and motorists are resulting from RTOR's.
2. More than one RTOR accident per year occurs on any one approach.
3. An unusual movement such as double left turn lanes would not be anticipated by the RTOR driver.
4. School crossings or large numbers of children or elderly pedestrians would make an RTOR unsafe. In this case, the RTOR may be prohibited only during certain hours of the day.

CHAPTER 10

ROADWAY LIGHTING

Roadway lighting provides for the safe movement of traffic during darkness, reduces night accidents, and reduces night crime in urban areas. Proper lighting will provide the visibility necessary for the driver to make decisions concerning the safe operation of vehicles. Inadequate lighting may cause drivers to misjudge the speed or location of other vehicles or fail to observe pedestrians, traffic control devices, or roadway geometric changes.

The objectives of roadway lighting are:

1. To supplement vehicle headlights by extending the visibility range beyond their limits both laterally and longitudinally.
2. To improve the visibility of objects and features on or near the roadway.
3. To delineate the roadway.
4. To provide visibility of the environment.
5. To reduce the apprehension of those using the roadway.

In most municipalities, street lighting is installed either by the public or private utility company or by a private electrical contractor. When lighting is desired on a roadway maintained by the Kansas Department of Transportation (KDOT), the District Engineer should be contacted before proceeding with any work. The District Engineer will advise the local governmental agency as to the specific requirements for lighting installations on a state right-of-way.

WHAT ILLUMINATION LEVELS SHOULD BE USED IN STREET LIGHTING?

The function of the roadway should always be considered when determining lighting needs. The recommended values for roadway illumination levels have been developed by the Illuminating Engineering Society (IES).

The IES recommends average-to-minimum uniformity ratios of 3:1 for all roadways except local residential streets, which should have a ratio not exceeding 6:1. The uniformity ratio on the pavement area is the ratio of the average footcandles of illumination to the foot candles at the point of least illumination.

Average footcandles of illumination can be calculated using the following formula:

$$\text{Avg fc} = \frac{\text{Lamp Lms} \times \text{Util Coef} \times \text{Maint Factor}}{\text{Spacing} \times \text{Width of road}}$$

Where: Avg fc = Average foot candles (lumens/sq. ft.)
 Lamp Lms = Initial lamp lumens
 Util Coef = Coefficient of Utilization
 Maint Factor = Luminaire and Lamp Maintenance Factor

The luminaire maintenance factor takes into account the loss of lamp output prior to replacement and the loss of light due to dirt accumulation. Typical values for maintenance factors would be:

0.87-0.95 Cleaning every year

0.67-0.86 Cleaning every three years

HOW ARE LIGHTING INSTALLATIONS DESIGNED?

To determine if a lighting installation will be appropriate, the uniformity ratio of illumination and the average illumination provided must be calculated using utilization and isofootcandle curves. The utilization curve indicates how much light falls on the roadway (see Figure 16). The isofootcandle curve shows the illumination on a roadway surface from one or more luminaires. Points of equal illumination are connected by a continuous line (see Figure 17).

In order for these curves to be applicable to all conditions, they are computed for a given mounting height and plotted versus ratios of the actual horizontal distances (both lateral and longitudinal) to the mounting height. Correction factors for other mounting heights are given with the isofootcandle curve.

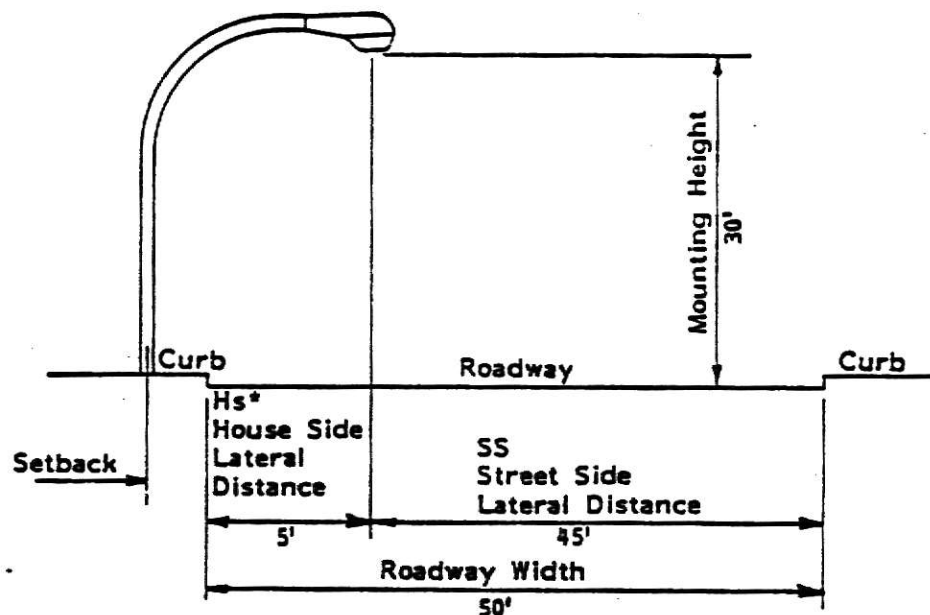
WHAT IS A TYPICAL SET OF CALCULATIONS TO DETERMINE A LIGHTING INSTALLATION?

Data

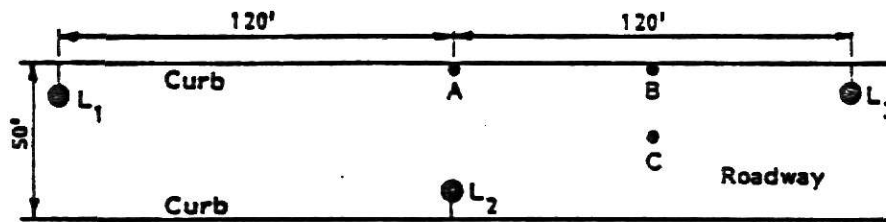
A major route in a residential area is to be lighted using a staggered luminaire spacing of 120 feet (see illustration below).

Roadway Width	50 Feet
Luminaire Mounting Height	30 Feet
Luminaire Overhang	5 Feet
Luminaire Maintenance Factor	0.80
Mercury Vapor Lamp, 400 Watt,	21,500 lumens

Average lumens - 15,800 @ 12,000 hours



* Sometimes called "overhang".



L = Luminaire Number

Calculation Required

1. Average Illumination per square foot (footcandles) for the road pavement.
2. Uniformity Ratio -- Compare the average illumination to the lowest footcandle value at any point (should not be more than 3:1).

Step 1 - Determine Average Illumination

1. Estimate coefficient of utilization for the "street side" of the luminaire:

$$\text{Ratio (Lateral distance/mounting height)} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.5$$

From Figure 16 - coefficient of utilization = 0.48 (for a ratio of 1.5).

2. Estimate coefficient of utilization for the "house side" of the luminaire:

$$\text{Ratio (Lateral distance/mounting height)} = \frac{5'}{30'} = 0.16$$

From Figure 16 - coefficient of utilization = 0.02 (for a ratio of .16).

3. Obtain total coefficient of utilization

$$\begin{aligned} \text{Street Side} &= 0.48 \\ \text{House Side} &= 0.02 \\ \text{Util. Coeff.} &= 0.50 \end{aligned}$$

4. Calculate the average illumination on the roadway by the formula:

$$\text{Average Footcandles} = \frac{\text{Lamp lumens} \times \text{Util Coeff} \times \text{Maint Factor}}{\text{Spacing} \times \text{Width of Road}}$$

$$\frac{15,800 \times 0.50 \times 0.80}{120 \times 50} = 1.05 \text{ footcandles}$$

The average illumination at 120' would be 1.05 footcandles which is almost equal to the amount specified for this type of street in the IES Recommendations (1.0 fc).

Step 2 - Determine Uniformity Ratio

$$\text{Uniformity Ratio} = \frac{\text{Average Intensity}}{\text{Minimum Intensity}}$$

1. Using the previous data, determine the estimated footcandles of illumination contributed by each luminaire at the location along the pavement having the lowest level of illumination (i.e., Point A).

Luminaire 1

$$\text{Ratio (lateral distance/mounting height)} = \frac{5'}{30'} = .16$$

(house side)

$$\text{Ratio (longitudinal distance/mounting height)} = \frac{120'}{30'} = 4.0$$

$$\text{Estimated footcandle value (Figure 17)} = .025$$

Luminaire 2

$$\text{Ratio (lateral distance/mounting height)} = \frac{45'}{30'} = 1.5$$

(street side)

$$\text{Ratio (longitudinal distance/mounting height)} = \frac{0}{30'} = 0$$

$$\text{Estimated footcandle value (Figure 17)} = .80$$

Luminaire 3

$$\text{Ratio (lateral distance/mounting height)} = \frac{5'}{30'} = .16$$

(house side)

$$\text{Ratio (longitudinal distance/mounting height)} = \frac{120'}{30'} = 4.0$$

$$\text{Estimated footcandle value} = .025$$

2. Calculate total illumination value (Point A)

Luminaire 1	0.025 footcandles
Luminaire 2	0.800 footcandles
Luminaire 3	<u>0.025</u> footcandles

$$\text{Total illumination} = 0.85 \text{ footcandles}$$

3. Adjust illumination value for lamp intensity and luminaire maintenance factors.

Lamp Intensity Factor (LI)

Maximum Intensity (per Figure 17) - 21,500 lumens

Average Intensity (from data) - 15,800 lumens

$$\text{Lamp Intensity Factor} = \frac{15,800}{21,500} = 0.73$$

Luminaire Maintenance Factor (LM) = 0.80 (from data)

Adjusted Illumination Value

$$\begin{aligned} \text{Initial Value} \times \text{LI} \times \text{LM} &= 0.85 \times 0.73 \times 0.80 \\ &= 0.50 \text{ footcandles} \end{aligned}$$

4. Calculate Uniformity Ratio

$$\begin{aligned} \text{Uniformity Ratio} &= \frac{\text{Average Intensity}}{\text{Minimum Intensity}} \end{aligned}$$

$$= \frac{1.05}{0.50}$$

$$= 2.1 \text{ to } 1$$

This ratio of 2.1:1 is less than 3:1. Therefore, the illumination at Point A is in accordance with acceptable limits. A similar calculation should be performed at other locations along the roadway (i.e., Points B and C) to ensure that the illumination at all points meets the acceptable limits.

FIGURE 16
UTILIZATION CURVE

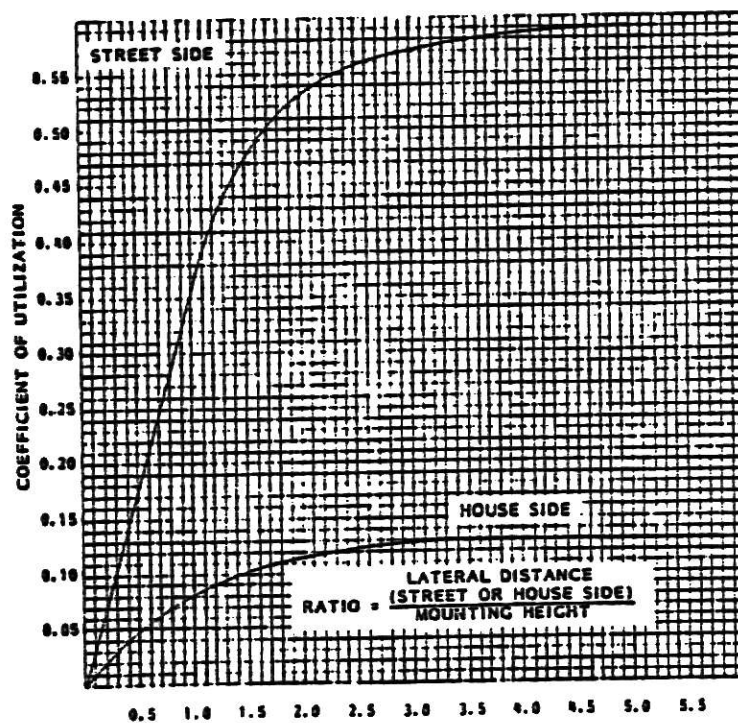
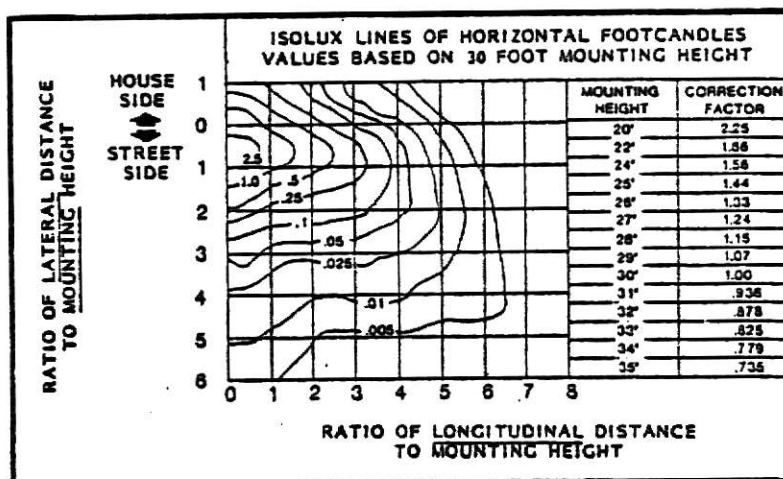


FIGURE 17
ISOFOOTCANDLE CURVE
(21,500 Lumen Lamp)



WHAT IS THE DIFFERENCE BETWEEN PARTIAL VS. CONTINUOUS LIGHTING?

Partial lighting refers to illumination at designated sections of the roadway such as at intersections, isolated curves, or rail-highway crossings where increased visibility is necessary for safe vehicle operation. Continuous lighting refers to uninterrupted illumination along the roadway. Continuous lighting is more expensive to install, operate, and maintain. However, a series of partial lighting systems along the roadway requires continuous eye adaptation by the driver. This increases driver stress and enhances the probability of an accident. By gradually increasing the light intensity to its maximum level and gradually phasing it back to darkness, the eye adaptation problem can be reduced.

WHAT IS THE MOST EFFECTIVE LIGHT SOURCE?

The selection of the most effective light source should increase the probability of maximum safety. Existing light sources have unique advantages and disadvantages that should be considered in the selection of lighting equipment.

1. Incandescent - low initial cost, good color, "instant-on" characteristics, and no need for ballast; but low luminous efficacy and short life.
2. Tungsten-Halogen - good color, no need for ballast, and "instant-on" characteristics; but high lamp cost; poor optical control, low luminous efficacy, and short life.
3. Fluorescent - good color, high luminous efficacy, and long life; but large size, poor optical control, and susceptibility to cold temperatures.
4. Mercury - good luminous efficacy, fair to good color, small in size, and long dependable life; but relatively low luminous efficacy.

5. Metal Halide - better color at higher efficacies than mercury lamps and good for high-mast lighting; but short life and sensitive to lamp orientation.
6. High Pressure Sodium - excellent luminous efficacy, good lumen maintenance, long life, and very acceptable color; but higher lamp cost and more expensive ballast.
7. Low Pressure Sodium - exceptionally high luminous efficacy; but monochromatic color and large size.

WHERE SHOULD STREET LIGHTING BE INSTALLED?

Accident experience is the primary factor in determining street lighting locations:

1. On freeways, a nighttime and daytime accident rate ratio of two or greater indicates lighting is needed.
2. Rural intersections should be considered for lighting if the average number of nighttime accidents per year exceeds one-third the average number of daytime accidents per year.
3. Major arterials in urban areas or sections of streets or highways in residential areas may need lighting where four or more night accidents have occurred in one year or six night accidents in two years (provided the cause of the accidents was attributed to improper lighting) or where the ratio of nighttime to daytime accident rates is higher than the statewide average for similar locations.
4. All channelized intersections should be illuminated.
5. Crosswalks should be illuminated if a study of four consecutive years indicates a minimum of three pedestrian accidents in this crosswalk were attributed to poor visibility of the pedestrian.

WHAT TYPE OF LUMINAIRE SPACING SHOULD BE USED?

The safest luminaire support location is one that is protected from traffic such as upon or behind an existing barrier or retaining wall. If the support is not protected, the probability of a vehicle-object collision is greater as the number of supports increases or the distance from

the roadway edge decreases. If a support must be installed less than 30' from the roadway edge, breakaway devices should be considered. However, breakaway supports should not be used when the hazard of a falling support is greater than a vehicle-object collision (such as in pedestrian areas).

Luminaire spacing is based upon the average intensity of illumination required. It can be calculated by the following formula:

$$\text{Spacing} = \frac{\text{Lamp Lms} \times \text{Util Coef} \times \text{Maint Factor}}{\text{Avg Fc} \times \text{Width of Road}}$$

Where: Lamp Lms = Initial lamp lumens

Util Coef = Coefficient of utilization

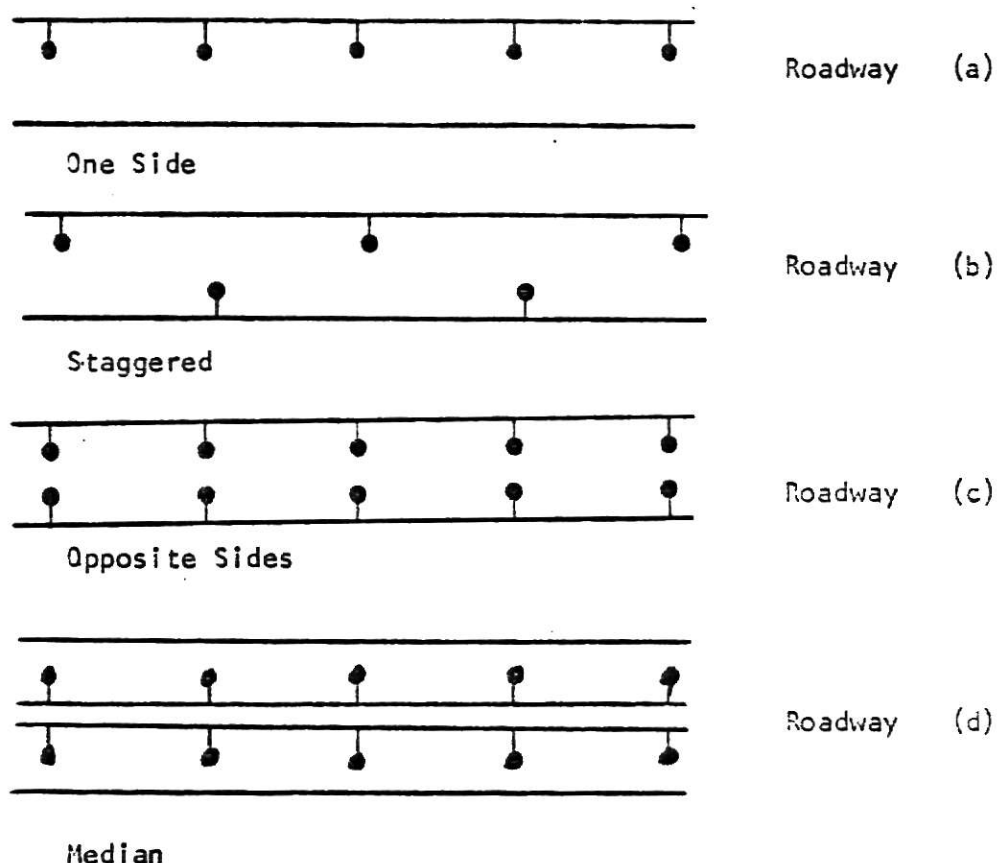
Maint Factor = Luminaire and lamp maintenance factor

(Typical values: 0.87-0.95 for cleaning every year or 0.67-0.86 for cleaning every three years)

Avg Fc = Average footcandles (lumens/sq. foot)

Table 8 shows the recommended luminaire spacing for typical roadways. It is based upon the more commonly used luminaire wattages. Figure 18 shows typical luminaire mounting arrangements. Staggered spacing is the preferred arrangement as there are less supports adjacent to the edge of roadway which could result in a vehicle-object collision. Opposite spacing would be appropriate where the width of street exceeds twice the mounting height. Median spacing is more commonly used on freeways or divided highways in urban areas. One side spacing should only be used on narrow roadways.

FIGURE 18
TYPICAL LUMINAIRE MOUNTING ARRANGEMENTS



WHAT MOUNTING HEIGHT SHOULD BE USED?

The mounting height is determined by lamp output, desired average illumination, and uniformity of distribution. Light sources of 20,000 lumens or less should be mounted at heights of approximately 30' and light sources of from 20,000 to 45,000 lumens should be mounted at heights from 30' to 40', respectively. Uniformity of lighting is more important than intensity.

WHAT TYPES OF LUMINAIRE SUPPORTS SHOULD BE USED?

There are five types of poles used for luminaire supports:

1. Steel - galvanized steel poles are inexpensive and have a long life; painted steel poles require extensive maintenance; weathering steel poles when rained on have a rusty runoff that can present aesthetic problems. Many breakaway devices have been developed for steel poles.
2. Aluminum - Aluminum poles are relatively maintenance-free, lighter than steel poles, but higher in cost. Because of their light structure, they break away easily under impact.
3. Stainless steel - Stainless steel poles are relatively maintenance-free, lightweight, but more expensive than the previous two types. Breakaway devices have been developed for stainless steel poles.
4. Wood - Wood is the most economical lighting pole, can be treated to prevent rotting, and may be painted to improve its appearance. One wood pole can be used for several utility functions such as supporting telephone and power lines. However, wood poles have poor breakaway characteristics.
5. Concrete - Concrete poles are economical in certain geographic locations, but they cannot be made breakaway.

WHAT IS A TYPICAL LAYOUT FOR INTERSECTION LIGHTING?

See Figure 19.

WHAT PROBLEMS ARE CAUSED BY GLARE?

Glare reduces visibility and causes eye discomfort. Glare can be diminished by reducing luminaire brightness, by increasing mounting height and by increasing the effective luminaire area.

TABLE 8
RECOMMENDED LUMINAIRE SPACING FOR TYPICAL ROADWAYS

<u>Area Class</u>	<u>Traffic Class</u>	<u>Average fc</u>	<u>Unif. Ratio</u>	<u>Road Width</u>	<u>Mounting Height</u>
Residential	Local	0.4	6:1	30	30
				40	30
				30	30
				40	30
	Collector	0.6	3:1	30	30
				40	30
				30	30
				40	30
	Major	1.0	3:1	40	30
				60	30
Intermediate	Local		(USE RESIDENTIAL COLLECTOR)		
	Collector	0.9	3:1	30	30
				40	30
	Major	1.4	3:1	40	30
				60	40
Commercial	Local		(USE RESIDENTIAL COLLECTOR)		
	Collector	1.2	3:1	40	30
	Major	2.0	3:1	40	30

WHAT TYPE OF ROUTINE MAINTENANCE IS REQUIRED FOR LIGHTING INSTALLATIONS?

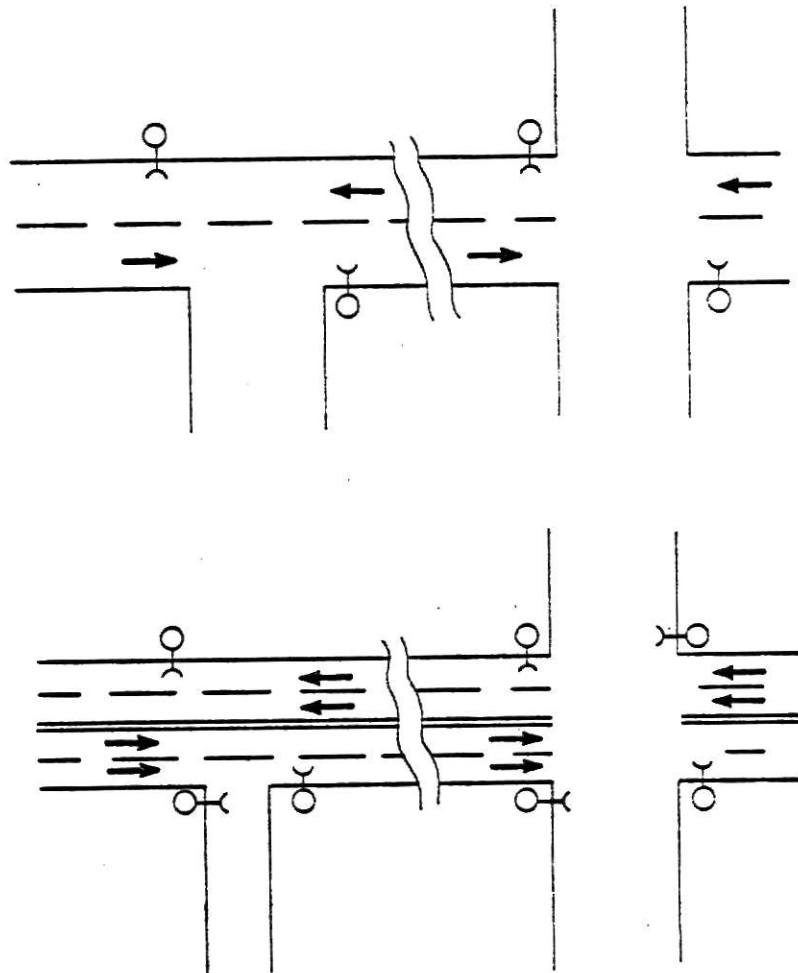
Proper maintenance of the system insures continued levels of illumination at the original design value. It also minimizes repair cost and protects the capital investment.

The responsible department or agency should establish a cleaning and washing schedule. Based upon the surrounding conditions, glassware should be washed at least one or two time per year. It is also necessary to set up an inspection system to insure replacement of burnout lamps. Filtered optical assembly should be used to reduce maintenance.

AN EXISTING INTERSECTION HAS EXPERIENCED SEVERAL NIGHTTIME ACCIDENTS.
IS LIGHTING WARRANTED?

Lighting should be considered when four or more night accidents
susceptible to correction by safety lighting have occurred in one year
or six night accidents have occurred in two years.

FIGURE 19
TYPICAL LIGHTING PLAN FOR INTERSECTIONS
30 FOOT MOUNTING HEIGHT



WHAT TYPES OF ACCIDENTS MAY BE CORRECTIBLE BY STREET LIGHTING?

Street lighting will assist in preventing nighttime accidents
involving:

1. Obstacles located within the roadway (islands, medians, bridge piers).
2. Single vehicle accidents at locations where the geometrics of the road (or intersection) may contribute to the cause of the accident ("T" intersection, curve, with poor horizontal alignment).
3. Right angle collisions.

CHAPTER 11

RAILROAD CROSSINGS

There are approximately 219,000 public rail-highway grade crossings in the United States and a substantial number of these crossings are estimated to be lacking some type of special warning device. Each year, a number of crossings are improved with signals, gates and other more sophisticated warning devices. A large number of crossings, however, primarily located in rural areas, remain marked only by cross-buck and advance warning signs and where possible, pavement markings.

Unsignalized crossings in rural areas are among those crossings which can be particularly dangerous, although it is a fact that most rail-highway accidents occur at "protected" busier urban locations where vehicular traffic is much higher. Train-car collisions may not be the most frequent type of accident, but when these accidents do occur, they often result in fatalities. This chapter will assist you in determining when to take steps to upgrade a railroad crossing and how to decide upon the best protective measures. In addition, because crossing improvements are costly, there are directions on how to apply for assistance in financing protective devices for local crossings.

WHAT FACTORS DETERMINE WHETHER A RAILROAD CROSSING IS SAFE?

Various formulas have been developed for use by traffic engineers in evaluating railroad crossings. An obvious indicator, however, is the accident history at a crossing. Most formulas look at three variables if a crossing is suspected to be hazardous.

1. Are the warning devices now at the crossing appropriate and sufficient to warn motorists of approaching trains.

2. What is the probability of a conflict between vehicles and trains at a crossing, i.e. how often do trains frequent a crossing; how long do they occupy the right-of-way; and is the traffic volume at the crossing particularly heavy?
3. Do motorists have sufficient sight distance in approaching the crossing to avoid collisions?

A study of typical railroad-highway grade crossings identified these 10 conditions as major contributors to unsafe crossings:

1. Pavement markings were missing, improperly located, or in need of maintenance.
2. Vehicles required by law to stop at all crossings presented a hazard to other vehicles by blocking traffic lanes and obstructing the protective signs and signals.
3. The driver's visibility of a railroad approach was obstructed by vegetation growth.
4. There was a lack of illumination at night.
5. The driver's attention was distracted by traffic conditions and other traffic controls on adjacent roads.
6. Advance warning signs were missing, improperly located or in need of maintenance.
7. No appropriate areas were available for the driver to take evasive action.
8. The driver's view of the crossing signs or signals was obstructed by highway signs and fixed objects.
9. Fixed-mount protective devices (the crossing gate) were themselves a hazard to vehicles.
10. Legally parked vehicles blocked the motorist's view of the warning devices.

WHAT SIGNS AND MARKINGS SHOULD BE USED TO WARN MOTORISTS OF A RAILROAD CROSSING?

Signs and markings are passive traffic control devices and serve to alert the motorist of the existence of a railroad crossing and to take appropriate action.

Railroad Crossing Markings are placed in advance of a railroad crossing and they consist of an "X," the letters "RR," a "No Passing" marking and certain transverse lines. They should be placed on all paved approaches to grade crossings where signals or gates are located, at crossings where the prevailing speed of traffic is 40 miles per hour or greater and at crossings where engineering studies indicate a significant potential for train-vehicle accidents (see Figure 20).

The signs to be used at a railroad crossing consist of the Railroad Advance Warning sign (W10-1), the Railroad Crossing sign (R15-1,2), more commonly known as the "crossbuck", and if there are two or more tracks, the number of tracks is to be indicated on an auxiliary sign mounted below the crossbuck.

WHAT CONTROL DEVICES AND SIGNALS ARE AVAILABLE FOR USE AT A RAILROAD CROSSING?

Because there are so many variables involved in evaluating a railroad crossing, there is no single standard system of active traffic control devices universally applicable for grade crossings. An engineering and traffic investigation must be made to determine which signals and devices are appropriate for each site.

Among the active devices available for use at crossings are the automatic flashing light signals which are either post-mounted or cantilever supported, or automatic flashing light signals with gates which are automatically activated by an approaching train. Highway traffic signals are sometimes located at or near grade crossings. When a railroad grade crossing has automatic protective devices present and is located within 200 feet of the near side of a signalized highway intersection, the control of the intersection traffic signal should be preempted

by the railroad crossing signal controller upon the approach of a train to avoid entrapping vehicles in the crossing.

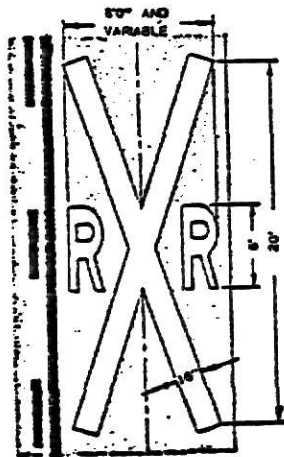
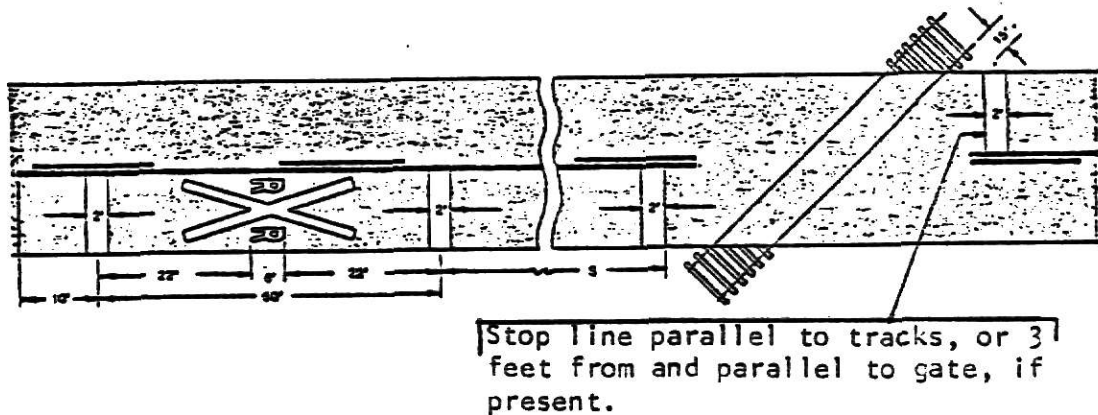
HOW MUCH DISTANCE DOES A MOTORIST NEED TO SIGHT AN APPROACHING TRAIN IN ORDER TO EITHER CLEAR THE TRACKS OR TO STOP SAFELY?

As a driver approaches a railroad crossing he has to decide whether or not it is safe to cross. In the absence of signals or gates, he must be able to observe any approaching train and make a judgement involving his own speed, that of the approaching train, and their respective distances from the crossing. At a minimum, he must be able to observe the approaching train while he is still far enough from the crossing to bring his vehicle to a safe stop, if necessary.

Figure 21 illustrates the distance (Y) required to react to the situation, apply the brakes, and decelerate to a stop at a safe distance in advance of the crossing. This distance, of course, varies with the speed of the vehicle, the driver's reaction time, and the braking characteristics of the vehicle which may in turn be affected by the roadway surface. The accompanying table (see Table 9) is based on some reasonably conservative assumptions with regard to the vehicle, driver and roadway, and establishes distance (Y) for various driving speeds. Distance (X) in the table is the distance the train will travel at various speeds during the same time that the driver is reacting and stopping. By comparing distances (X) and (Y) for any given combination of vehicle and train speeds, one can define the "line of sight" that must be clear of obstacles for safe operations at the crossing. It is particularly important that warning signs, markings and crossbucks be well placed and maintained in cases where sight distances are limited.

FIGURE 20

TYPICAL PAVEMENT MARKINGS AT RAILROAD-HIGHWAY GRADE CROSSING



The distance from the railroad crossing marking to the nearest track will vary according to the approach speed and the sight distance of the vehicular traffic approaching but probably should be not less than 50 feet.

A three-lane roadway should be marked with a centerline for two-lane approach operation on the approach to a crossing.

On multi-lane roads the transverse bands should extend across all approach lanes, and individual RXR symbols should be used in each approach lane.

FIGURE 21

SIGHT DISTANCE TRIANGLE FOR RAILROAD CROSSINGS

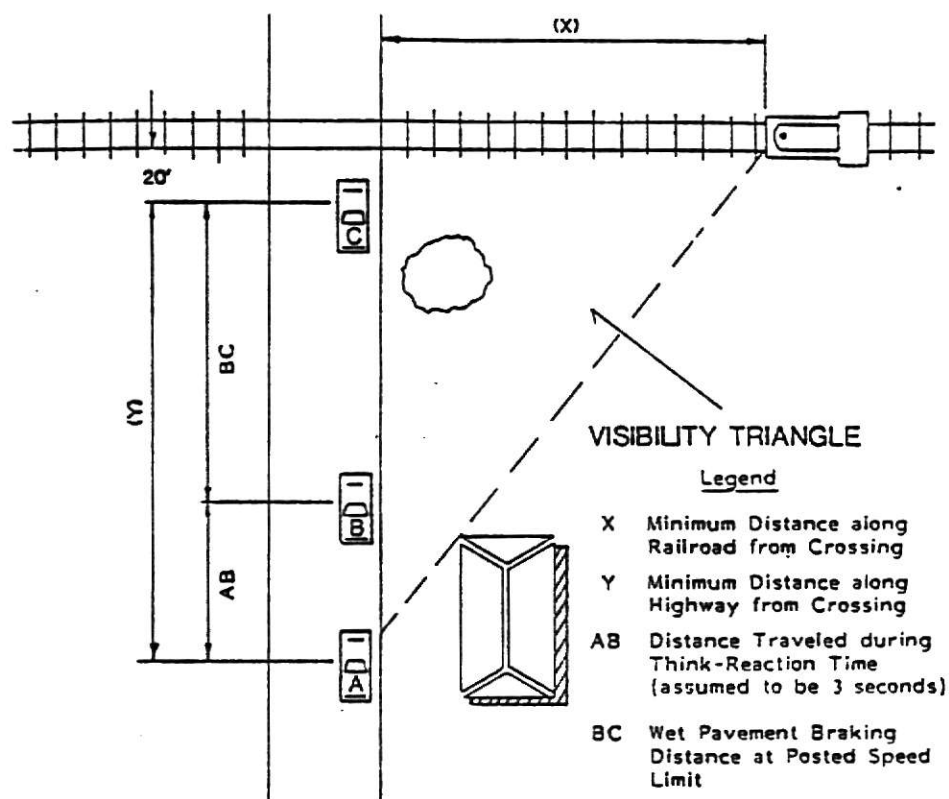


TABLE 9

MINIMUM SIGHT DISTANCES
FOR COMBINATIONS OF HIGHWAY AND TRAIN VEHICLE SPEEDS
(In Feet)

Train Speed	HIGHWAY SPEED IN MPH						
	0	10	20	30	40	50	55
	MINIMUM DISTANCE ALONG RAILROAD FROM CROSSING (X)						
10	162	126	94	94	99	107	113
20	323	252	188	188	197	214	225
30	484	378	281	281	295	321	337
40	645	504	376	376	394	428	450
50	807	630	570	470	492	534	566
60	967	756	562	610	590	642	675
70	1129	882	656	704	684	750	786
80	1290	1008	752	752	788	856	900
90	1450	1134	844	844	884	964	1010
	MINIMUM DISTANCE ALONG HIGHWAY FROM CROSSING (Y)						
	20	65	125	215	330	470	560

CHAPTER 12

DRIVEWAYS

Driveways are privately-owned roads which connect buildings, parking lots and other areas with public roads and highways. Although driveways are essential to provide access to these facilities, they can produce hazardous highway conditions. Engineering studies have shown that as commercial establishments become more frequent along a public road, accident rates increase. The objective, therefore, is to regulate the design and frequency of driveways and other private access roads so as to minimize the incidence of accidents and thereby maintain a reasonable traffic flow along the highway.

A permit is required for the construction of any new access driveway or the revision of any existing driveway within the right-of-way along a State highway. The permit is issued by the appropriate district office of the Kansas Department of Transportation and all construction work performed is subject to the condition of the permit with accompanying plans, drawings, sketches or other attachments.

WHAT FACTORS SHOULD A LOCAL AUTHORITY TAKE INTO ACCOUNT IN PROVIDING GUIDELINES FOR DRIVEWAY CONSTRUCTION?

Driveways accessing major highways require more stringent requirements than those accessing secondary roads or streets. Standards for all driveways, however, should minimize potential accidents and conflicts between through vehicles and those entering and leaving the driveway. Some of the objectives to be achieved through the use of proper driveway design standards are:

1. Minimize the speed differential between through vehicles and those using the driveway.

2. Eliminate encroachment of turning vehicles on adjacent lanes.
3. Prohibit motorists from using the road or highway as a means of circulating between parking rows.
4. Provide sufficient space between driveways to reduce interference from traffic using adjacent driveways.
5. Discourage motorists from parking on streets or backing out onto the highway or road.
6. Preserve the original intent of the roadway, pedestrian walkway and drainage facilities.
7. Provide adequate sight distance of on-coming traffic for motorists exiting the driveway.

WHAT CRITERIA SHOULD BE USED IN DETERMINING WHERE DRIVEWAYS CAN BE SAFELY LOCATED?

When considering a proposed driveway, the following criteria should be used in determining that its construction will not endanger lives and property.

1. The driveway should be located where motorists using the proposed drive and abutting road will have adequate sight distance, and where grade and alignment conditions are favorable.
2. There should be no unnecessary interference with the free and safe movement of highway traffic.
3. The safety and convenience of pedestrians and other users of the roadway should not be compromised.
4. Driveways serving commercial, industrial and high density residential developments can affect the efficiency and safety of the street or highway onto which they enter and exit. Perhaps the single most important factor in developing a safe access plan for these developments is a determination of the potential traffic volumes generated (see Chapter 13).

WHAT ARE THE DESIGN STANDARDS FOR A NON-COMMERCIAL DRIVEWAY?

The following standards are recommended:

Width of Drive - All residential or non-commercial driveways should have a width between 10 and 20 feet with appropriate flares at the curb or pavement edge.

Flare Radii - The recommended radii for residential drives is five feet at minimum and 15 feet maximum.

Angle of Driveway - The driveway center line should generally be at a right angle (90 degrees) to the pavement edge and follow this angle from the roadway to the right-of-way line, or in rural areas, to a distance of 40 feet from the edge of the pavement.

WHAT ARE THE DESIGN STANDARDS FOR A COMMERCIAL DRIVEWAY?

The following standards are recommended:

Width of Drive - Commercial driveways should be limited to a maximum width of 30-40 feet measured at right angles to the center line of the drive and exclusive of flares. In rural locations, the maximum opening along the pavement should be 60 feet, measured six feet back from the pavement edge. Curb openings in urban locations should be limited to 85 feet.

Flare Radii - In rural locations the radii should be between 10 and 40 feet, and in urban areas, between 15 and 25 feet.

Angle of Driveway - Generally, the driveway should be at a right angle to the roadway or parallel to the property line. The angle can be reduced to 60 degrees for two-way driveways or 45 degrees for multiple one-way entrances.

WHAT IS THE RECOMMENDED GRADE FOR A DRIVEWAY?

Driveways in rural locations should have a grade that slopes away from the highway surface at a rate equal to the slope of the shoulder but not less than 3/16 inch nor greater than one inch per foot. The slope should continue for a distance equal to the shoulder width. Beyond the shoulder the driveway grade should not exceed 10 percent.

In urban areas, the slope should be compatible with the drainage of the area but should not exceed 6 and 8 percent, respectively, for commercial and non-commercial driveways.

HOW CLOSELY CAN DRIVEWAYS BE SPACED?

Normally, only one driveway should be permitted for each residential property with a minimum of 10 feet between drives. The typical commercial property should be allowed a maximum of two driveways. A minimum distance of 440 feet, and preferably 660 feet, should be required between the center lines of entrances into shopping centers and similar developments that generate high traffic volumes. However, service drives into these centers which are not used by the general public may be closer than 440 feet as long as they do not encroach on turning lanes. The minimum distance of 440 feet is also desirable between major commercial entrances and the nearest public road. For residential drives along rural highways, the minimum distance between the drive and the nearest public road is 50 feet. Corner lots can reasonably be allowed one drive per street frontage.

CAN A DRIVEWAY BE SHARED JOINTLY BY TWO ADJACENT PROPERTY OWNERS?

If two or more property owners have a legal agreement describing their joint right to property access, the only barrier to allowing such a driveway would be the safety and traffic flow issues already addressed in this chapter.

ARE THERE GUIDELINES FOR DRIVEWAYS FOR SPECIAL USES SUCH AS DRIVE-IN THEATRES AND SERVICE STATIONS?

Along with traffic volumes, other critical factors to be examined include the number of entrances, the size of the parking area, the length of storage lanes for traffic entering and leaving these establishments, and the internal traffic circulation pattern. Different kinds of developments also demand special conditions.

1. Office Space. The exits should be designed to accommodate heavy traffic during peak hours.
2. Drive-in Service Establishments. The layout of the site must provide that all waiting vehicles are off the right-of-way and not concentrated on the entrance driveway.
3. Drive-in Theatres. A storage area between the ticket booths and the highway should be provided for an equivalent of 10 percent of the rated vehicle capacity of the theatre.
4. Service Stations. The site should be laid out so that the minimum distance from the right-of-way line to the near edge of the pump island is 13 feet. A greater distance is recommended to permit freer movement of larger vehicles and to ensure they are entirely off the street.

CHAPTER 13

COMMERCIAL DEVELOPMENT

Changes in land use can greatly modify the traffic patterns of an area. These changes are particularly significant if the property undergoes change from a relatively undeveloped parcel to one having commercial usage.

The traffic impact of such development proposals should be carefully reviewed. Of particular importance are the following two issues:

- Will this project cause congestion or create an unsafe traffic condition?
- Is sufficient off-street parking being provided?

This chapter examines these issues as well as other questions which may arise concerning this type of project.

HOW MUCH TRAFFIC WILL BE GENERATED BY A NEW COMMERCIAL DEVELOPMENT?

Because of the many variables affecting traffic generation, it is difficult to predict the precise amount of traffic which will be generated by a given project. However, transportation studies have quantified, in general terms, the volume of traffic generated for different types of projects.

Table 10 presents a tabulation of generation values which may be expected for both residential and commercial developments. Daily and p.m. peak hour forecasts are given for each type of project.

HOW MANY PARKING SPACES ARE NEEDED FOR A NEW DEVELOPMENT?

Table 11 has been developed as a guideline to determining how many

on-site parking spaces should be provided for different land uses. The number of spaces shown will normally accommodate peak parking demand for that type of development.

IF A DEVELOPMENT INCLUDES A MIX OF OFFICES AND RETAIL ESTABLISHMENTS, WON'T SOME TRIPS BE TO BOTH OFFICES AND STORES?

Yes, it is reasonable to assume that some of the trips generated by the site will utilize both the office and retail facilities. For the type of commercial development, the number of office trips forecasted using Table 10 can be reduced by up to 20 percent to reflect an intermingling of uses.

HOW MANY ACCESS DRIVES ARE NEEDED TO ACCOMMODATE A DEVELOPMENT?

There is no standard answer to this question. Access requirements will depend upon the volume of traffic on the main road, the number of trips generated by the development, existing roadway conditions, property dimensions, etc. As a practical point, it is generally a good policy to provide two access driveways if the size of the commercial development exceeds 25,000 square feet.

The following are other guidelines which should be considered:

- Access driveways should generally be designed with two exiting lanes when the left turn volume exceeds 100 vehicles per hour.
- A left-turn storage lane should be provided along the adjacent highway when left turning movements into the site exceed 100 vehicles per hour at any given location.
- Where at all possible, align the proposed access drives directly opposite existing driveways or streets so that offset intersections can be avoided.

TABLE 10
SUMMARY OF TRIP GENERATION RATES
(FOR URBAN AREAS OF POPULATION GREATER THAN 25,000)

<u>Land Use</u>	<u>Average Weekday Vehicle Trip Ends</u> ⁽¹⁾	
	<u>Daily</u>	<u>P.M. Peak Hour</u>
Residential		
Single Family Unit	10 per unit	1 per unit
Apartment	6 per unit	0.7 per unit
Retail		
0 to 50,000 GSF	115 per 1000 GSF ⁽²⁾	15 per 1000 GSF
50,000 to 100,000 GSF	80 per 1000 GSF	8 per 1000 GSF
100,000 to 200,000 GSF	60 per 1000 GSF	6 per 1000 GSF
Office		
General Office	12 per 1000 GSF	2.5 per 1000 GSF
Medical Office	75 per 1000 GSF	6.5 per 1000 GSF
Restaurant		
Fast Food	550 per 1000 GSF	30 per 1000 GSF
High Turnover, Sit Down	165 per 1000 GSF	10.5 per 1000 GSF
Industrial		
Per Employee	3	0.6
Per 1000 GSF	5.5	1
Per Acre	60	12

(1) A trip end is one trip either entering or exiting the development.

(2) GSF = Gross Square Feet of floor area in the building.

TABLE 11
PARKING REQUIREMENTS

<u>Land Use</u>	<u>Parking Spaces Required</u>
Residential	
Single Family Unit	2 per unit
Apartments	1.75 per unit
Retail	
Convenience Retail	5 per 1000 GSF
Other	4 per 1000 GSF
Office	4 per 1000 GSF
Restaurants	1 per 3 seats
Industrial	1 per 2 employees

WHAT ARE THE GUIDELINES TO DETERMINE IF A DEVELOPMENT WILL NEED ADDITIONAL TRAFFIC LANES ALONG AN ADJACENT STREET?

The critical lane analysis is useful in determining if additional traffic lanes will be needed. Count peak hour volumes on the adjacent street. If the volume of traffic in the heaviest direction of travel (expressed in vehicles per lane per hour) plus that exiting from the access road to the development (vehicles per lane per hour) exceeds 1200 vehicles, additional lanes will be required.

Example

Main Street

- Has two traffic lanes (one in each direction)
- Peak hour traffic volumes

Northbound - 800 Southbound - 400

Driveway to the Proposed Development

- Has two traffic lanes (one in each direction)
- Peak hour exiting traffic volume - 500

Critical Lane Analysis

- Main Street	300 Vehicles per lane per hour
- Driveway	<u>500</u> Vehicles per lane per hour
Total Volume	1300 Vehicles per lane per hour

The total volume exceeds 1200 vehicles per hour. Therefore, additional lanes will be required on Main Street or additional exiting lanes (or driveways) should be built to the proposed development.

ARE THERE GUIDELINES FOR STREET AND AREA LIGHTING IN COMMERCIAL DEVELOPMENT?

Lighting on commercial properties is normally the responsibility of the property owner(s) and must be located on private property unless special permits allow location on the right-of-way. Lights on commercial properties should not be a nuisance to passing motorists and cannot be similar to traffic control devices. No flashing, oscillating or rotating lights visible from any public highway should be permitted to be placed on any building or structure within 200 feet of and visible from the highway, and no illuminated signs should be allowed to have unshielded lights which might impair the vision of passing motorists on the adjacent street. Local codes may, and often do, restrict all lighting and signs. Developers must comply with local codes which are often more restrictive than state codes.

WHAT PROCESS MUST A DEVELOPER FOLLOW TO OBTAIN THE NECESSARY PERMITS?

The developer of a commercial property which accesses State and/or municipal roads must comply with local building codes, setback requirements, minimum lot sizes, density of building, provision for

adequate parking and other regulations. A State permit will not be granted for access to State highways unless the development's land use and zoning plans conform with local laws. In the case of subdivided lands abutting a State highway, reasonable access to the highway will be permitted, but internal circulation must be provided and individual entrances on the highway are not allowed. Where extensive work will be required on the State highway itself, a formal joint agreement, instead of the usual permit, is required.

CHAPTER 14

TURN RESTRICTIONS AND ONE WAY STREETS

With increasing traffic volumes on local street systems, various means have been sought to improve traffic flows without having to construct new streets and street systems. The use of turn restrictions at intersections and the conversion of two-way streets to one-way offer two such opportunities. In order to achieve these efficiencies, however, the travel routes of some motorists will be affected. This chapter discusses the use of turn restrictions and one-way street regulations and their impact on traffic flows. It offers guidelines as to when these alternatives would be useful in improving the circulation of traffic.

WHEN SHOULD LEFT TURNS BE PROHIBITED AT AN INTERSECTION?

Left-turn movements at intersections are a leading cause of congestion and delays. If opposing traffic is heavy, left turns may be particularly difficult to make. Furthermore, these turning vehicles may impede the flow of through traffic if separate left-turn lanes are not provided. Because of greatly varying conditions from intersection to intersection, however, no specific rules have been developed for determining when left turns should be prohibited.

The following general guidelines will help in evaluating traffic conditions to decide if a left turn prohibition would be useful at a particular intersection.

1. Are other measures available to alleviate the traffic problem? As a general rule, other solutions such as the provision of a separate left-turn lane, the addition of a special left-turn phase (if the intersection is signalized), etc., should be considered before initiating a left-turn prohibition.

2. Does the motorist have an alternate point at which to make the left turn if that movement is prohibited at this particular location? If so, are left turns warranted or possible at this other location? It may be a residential street which cannot handle additional traffic, and would thereby create an equally objectionable or unsafe condition:
3. How many motorists are turning left? As a guideline, left turns should average at least two per minute for the period under study to warrant consideration of a left-turn prohibition as a means of limiting congestion.
4. How frequent is the conflict between left turns and opposing through traffic? As a general rule, the total of left turns and opposing traffic volumes should exceed 750 vehicles per hour for at least two hours of the day before left turns are prohibited.

CAN LEFT TURNS BE PROHIBITED AT AN INTERSECTION FOR ONLY PART OF THE DAY, FOR EXAMPLE, THE PEAK HOUR?

As a general rule, it is not a good practice to prohibit left turns for only part of the day. Such restrictions are difficult to sign (unless internally illuminated signs are used) and tend to confuse motorists. In instances where the hours of prohibition are painted on the sign, some motorists may not be aware of the time of day. Where internally illuminated signs are used, opposing through traffic may not know if the sign is illuminated. In Kansas, peak hour restrictions are normally more applicable.

Nevertheless, if the traffic pattern exhibits a great deal of fluctuation, for example, a large number of left turns during the peak hour and very few during the remainder of the day, a parttime prohibition could be considered.

HOW SHOULD LEFT-TURN PROHIBITIONS BE SIGNED?

Turn prohibition signs should be placed where they will be most

readily seen by drivers intending to turn. No Left Turn signs are to be placed in the near right-hand and far left-hand corners of an intersection facing approaching traffic.

Turn prohibitions during certain periods of the day require special treatment. Internally illuminated signs lighted only during the hours of prohibition, or mechanically-operated variable message signs are recommended. Permanently mounted signs incorporating supplementary legend showing the hours of prohibition can be used as a substitute. However, these signs are not nearly as effective as those which have internally illuminated or "blank out" messages.

IF A STREET IS EXTREMELY NARROW, WOULD THE BEST APPROACH BE TO MAKE IT ONE-WAY OR TO PROHIBIT PARKING?

There is no set answer to this question. In commercial areas where parking is a premium it is probably more desirable to make the street one-way than eliminate curb parking. However, a parallel street, preferably not more than a block away, should be available for one-way flow in the opposite direction.

For residential areas serviced by driveways and/or an alley, it is generally more acceptable to eliminate curb parking thereby continuing to allow two-way traffic movements. Maintaining two-way traffic is also desirable in residential areas where the blocks are unusually long.

Table 12 indicates the Kansas Department of Transportation's guidelines on minimum widths for one-way and two-way streets with and without parking. The table establishes the Department's policy on widths of streets for urban improvements and is meant for state controlled and maintained roads. But the guidelines are also recommended for local authorities

who are concerned with street improvements or who require such guidelines for situations such as determining when to make a street one way. The first column indicates the minimum hourly traffic volume projected for that street for the next 20 years.

UNDER WHAT CONDITIONS IS IT DESIRABLE TO MAKE A STREET ONE-WAY?

As a general rule, two-way streets should be made one-way only under the following conditions:

1. It can be shown that a specific traffic problem will be relieved by the proposed one-way street system.
2. A one-way operation is more desirable than alternate solutions.
3. Parallel streets of suitable capacity, preferably not more than a block apart, are available.
4. Such streets provide adequate traffic service to the area traversed and carry traffic through and beyond the congested area.
5. Safe transition to two-way operation can be provided at the end points of the one-way sections.
6. Thorough study shows that the total advantages outweigh the disadvantages.

WHAT BENEFITS CAN BE ACHIEVED FOR MOTORISTS AND PEDESTRIANS BY IMPLEMENTING A ONE-WAY STREET SYSTEM?

One-way streets will increase traffic efficiency by minimizing conflicts and making more effective use of the roadway. In many cases, one-way streets will result in a reduction of accidents by?

1. Reducing conflicting movements at intersections such as between left-turning vehicles and opposing through traffic.
2. Eliminating head-on collisions.
3. Eliminating headlight glare.

4. Increasing lane width.
5. Eliminating entrapment of pedestrians between opposing streams of traffic.
6. Improving signal timing at successive intersections to give smooth, continuous flow.
7. Improving the driver's field of vision at intersection approaches.

One-way streets will improve transportation efficiency by relieving traffic congestion on two adjacent two-way streets thereby reducing travel time, stops, and delays. Traffic signals can be simplified by eliminating the need for separate left-turn phases on two-way streets.

IS THERE REASON FOR BUSINESSMEN TO BE CONCERNED IF THE STREETS ON WHICH THEIR BUSINESSES ARE LOCATED ARE MADE ONE-WAY?

It is not uncommon for business owners to be concerned that making their street one-way will harm their businesses. However, studies made in various parts of the country generally tend to disprove this claim.

Some of the findings from these studies include the following:

1. There is no indication of adverse economic influence on business activity within the one-way corridor. In one study, the number of business failures was reduced substantially after one-way conversion.
2. Property values along streets converted to one-way were not adversely affected.
3. Many businessmen formerly opposed to a one-way street plan become its strongest supporters after experiencing its traffic benefits.

TABLE 12

RECOMMENDED WIDTHS FOR ONE-WAY
AND TWO-WAY STREET IMPROVEMENTSTwo-Way Streets

<u>Two-Way DHV-20*</u>	<u>Number of Traffic Lanes</u>	<u>Minimum Width of Median</u>	<u>Without Parking</u>	<u>Widths With Parking On One Side</u>	<u>With Parking On Both Sides</u>
Less than 1400	2	None	30'**	36'	44'
1400 to 2400	4	4'***	56'	64'	72'
2400 to 3400	6	4'***	80'	88'	96'

One-Way Streets

<u>One-Way DHV-20</u>	<u>Number of Traffic Lanes</u>	<u>Without Parking</u>	<u>Widths With Parking On One Side</u>	<u>Without Parking On Both Sides</u>
Less than 1400	2	30'**	36'	44'
1450 to 2150	3	40'	48'	56'
Over 2150	4	52'	60'	68'

NOTES

* DHV-20 = Design Hourly Volume - 20 Years Projected.

** Provides for two-lane operation passing a stalled vehicle.

*** Barrier medians shall not exceed six feet.

1. All widths are face to face of curbs and 2' width gutters provided on right throughout except that one foot gutter flags may be used adjacent to parking lanes.
2. On two-way streets where the DHV-20 is less than 500, consideration should be given to the use of flexible base and surface treatment for the parking lanes.
3. The above widths are based on 12' traffic lanes and provide for a 2' side clearance from the face of curbs to adjacent traffic lanes on right. Eleven foot lanes are not desirable and an

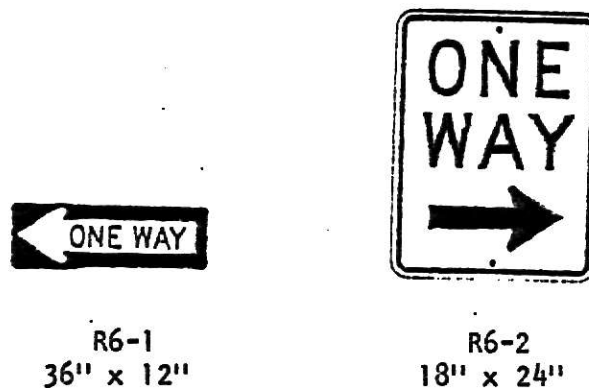
economic justification for their use will be required. Where 11' lanes are considered, the indicated maximum traffic volumes in each classification are to be reduced 12½%.

4. Geometrics of the termini of a one-way couple are to be commensurate with the design speed of the adjacent two-way roadway.

WHAT IS THE BEST USE OF TRAFFIC SIGNS TO ADVISE MOTORISTS OF ONE-WAY TRAVEL ON A ONE-WAY STREET?

The signs used to inform motorists that the street is one-way shall be either: a) a white arrow, right or left, on a black horizontal rectangle of a minimum of 36" x 12" size with the words "One-Way" centered in the arrow (R6-1); or b) a vertical rectangle of a minimum of 18" x 24" size with the words "One-Way" and a right or left arrow on a white background (R6-2). (See Figure 22).

FIGURE 22
TYPICAL ONE-WAY STREET SIGNS



One-Way signs (R6-1) shall be placed on the near right hand and the far lefthand corners of the intersection so they face traffic entering or crossing the one-way street. One-Way signs (R6-2) should also be placed parallel to the one-way street directly opposite the exits from the alleys, parking lot driveways, etc.

To further aid motorists on the cross street, No Left Turn or No Right Turn signs (R5-1) can be posted on the far side of the intersection. Figure 23 illustrates typical signing along a one-way street.

FIGURE 23
TYPICAL SIGNING ALONG A ONE-WAY STREET

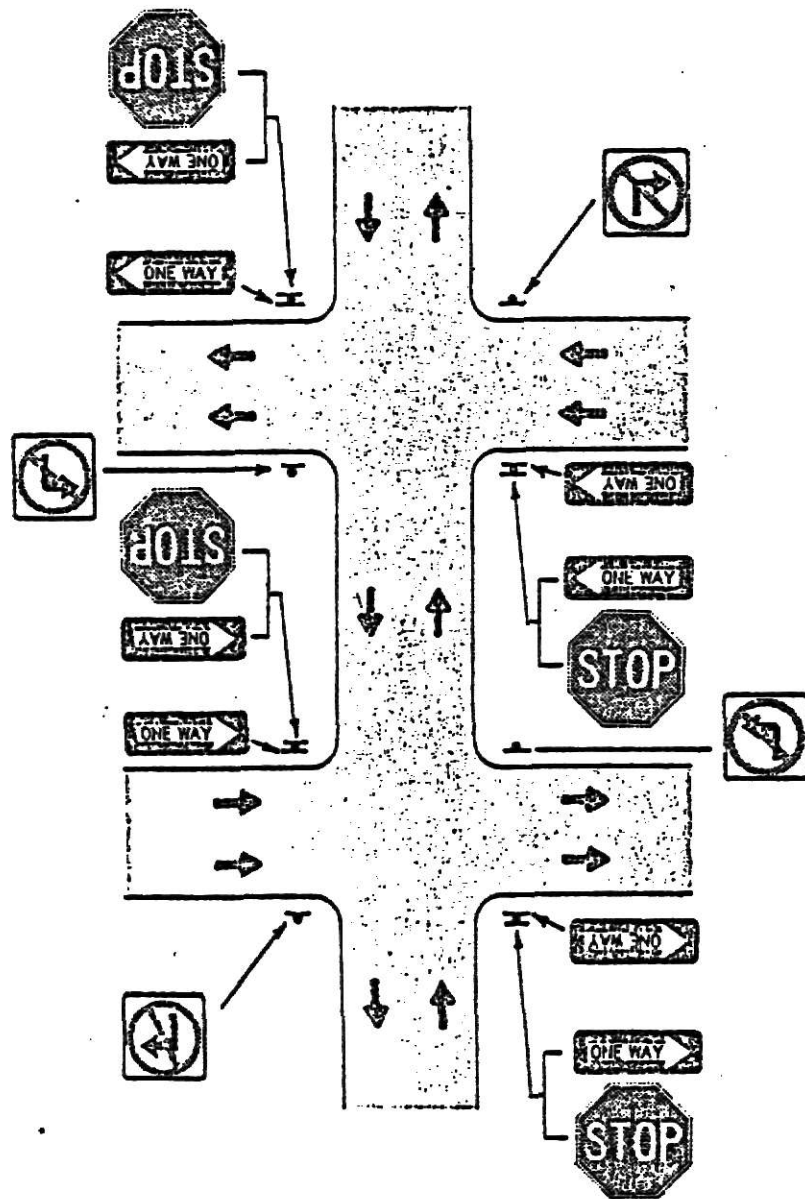
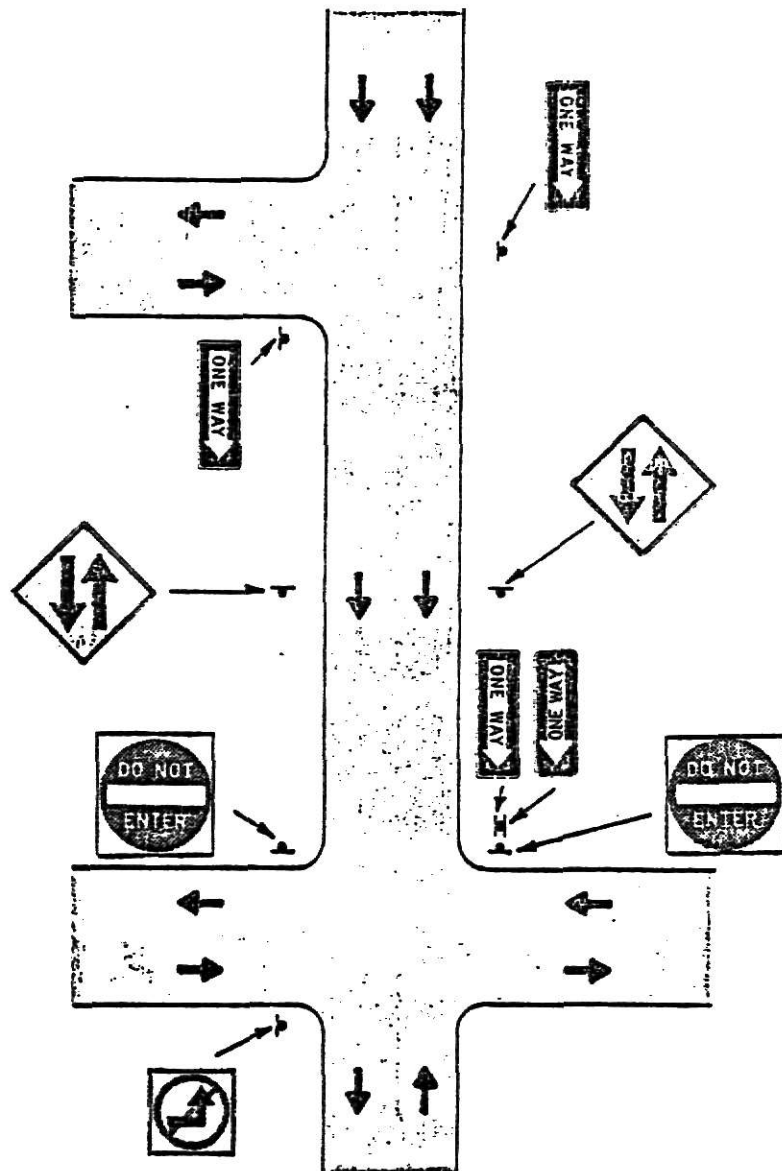


FIGURE 23 (Continued)



CHAPTER 15

TRAFFIC ACCIDENTS

Establishment of an accident record system which permits the accurate retrieval and analysis of traffic accident records is of utmost importance to all governmental jurisdictions. Good accident records will facilitate the planning of accident prevention measures through engineering, education and enforcement.

HOW SHOULD LOCAL ACCIDENT RECORDS BE FILED SO THAT THEY CAN BE USED MOST EFFECTIVELY FOR ACCIDENT ANALYSIS?

To facilitate the accident analyses, the original reports of accidents should be filed by year and by location of accident occurrence. As an alternative, the original reports could be filed chronologically and a location cross-reference index file could be developed to permit retrieval of accident data for specific locations.

In cities, the location file is generally an alphabetical file of street names, with intersection accidents filed behind a primary guide bearing the name of the street that comes first alphabetically and a secondary guide bearing the name of the intersecting street or streets. Accidents between intersections are filed immediately behind a primary guide for the street on which the accident occurred, with subdivisions by block numbers as needed. County accident reports are usually indexed first by township, then by route number, and finally by route section or field reference system location.

Local agencies needing assistance in setting up an accident records system are encouraged to contact the Safety Department, Kansas Department of Transportation. An excellent guide to traffic accident

report filing is the Manual on Identification, Analysis and Correction of High Accident Locations which is available from the Safety Department, Kansas Department of Transportation.

ARE THERE SPECIAL TECHNIQUES FOR SUMMARIZING TRAFFIC ACCIDENT DATA WHICH WILL HELP IDENTIFY THOSE LOCATIONS EXPERIENCING AN ACCIDENT PROBLEM?

Accident spot maps and high accident frequency location lists are two tools which can be used to pinpoint problem locations. In particular, a spot map furnishes a quick visual index of the location of accident concentrations, thus supplementing the location file.

The most common spot map is one showing accidents by pins, spots, or symbols on the map at the location of occurrence. This map is posted currently as reports are received, using different shapes, sizes or colors to indicate different types and severities of accidents. The legend should be as simple as possible, using not over four or five types, sizes, or colors of spots.

Accident spot maps are normally maintained for the calendar year, then photographed and the picture filed so that it can be retrieved for comparison purposes. Types of special maps sometimes used are:

- Pedestrian accident spot map
- Night accident spot map
- Spot map of accidents involving drinking drivers
- School child accident spot map

With the aid of these spot maps and the accident location file, "high accident frequency locations" are readily detectible. Annual or more frequent periodic listings of these locations can then be compiled for purposes of analysis and correction. For additional information on spot maps refer to the Manual on Identification, Analysis and Correction of High Accident Locations.

HOW CAN THE PROBABLE CAUSES FOR A HIGH ACCIDENT LOCATION BE DETERMINED?

Collision and condition diagrams are the most effective tools for analyzing traffic accident patterns to determine probable causes for unusually high rates.

A collision diagram illustrates graphically, by means of directional arrows and symbols, the paths and nature of collision by vehicles and pedestrians involved in accidents. These diagrams are schematic and, therefore, are seldom drawn to scale. As is shown in Figure 24, a set of arrows is used to represent each accident. The date, time of day, and other special information is written next to one of the arrows depicting that particular accident.

Collision diagrams illustrate accident patterns and can be used to identify the types of remedial actions required to correct the problem. For example, a large number of rear-end collisions at an intersection with Stop sign control may indicate that the Stop sign is not adequately visible.

Condition diagrams are scaled drawings showing the physical characteristics of the intersection (or other location being studied). The type of information typically shown includes:

- Curb Lines
- Property Lines
- Sidewalks & Driveways
- Traffic Controls
- Building Structures
- Trees, Shrubberty
- View Obstructions

This drawing can be used in conjunction with the collision diagram to identify the reason for a particular type of accident, i.e., a high incidence of right angle collisions may be caused by a visibility obstruction in one corner.

An excellent guide to collision and condition diagrams is the Manual on Identification, Analysis and Correction of High Accident Locations.

WHAT MEASURES CAN BE EMPLOYED TO LOWER THE ACCIDENT RATE AT A HIGH ACCIDENT LOCATION?

The spot maps, collision diagrams and condition diagrams will be helpful in identifying the accident pattern and possible causes for accidents at a particular location. Selection of the appropriate countermeasure to alleviate the accident problem is the next step. Table 13 is a summary of some of the countermeasures which can be employed to deal with the more typical accident causes. If these measures do not prove effective for a particular location, the local agency is encouraged to seek the help of a professional traffic engineer.

FIGURE 24
TYPICAL COLLISION DIAGRAM

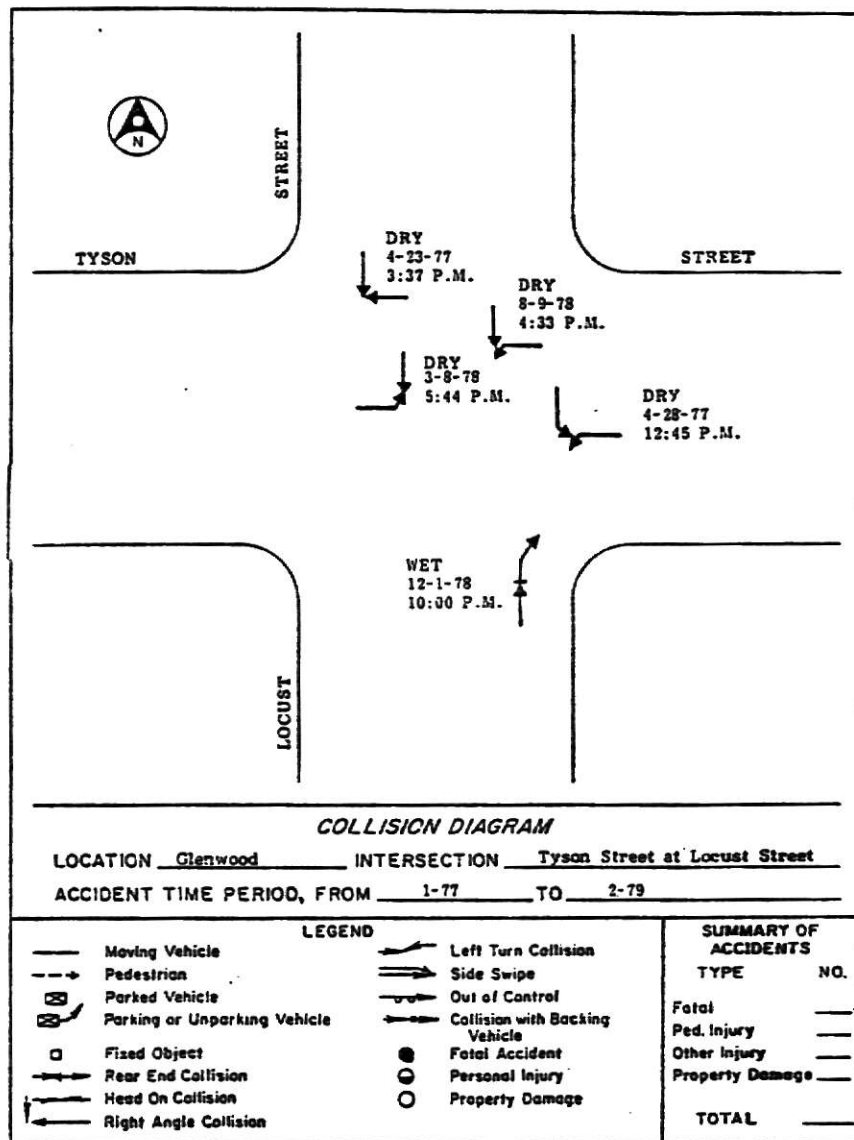


TABLE 13
GENERAL COUNTERMEASURES FOR ACCIDENT
PATTERNS AND THEIR PROBABLE CAUSES

<u>Accident Pattern</u>	<u>Probable Cause</u>	<u>General Countermeasure</u>
Right Angle Collisions (Signalized Intersection)	Poor Signal Visibility	Install 12" signal lenses Install overhead signals Install backplates, visors Install advance warning signs Improve signal head locations Add signal heads
	Inadequate Signal Timing	Adjust amber phase Provide all-red clearance Retime signals
Right Angle Collisions (Unsignalized Intersection)	Restricted Sight Distance	Remove sight obstructions Restrict parking Install Stop signs Install warning signs Reduce speed limit Install signals
	Heavy Traffic Volume	Install signals
	High Approach Speed	Reduce speed limit Install rumble strips
	Poor Signal Visibility	Install advance warning signs Install overhead signals Install 12" signal lenses Install backplates, visors Relocate signals Add signal heads Improve signal head location
Rear End Collisions (Signalized Intersections)	Inadequate Signal Timing	Adjust amber phase
	Slippery Surface	Overlay pavement Groove Pavement Reduce speed limit
	Large Turning Volumes	Create turning lanes Prohibit turns Increase curb radii

TABLE 13 (Continued)

<u>Accident Pattern</u>	<u>Probable Cause</u>	<u>General Countermeasures</u>
Rear End Collisions (Unsignalized Intersection)	Driver Not Aware of Intersection	Install/improve warning signs
	Slippery Surface	Overlay pavement Groove pavement Reduce speed limit
Fixed Object Collisions	Objects Near Traveled Way	Remove obstacles Install barrier curbing Protect objects with guardrail
	Slippery Surface	Overlay pavement Groove pavement Reduce speed limit
Night Accidents	Poor Visibility	Install/improve street lighting Install/improve warning signs Install/improve delineation markings
Left-Turn Collisions	Large Volume of Left Turns	Provide left turn signal phase Prohibit left turns Channelize intersection Create one-way streets

CHAPTER 16

WORK ZONE PROTECTION

Because of varying construction conditions, the safe and expeditious movement of traffic through work zones is a difficult problem. Studies of accident patterns in work zones show there is almost always an above-average accident rate during those periods when a construction or maintenance activity is taking place.

This chapter answers some of the basic questions concerning the design, application, installation and maintenance of various types of traffic control devices required for road or street construction, maintenance and utility operations. More detailed information on this subject is contained in Part VI of the Manual on Uniform Traffic Control Devices.

WHAT TYPES OF CONSTRUCTION SIGNS ARE AVAILABLE FOR WORK ZONE TRAFFIC CONTROL?

There are three types of traffic signs for this use: regulatory warning and guide. Regulatory signs (Stop, Yield, Speed Limit, etc.) will be of the same size, shape and color as for normal use. Because of the legal obligations imposed by these signs, it is essential that their use be authorized by the public body or official having jurisdiction.

Warning signs (Road Work Ahead, Detour 1000 Feet, Flagger Ahead, etc.) are also of the same size and shape as regular warning signs. However, they have one distinguishing difference; the background for warning signs for work zones are orange, not yellow as for normal

application. Furthermore, where any part of the roadway is obstructed or closed, the approach warning signs should have a standard size of 48" x 48". Where speeds are low, 36" x 36" signs may be used.

Guide signs have a number of purposes and, consequently, may have messages and shapes other than the standard orange diamond. "End Construction" and "Pilot Car Follow Me" are two examples. Where these signs are used, they shall have a black symbol or message on an orange background and shall be rectangular in shape. Figure 25 illustrates many of the signs used in construction and maintenance activities.

IS THERE A SPECIFIC MOUNTING HEIGHT AND LOCATION FOR THESE SIGNS?

The standards for positioning these signs are the same as for normal signs. Figure 3, Page 33, illustrates typical applications of warning signs in rural and urban areas.

WHICH WARNING SIGNS SHOULD BE USED FOR A TYPICAL WORK ZONE SITUATION?

No one standard sequence of signs or other control devices can be set up as an inflexible arrangement for all situations due to the variety of conditions encountered. In general, however, warning signs are used to achieve three objectives: i.e. 1) to warn the motorist of unusual activity, 2) to inform the motorist of conditions that will be encountered, and 3) to guide the motorist through the area.

Warning signs are generally used in that sequence. Approach warning signs such as "Road Work Ahead" warn motorists of an upcoming work zone. These signs would be the first in the sequence of traffic control devices employed. Signs such as "Right Lane Closed Ahead" are

specific warning signs and follow next in the sequence. These signs tell the motorist what to expect. Finally, signs such as "Lane Ends Merge Left" and other devices such as cones or barricades help guide the motorist through the area. Figure 26 illustrates a typical application of these signs.

FIGURE 25
CONSTRUCTION SIGNS

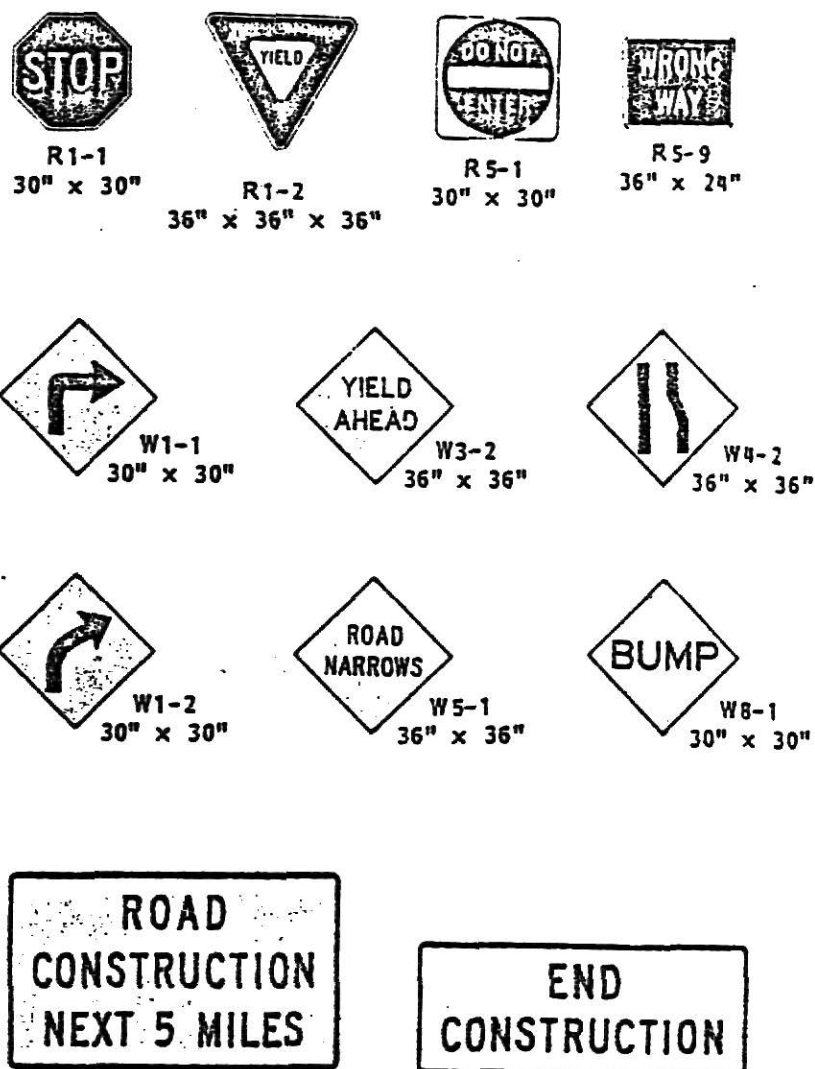


FIGURE 26

TYPICAL WORK ZONE SIGNING

NOTES:

1. Taper Formula:

$L = SXW$ for speeds of
45 or more.

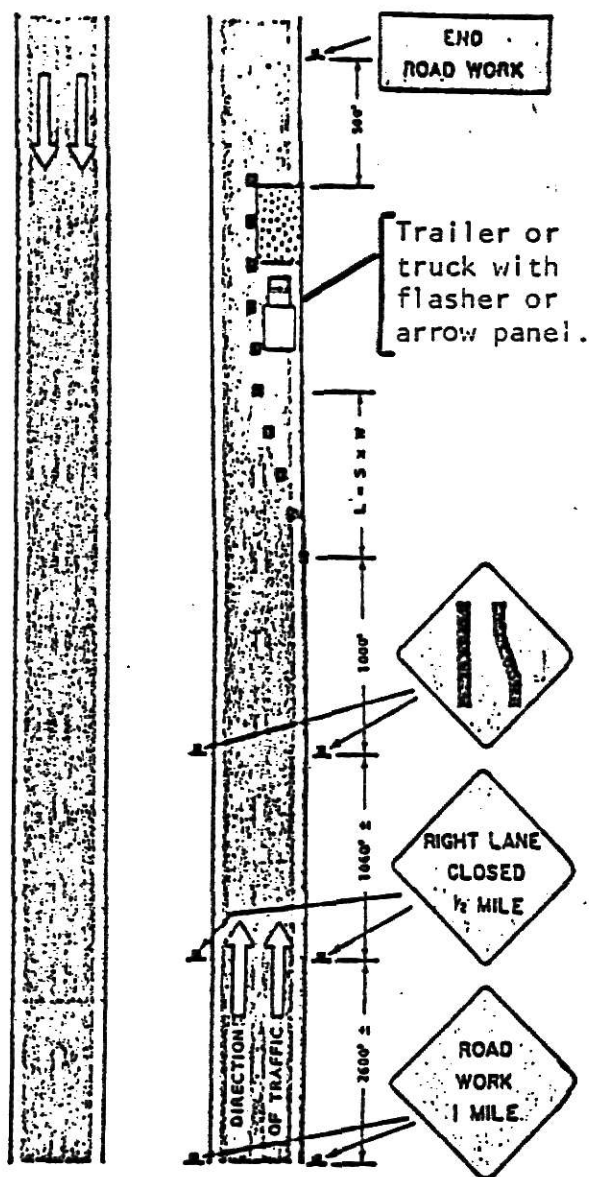
$L = \frac{WS^2}{60}$ for speeds of
40 or less.

Where:

L = Minimum length
of taper.

S = Numerical value
of posted speed
limit prior to
work or 85 per-
centile speed

2. The maximum spacing between channelizing devices in a taper should be approximately equal in feet to the speed limit.



KEY:

■ Channelizing devices

HOW FAR IN ADVANCE OF THE WORK ZONE SHOULD THE WARNING SIGNS BE PLACED?

Where open highway conditions prevail on the approach to the work site, advance warning signs should be placed approximately 1500 feet in advance of the condition to which they are calling attention. Where a series of advance warning signs are used, the warning sign nearest the work site should be placed approximately 500 feet from the point of restriction with additional signs at 500-1000 foot intervals. On expressway and limited access facilities, the advance warning distance should be increased to one-half mile or more. On city streets, where more restrictive conditions generally prevail on the approach to the work area, signs in the immediate vicinity of the work may be placed at closer spacings of 150 to 300 feet.

WHAT TYPE OF DEVICES ARE MOST USEFUL FOR CHANNELIZING TRAFFIC?

Cones, vertical panels, drums, barricades, pavement markings, and temporary concrete barriers may all be used to channelize traffic flows through work zones. The device to use depends upon the type of project, the length of time during which the work activity will take place, and the volume and speed of traffic. For example, cones are easiest to install and remove and, therefore, best suited for short term projects during daytime. Conversely, if the project will be of some duration, will require nighttime channelization, or is on a high volume (or high speed) road, barricades or drums would provide more permanent protection and would be more appropriate. As would be expected, channelizing devices for nighttime use should be reflectorized with warning lights on each device. Barriers are generally used to channelize or separate traffic on high speed roads such as freeways. More information

concerning the design and application of these devices is contained in Part VI of the MUTCD.

WHAT TYPES OF WARNING LIGHTS ARE AVAILABLE AND HOW SHOULD THEY BE USED?

Warning lights are normally used to supplement and draw attention to other warning or channelizing devices during the hours of darkness.

Most of the warning lights in common use are portable, battery-powered, lens directed enclosed units and may be used on channelizing devices and signs.

The principal types and uses of warning lights are:

1. Flashing lights, Type A, are appropriate for use on a channelizing device to warn of an isolated hazard at night.
2. High intensity flashing lights, Type B, are appropriate to use on advance warning signs day and night.
3. Steady-burn lights, Type C, are appropriate for use on a series of channelizing devices which either form the taper to close a lane or shoulder or keep a section of lane or shoulder closed, and are also appropriate on the channelizing device alongside of the work area at night. Flashing lights should not be used in such applications.

Type A and Type C lights may have either one or two directional faces.

WHAT LENGTH OF TAPER SHOULD BE SELECTED TO CHANNELIZE TRAFFIC FLOWS AROUND A REDUCTION IN PAVEMENT WIDTH?

The single most important element of a traffic control plan in a work zone is the taper used for channelization. The minimum desirable taper length for construction and maintenance purposes should be computed by the formula $L = S \times W$, for all roadways having a posted speed of 45 MPH or greater. The formula $L = WS^2/60$ should be used for streets having a posted speed of 40 MPH or less. Under these formulas, L equals

the taper length in feet, W the width of offset in feet, and S the posted speed or off-peak 85th percentile speed. Where the terrain is hilly or sight distance is limited, some adjustments may be required to provide sufficient visibility.

The following calculations illustrate the application of these formulas.

Example 1

Posted Speed = 50 MPH
 $W = 12$ feet
 Taper = $50 \times 12 = 600$ Feet

Example 2

Posted Speed = 30 MPH
 $W = 11$ Feet
 Taper = $11 \times 30 \times 30/60 = 165$ Feet

IS THERE A PROPER SEQUENCE FOR INSTALLING OR REMOVING TRAFFIC CHANNELIZING DEVICES AND WARNING SIGNS?

All traffic signs and channelizing devices should be installed so that they will be seen by an approaching motorist, i.e., the sign farthest from the work zone would be installed first. Where one lane of a two-lane, two-way roadway is to be closed and all motorists must use the other lane, the sign farthest from the work zone but on the opposite side of the road (the lane open to traffic) would be placed first. The remaining signs and devices along that side of the roadway would then be placed in the order seen as one approaches the work zone. The same procedure would then be repeated for the opposing traffic lane.

When work is completed, the devices should be removed but in the opposite order of installation by starting with the devices closest to the work area and continuing away from the area. Use flashing arrow

panels, high-level warning devices, flaggers, or flashing vehicle lights to protect the workers removing the devices.

WHAT IS THE BEST PROCEDURE FOR INFORMING A CONTRACTOR AS TO WHICH DEVICES TO USE FOR TRAFFIC CONTROL AT A WORK ZONE?

The use of a traffic control plan (TCP) is the best technique for informing the contractor (or the project engineer) specifically which devices to use. This TCP should provide for the safe and efficient movement of traffic through the work zone in a manner conducive to the safety of both motorists and workers. The TCP should include, but not be limited to, such items as signing; application and removal of pavement markings; construction scheduling; methods and devices for delineation and channelization; placement and maintenance of devices; roadway lighting; traffic regulations; and surveillance and inspection.

IF FLAGGERS ARE NEEDED, WHAT SIGNALING TECHNIQUES SHOULD THEY EMPLOY IN DIRECTING TRAFFIC?

Flaggers use Stop/Slow paddles to control traffic in work areas, as is described in the Kansas Traffic Control Handbook for Flaggers. Figure 27 shows how both the flag and the paddle are used, but the following technique using the paddle is much more positive and easily understood by the motorist.

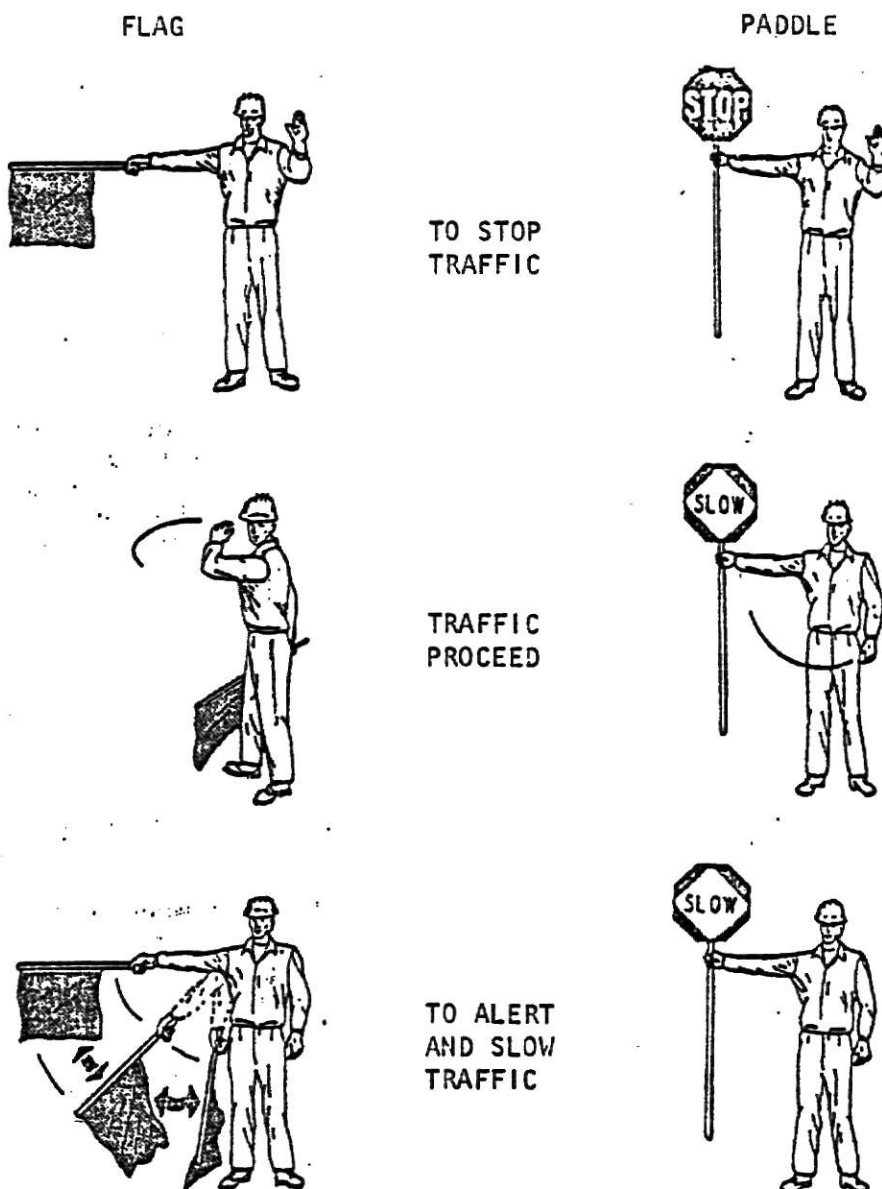
1. To Stop Traffic. The flagger shall face traffic and extend the paddle in a vertical position so the full STOP face is visible. For greater emphasis, the free arm may be raised with the palm toward approaching traffic to indicate that the vehicle is required to stop.
2. When it is Safe for Traffic to Proceed. The flagger shall move to a safe position on the shoulder. He shall face traffic and extend the paddle in a vertical position so the full SLOW face is visible. He then waves traffic forward by moving his free arm across his body.

3. Where It Is Desired to Alert or Slow Traffic. Where it is desired to alert or slow traffic the flagger shall stand in a safe position on the shoulder. He shall face traffic and extend the paddle in a vertical position so the full SLOW face is visible. For added emphasis the free arm may be extended horizontally away from the body and raised and lowered.

To flag traffic at night the flagger's station should be adequately illuminated.

FIGURE 27

USE OF HAND SIGNALING DEVICES BY FLAGGER



ARE THERE CERTAIN RULES OF SAFETY WHICH A FLAGGER SHOULD FOLLOW IN HIS JOB?

Flaggers are responsible for the safety of motorists and workers. Because of the importance of this job, there are certain safety rules which they should observe:

1. Be alert.
2. Always look towards traffic.
3. Stand clear of other workers so that the flagger is always clearly visible to motorists.
4. Don't block or be blocked by signs.
5. Avoid standing on the pavement. An exception to this rule is when the flagger must stand on the pavement to be seen around vehicles already stopped by the flagger.
6. Don't stand inside of obstacles which could restrict the flagger's ability to avoid an oncoming vehicle.
7. Wear appropriate clothing.

WHAT TYPE OF RECORDS SHOULD BE KEPT OF THE SIGNS AND OTHER DEVICES USED AT A WORK ZONE?

Good records are a key to minimizing an organization's legal liability in the event a traffic accident occurs at the work zone site. A careful record of job-related activities will document the efforts made to provide good traffic control at the work site. The record system should reflect priorities and a planned safety program and may include any of the following types of records:

1. Traffic control plan.
2. Notes on the construction plans showing the placement of devices.
3. Photographs at key project stages and for unusual situations.
4. A daily diary.
5. Inspection sheet or checklist showing the status of the devices in place.

HOW OFTEN SHOULD AN INSPECTION BE MADE OF TRAFFIC CONTROLS IN WORK ZONES?

There are no set standards for frequency of inspection. At a minimum,

however, these inspections should be of such frequency as to assure the continuity and quality of the traffic control system. An inspection each morning as work is commencing for the day may suffice. Other guidelines to use in establishing inspection intervals include:

1. Traffic volumes.
2. Frequency of observed deficiencies.
3. Frequency of accident experience.
4. Severity of hazards.
5. Size of project.

WHAT ARE THE MOST COMMON DEFICIENCIES TO BE WATCHFUL FOR DURING INSPECTIONS?

The type of deficiencies may vary depending upon whether it is a daytime or nighttime inspection. Typical daytime deficiencies include:

1. Lack of a taper or insufficient taper length.
2. Channelizing devices out of place.
3. Inappropriate sign messages.
4. Inadequate flagging protection.
5. Inadequate sign spacing.

The most commonly experienced nighttime deficiencies are:

1. Warning lights not working.
2. Warning lights misaimed.
3. Reflectorization not sufficient.
4. Unmarked hazards.

CHAPTER 17

TRAFFIC SIGN INVENTORY

The overall purpose of a traffic sign inventory is to allow local governments to keep a current file on record of all signs in their jurisdiction. Having such an inventory will help to maintain the local sign system in the following ways:

1. It will establish a basis for the upgrading of traffic signs through a planned program of modernization.
2. It will establish the location and condition of all signs within the jurisdiction.
3. It will provide written evidence that inspection of signs has been conducted with regularity. This will help to protect against liability claims.

WHAT INFORMATION SHOULD BE INCLUDED IN A SIGN INVENTORY?

Some information which should be included in a sign inventory includes a record of:

1. Type of sign and support system.
2. Size of sign.
3. Location of sign.
4. Time, date, and by whom the sign was installed or inventoried.
5. Condition of sign and support
 - a) Is sign reflectorized?
 - b) Is sign peeling or faded?
 - c) Has the sign been vandalized?
 - d) Is sign reasonably clean (i.e., can it be read)?
6. Date and by whom maintenance was performed may be marked on the sign. Care should be taken to insure that all records are updated whenever maintenance is performed on a sign.

HOW SHOULD THE INVENTORY INFORMATION BE RECORDED AND FILED?

After determining what types of information need to be included in the sign inventory, a convenient way to record and file the information must be provided. There are several different methods currently in use:

1. Sign Inventory Card Systems - These systems allow the user to group and arrange data into any form that is desired, thus allowing sign information to be located by type. These cards are easily filed in that there is no order necessary for storing the cards. These sign inventory card systems are inexpensive, simple, and adaptable to all levels of roads, and are available from commercial sources.*
2. Location - Identification Map - This system utilizes color coded pins to represent different type signs. A large size map of the jurisdiction, or sections of the jurisdiction, can be used. Appropriate pins are then placed on the map at the sign locations, with each pin having a slip of paper attached to it identifying the sign, its exact location, and the last date of maintenance and inspection.

HOW CAN THE CITY BENEFIT BY USING A SIGN INVENTORY SYSTEM?

With the initiation of a sign inventory system, the city can likely reduce the number of liability claims resulting from traffic accidents. Many times these accidents are caused by signs that have been stolen, vandalized, or are well past their expected life and in need of replacement. By using a sign inventory system most of these problem areas can be spotted and proper action can be taken to upgrade the signing.

A traffic sign inventory also can help the engineer evaluate other areas of concern and interest. For example, as vandalism rates increase all around, these increased rates can be seen in the sign system also.

* The 3M Corporation and McBee Systems are two companies that have such a system

By analyzing sign inventories, costs of replacing signs that have been vandalized can be estimated. Also, other signing costs could be estimated in a similar fashion. By making these estimations the engineer will be able to make a more precise budget for the signing system in the city.

WHAT TYPE OF SYSTEM IS RECOMMENDED?

The Sign Inventory Card System seems to be the best choice of the systems discussed. This system is relatively inexpensive in several respects. First of all, the cards alone are inexpensive when purchased in large quantities, and secondly, highly skilled personnel are not required to operate the system.

The inventory card system has advantages over the Location-Identification map because of the fact that signs can be located by type, condition, visibility, color, mounting type and condition, and many other items. (See Figure 23) For example, if all signs in their tenth year of life are generally going to need replacement, all signs in their tenth year of life can be located very quickly; or, if one wants to know how many stop signs are in the city and their locations, this can be done very quickly with the inventory card system. The speed of determining various types of sign information is the major advantage that the inventory card system has over other inventory methods.

FIGURE 28

TRAFFIC SIGN INVENTORY CARD

[illegible]

WHAT PREPARATION IS NECESSARY PRIOR TO CONDUCTING A SIGN INVENTORY?

Before a sign inventory can be made, care must be taken to organize and plan all aspects. The following guidelines should be followed:

- A. Divide the geographical area of interest into, say 10 control sections and number them 1-10. (A control section is a small area within which a sign inventory is performed. The number will vary according to the size of the city.
- B. Plot the 10 control sections on a reproducible mylar master map.
- C. Be sure that road names are on the reproducible mylar master map. As an added option, the following things should be done:
 1. Produce one map of each control section for field data collection purposes. Sign inventory crews should then color

the road segments, as the sign survey is completed, with a red or yellow marker to avoid duplication and to aid in planning the work effort.

2. One copy of the complete master map should be reproduced for office purposes and should be mounted on a wall near the card storage area to aid in cataloging and for reference.

- D. Develop a sign code list for each of the survey teams. Use state sign codes, or the 3M Traffic Control Materials (1) catalog as a basis for developing the list. Unique numbers should be assigned for each sign type, including special signs and pavement markings.
- E. To aid survey teams in identifying sign age, samples from existing signs should be made. Small samples (i.e. 1" x 3") for each color and material type should be produced. These samples should then be rated as either "good", "average" or "bad", and have their age marked on the backside.
- F. Train all applicable employees. This includes not only the survey teams, but other employees who may aid in the survey during their regular routine. Some possibilities include:
 1. City road crews
 2. Law enforcement officers
 3. Water meter readers
 4. Electric meter readers

(1) Traffic Control Materials/3M, 223-3M 3M Center, St. Paul, MN 55101

WHAT ARE THE FIELD DATA COLLECTION STEPS TO TAKE?

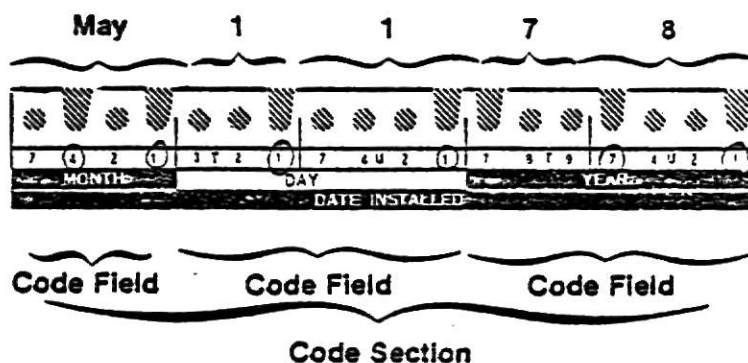
- A. Personnel and equipment consist of the following:
 - 1. Ideally, two employees, one serving as a driver and the other as a recorder.
 - 2. Sufficient quantity of inventory cards for a day's work.
(One card for each sign).
 - 3. Set of instructions and sign code.
 - 4. Clipboard, section map, pencils, and a measuring device
(measuring wheel or tape).
 - 5. Sample of a completed card.
 - 6. Samples of reflective sign material.

HOW IS THE FILING DONE?

- A. Coding - The holes around the margin on the system cards are known as Code Positions, Code Fields, or Code Sections.
(See Figure 29) A Code Position is a single hole assigned to a number, letter or word. A Code Field contains one or more code positions relating to a single subject or classification. A Code Section contains one or more fields relating to the same subject.
- B. Notching - Code positions on the cards are notched individually. This is done by punch cutting a V-shaped notch for coding with a special tool. These notches provide the means by which the cards can later be separated by the use of a card sorter. This is usually done in the office after the field study.

FIGURE 29

CODE FOR MAY 11, 1978



- C. Sorting - The sorting of the system cards is achieved through the use of a sorting needle which is a steel needle set in a plastic handle. When properly used, a new operator can quickly attain a high degree of sorting efficiency by following certain basic principles and techniques. By using the system sorting method, efficiency can be up to 10 times as great as compared to the usual index filing.

HOW CAN THE INVENTORY BE UPDATED?

After the initial inventory of signs, updating of the inventory will be required. The frequency of updating will depend upon various factors such as employee availability and funding. To aid in the updating process, certain city employees should be trained to watch for and report problems noted during their normal routine. Possible employees that could be utilized in a system like this include the following:

1. City road crews could perform inventory on slow work days, and also in going to and from job sites.
2. Law enforcement officers.

Pre-inventory organization section is based upon 3M's "Guidelines for Developing a Multi-Purpose Manual Traffic Sign Inventory System."

CHAPTER 18

TRAFFIC ORDINANCES

Municipalities have the authority to adopt ordinances for control of traffic on their street systems. Ordinances may not, of course, conflict with State regulations, such as driving on the right side of a two-way roadway, and they must be within the scope of those matters specifically authorized by the State legislature. All municipalities have an obligation as well to periodically review their ordinances and to update them as conditions change and new needs arise. The National Model Traffic Ordinance, developed and published by the National Committee on Uniform Traffic Laws and Ordinances (NCUTLO), 1977 Massachusetts Avenue, N.W., Washington, D.C. 20036, may serve as a useful reference in drafting local traffic ordinances.

ARE THERE LIMITS TO THE LOCAL CONTROL AND REGULATION OF TRAFFIC?

Local governments may exercise control only over those portions of the local streets or highway systems over which they have jurisdiction. If the traveled portion of a street is under state jurisdiction, for instance, the municipality may not regulate the speed. On the other hand, if the municipality is responsible for maintaining the parking lanes on the same street, it may regulate such parking. The Kansas Vehicle Code permits local regulation of the following traffic elements:

- Standing or parking.
- Traffic regulation by police officers or traffic signals.
- Processions or assemblages on highways.
- Designation of one-way streets.
- Speed regulation in public parks.
- Designation of "through" streets and Stop signs at intersections.
- Permits for excess size and weight.
- Regulation of bicycles, including licensing.

- Turn movements at intersections.
- Speed regulation on city streets (see Chapter 3 for information on setting speed limits).
- U-turns.
- Jaywalking (establishment of pedestrian crossings).
- Parking restrictions during snow removal.
- Handicapped parking.

Other sections of the law permit local authorities to establish temporary or permanent weight restrictions and to limit the use of highways by vehicle type (establishment of truck routes). Any local regulation is effective and enforceable only when the appropriate signs or other regulatory devices are in place.

IS AN ORDINANCE NECESSARY FOR EACH LOCATION IN THE CITY HAVING SOME TRAFFIC CONTROL DEVICE?

An ordinance must be passed which restricts or prohibits a specific traffic operation. This ordinance must specify each location, street, or section within the municipality to which it applies. In other words, if a city passes an ordinance that prohibits parking at all times, the language of the ordinance must include the names of all streets in the city and the specific locations where parking will be prohibited. This underscores the need not only for making an initial assessment of the location in the city that must be covered by ordinance, but also the need for a periodic review of these locations to determine if changes are necessary.

WHAT TYPES OF TRAFFIC CONTROL SIGNS, SIGNALS, AND DEVICES REQUIRE AN ORDINANCE?

The MUTCD illustrates most of the standard devices now available and details their appropriate uses. However, not all devices require an ordinance. The following is a list of those which should have ordinance authority:

Stop Signs	Weight Limit Signs
Yield Signs	Truck Route or Truck Prohibition Signs
Speed Limit Signs	Loading Zone Signs
Parking Signs	Traffic Signals
One-Way Street Signs	

DO WARNING AND ADVISORY SIGNS NEED TO BE COVERED BY ORDINANCE?

Warning and advisory signs do not require ordinances, but all such signs do need to conform to the shape, size and color indicated in the Manual on Uniform Traffic Control Devices.

CAN A MUNICIPALITY REGULATE TRAFFIC ON PRIVATE PROPERTY?

Normally, no. However, local governmental agencies may enter into agreements with school boards, hospitals, shopping centers and apartment complexes to establish and enforce traffic regulations in parking areas associated with those facilities.

WHAT STEPS SHOULD A MUNICIPALITY TAKE TO MAKE SURE ORDINANCES ARE PROPER AND ENFORCEABLE?

A municipality should take steps to ensure that:

- The ordinance deals with an activity over which the municipality has jurisdiction and that it does not conflict with state statutes.
- The ordinance is clear and specific in defining the activity being regulated and the nature of the restriction or limitation.
- The public is adequately notified through appropriate regulatory devices.
- All regulatory signs and other devices comply with the requirements of the MUTCD and that any MUTCD-specified warrants are, in fact, met.

BIBLIOGRAPHY

- American Association of State Highway and Transportation Officials, "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements," 1977, Washington, DC, page 132.
- American Automobile Association, Manual on Pedestrian Safety, Washington, DC, 1964.
- Berger, W. G. (Vol.1) and Knoblauch, R. L. (Vol. 2), "Urban Pedestrian Accident Countermeasures," Bio Technology, Inc., DOT Report Available NTIS-HS-801-346.
- Gallaher, J. A., "Driver Characteristics in Parallel Parking on One-Way Streets," Traffic Engineering, Vol. 20, No. 7, April 1950, pp.276-279.
- Garwood, F., "Fatal and Serious Accidents Involving Parked Vehicles," Road Research Laboratory, Crow-Thorne, England, September 1958, page 8.
- Highway Users Federation for Safety and Mobility, "Traffic Control and Roadway Elements--Their Relationship to Highway Safety." Chapters: Railroad Grade Crossings, 1969; illumination, 1969; Driveways, 1979; Speed and Speed Control, 1970.
- Homburger, Wolfgang, S. and Kell, James H., Fundamentals of Traffic Engineering, 9th Edition, Institute of Transportation Studies, University of California, 1977.
- Institute of Transportation Engineers, Manual of Traffic Engineering Studies, 4th Edition, Arlington, Virginia, 1976.
- Institute of Traffic Engineers, Transportation and Traffic Engineering Handbook, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1976.
- Kansas Department of Transportation Highway Safety Coordinating Office, Manual on Identification, Analysis and Correction of High Accident Locations, September 1976.
- National Advisory Committee on Uniform Traffic Control Devices, Traffic Control Devices Handbook--An Operating Guide, U.S. Department of Transportation, Federal Highway Administration, 1975
- National Committee on Uniform Traffic Laws and Ordinances, Uniform Vehicle Code, Washington, DC, 1962.
- "Procedure for Estimating Highway User Costs, Fuel Consumption and Air Pollution," May 1980, U. S. Department of Transportation, Federal Highway Administration, Washington, DC, page 13.
- U.S. Department of Transportation, Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways, 1978.

HANDBOOK OF TRAFFIC ENGINEERING PRACTICES
FOR SMALL CITIES

by

SUSAN LYNN GERTH

B.S., University of Wisconsin - Platteville, 1978

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

ABSTRACT

The safe and efficient flow of traffic is an objective equally shared by state and local officials. Traffic congestion, vehicular and pedestrian accidents, and motorist delays are usually an indication of deficiencies in the roadway system or in the use of traffic control devices along the system.

The purpose of the Handbook of Traffic Engineering Practices for Small Cities is to assist local governmental officials in identifying, analyzing and solving traffic related problems. This handbook has condensed many of the thoughts and requirements of the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD).

Some of the topics which are dealt with include Stop signs, speed limits, school crossings, traffic signs, pavement markings, parking, flashing beacons, signals, roadway lighting, railroad crossings, drive-ways, commercial development, turn restrictions and one-way streets, traffic accidents, work zone protection, traffic sign inventory, and traffic ordinances.

This handbook is in a question-and-answer type of format. Each chapter presents a series of questions or typical problems which are answered and discussed in terms of traffic engineering practice appropriate for small cities.

This handbook has been designed to be used in either of two ways. If a particular problem (or question) is apparent, the reader can refer directly to the chapter covering that subject area. As an added feature, a cross reference index will be placed in the Appendix. This index cross references symptoms to causes or problems.