Crossroute Access Design in Interchange Areas

R. C. GERN and H. R. JOYNER
Barton-Aschman Associates, Evanston, Illinois

•WITH THE rapid expansion of the Interstate Highway System, a critical need to eliminate or to minimize future congestion at freeway interchanges has developed. A major cause of this problem is that important new highway facilities tend to attract new uses of land that are heavy generators of traffic. Congestion or loss of functional efficiency may then result if: (a) the additional traffic volumes generated by the new land use have not been anticipated and exceed the capacity of the interchange facilities, or (b) the access demands of the land development are incompatible with the design of the interchange or crossroute.

In many cases the crossroute, rather than the expressway itself, is the scene of interchange area congestion. Although desiring to locate as close as possible to the expressway, land development in interchange areas often creates undesirable access conditions along the crossroutes. Private access points and public streets often serving substantial volumes of traffic are sometimes located in such close proximity to ramp terminals that hazardous and congested conditions result from conflicts between ramp, access point, and through traffic.

At least a partial solution to these problems may be found in an extension of access control for a certain distance along the crossroute. The added length of protected roadway would allow heavy ramp or access point volumes to enter the route in a more orderly fashion without impeding flow through the interchange. Although the need for (and benefits from) incorporating this additional access control near interchanges has been recognized for some time, the questions of "how much" or "how far" have not thus far been satisfactorily answered.

This paper describes an analysis of the design factors which would influence such an extension of access control. The objective of this research was to develop a design aid which would identify the elements controlling the desirable distance between a ramp terminal and the nearest access point along the crossroute. Inasmuch as this distance will vary for different types and combinations of ramp and access point design (as well as for various route speeds and volumes), it was necessary to determine the controlling elements for many possible situations. (Factors such as speed and volume do not themselves represent distance, but rather, they influence design elements, such as weaving sections, which do represent distance.) Because of the many variables involved, the mathematically possible number of ramp terminal-access point combinations runs into the thousands. However, not all of these combinations represent practical designs and even fewer represent the most common situations encountered by highway designers. In this research, approximately 60 of the most common and important design situations were studied in detail. For each of these situations the controlling design elements (i.e., merging, deceleration distances, storage, etc.) were determined and combined into equations. Given normal design criteria, such as route and ramp speeds and the magnitudes of the volumes involved, these equations can be solved to give the proper spacing between ramp terminals and access points along the crossroute. Their application in highway design is shown through the use of illustrative design problems later in this report.

In addition, a coding or reference system was developed to aid in the definition or description of all possible design situations. Using this reference system, it would seem feasible to eliminate all those mathematically possible combinations of ramp terminals and access points which did not represent practical designs. This would

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produce a virtually complete list of all practical design combinations for which equations could then be written.

The material in this paper was developed as part of a comprehensive study of highway-land use relationships in the vicinity of interchanges, and is only one of several areas of investigation included in the study. Special assistance was rendered on this phase of the study by the Bureau of Design of the Illinois Division of Highways and particularly by W. A. Frick of that agency.

Other aspects of the study investigated such areas as the use or application of land-use control techniques to reduce conflicts and congestion around interchanges. The over-all study was conducted under the joint sponsorship of the Illinois Division of Highways and the U. S. Bureau of Public Roads.

GENERAL DEFINITIONS

Divided Highway—a route whose directional traffic lanes are separated by a barrier median or divider.

Off Ramp—a ramp or roadway used by traffic to exit from a controlled-access route (expressway).

On Ramp—a ramp or roadway used by traffic to enter a controlled-access route (expressway).

Expressway—a divided highway with full or partial control of access and generally with grade separations at intersecting routes.

Interchange—a system of interconnecting roadways (ramps) with one or more grade separations providing for the interchange of traffic between two or more routes or highways.

Crossroute—the route interchanging with a controlled-access facility or expressway. (In some cases, the crossroute may also be a controlled-access facility—at least in the vicinity of the interchange.)

Access Point—a point of ingress and/or egress along the crossroute. It may provide local access to adjacent land or it may indicate the intersection of another street or highway with the crossroute.

Entrance Terminal—a ramp terminal where traffic leaves a ramp and enters the through traffic lanes of the crossroute.

Exit Terminal—a ramp terminal where traffic leaves the through lanes of the crossroute and enters a ramp.

Access Point Exit—point where traffic leaves the through lanes of the crossroute and enters a local driveway, street, or other roadway intersecting the crossroute.

Access Point Entrance—point where traffic enters the through lanes of the crossroute from a local driveway, street, or other roadway intersecting the crossroute.

IDENTIFICATION AND DESCRIPTION OF DESIGN SITUATIONS

As noted previously, there can be many possible combinations of ramp terminal and access point design—with each of these, in turn, influenced by certain characteristics of the crossroute. This multiplicity of factors produced one of the early problems encountered in this research, in that it made the definition or description of a design situation subject to the omission of important factors. In an attempt to systematize the consideration of these factors, a reference system was developed which classified and grouped them into six major categories, containing the possible factors which might be used to describe one part or aspect of a ramp terminal-access point situation:

A. Type of ramp and crossroute,
B. Type of ramp terminal operation,
C. Possible movements at ramp terminal,
D. Locational relationship of ramp terminal to crossroute access point,
E. Type of access point operation, and
F. Possible movements at access point.

Tables 1 and 2 give the various factors comprising these groups. The use of this system is illustrated in the following steps as it might be applied to the typical design

TABLE 1

GROUP CLASSIFICATION OF FACTORS DESCRIBING RAMP TERMINALS ALONG A CROSSROUTE

Group	Ramp Terminal Description
A: Type of ramp and crossroute	1. Off ramp to divided crossroute 2. On ramp from divided crossroute 3. Off ramp to undivided crossroute 4. On ramp from undivided crossroute
B: Type of ramp terminal operation	1. Free-flow ramp terminal with change in number of crossroute through lanes (i.e., lane(s) added or dropped at ramp terminal) 2. Free-flow ramp terminal without change in number of crossroute through lanes 3. Signal-controlled ramp terminal with change in number of crossroute through lanes 4. Signal-controlled ramp terminal without change in number of crossroute through lanes 5. Stop-or-yield-sign-controlled ramp terminal with change in number of crossroute through lanes 6. Stop-or-yield-sign-controlled ramp terminal without change in number of crossroute through lanes
C: Possible movements at ramp terminals	Ramp Entrance Terminal: 1. Left turns from ramp prohibited 2. Left turns from ramp permitted Ramp Exit Terminal: 3. Left turns into ramp prohibited 4. Left turns from ramp prohibited but left turns into ramp permitted from through lane from direction of approach on crossroute where access point is located 5. Left turns into ramp permitted from separate lane from direction of approach on crossroute where access point is located 6. Left turns into ramp permitted from through lane from direction of approach on crossroute opposite to where access point is located 7. Left turns into ramp permitted from separate lane from direction of approach on crossroute opposite to where access point is located

TABLE 2

GROUP CLASSIFICATION OF FACTORS DESCRIBING ACCESS POINTS ALONG A CROSSROUTE

Group	Access Point Description
D: Locational relationship of ramp terminal to access point	Access Point Exit: 1. From crossroute on same side of divided crossroute as ramp terminal 2. From crossroute on same side of undivided crossroute as ramp terminal 3. From crossroute on opposite side of divided crossroute as ramp terminal 4. From crossroute on opposite side of undivided crossroute as ramp terminal Access Point Entrance: 5. To crossroute on same side of divided crossroute as ramp terminal 6. To crossroute on same side of undivided crossroute as ramp terminal 7. To crossroute on opposite side of divided crossroute as ramp terminal 8. To crossroute on opposite side of undivided crossroute as ramp terminal
E:	1. Free-flow access point with change in number of crossroute through lanes (i.e., lane(s) added or dropped at access point) 2. Free-flow access point without change in number of crossroute through lanes 3. Signal-controlled access point with change in number of crossroute through lanes 4. Signal-controlled access point without change in number of crossroute through lanes 5. Stop-or-yield-sign-controlled access point with change in number of crossroute through lanes 6. Stop-or-yield-sign-controlled access point without change in number of crossroute through lanes
F: Possible movements at access point	Access Point Exit: 1. Left turns into access point prohibited 2. Left turns into access point permitted from through lane from direction of approach on crossroute where ramp terminal is located 3. Left turns into access point permitted from separate lane from direction of approach on crossroute where ramp terminal is located 4. Left turns into access point permitted from through lane from direction of approach on crossroute opposite to where ramp terminal is located 5. Left turns into access point permitted from separate lane from direction of approach on crossroute opposite to where ramp terminal is located Access Point Entrance: 6. Left turns from access point permitted 7. Left turns from access point prohibited

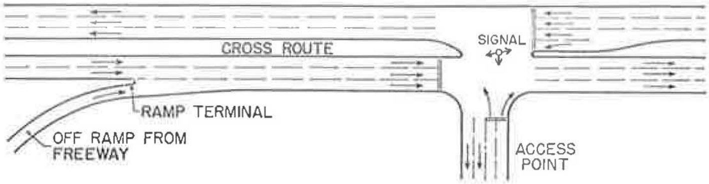


Figure 1. Typical ramp terminal-access point design situation.

situation shown in Figure 1. Entrance and exit movements are listed and analyzed separately; thus, the two-way access point in Figure 1 requires a description of both entering and exiting movements. The ramp terminal, however, serves one-way entering traffic and requires only one description.

Step 1. —Describe the ramp terminal condition. From Table 1, select Group A, Factor 1; Group B, Factor 1; and Group C, Factor 1.

There is no traffic exiting from the crossroute into the ramp at its terminal, thus the description is complete.

Step 2. —Describe the access point condition. The access point has both entering and exiting traffic; thus, each movement must be described. For the access point entrance condition, from Table 2, select: Group D, Factor 5; Group E, Factor 4; and Group F, Factor 6.

For the access point exit condition, from Table 2, select: Group D, Factor 1; Group E, Factor 3; and Group F, Factor 5.

Finally, the descriptions for the situation in Figure 1 are 1-1-1-5-4-6 (considering access point entrance) and 1-1-1-1-3-5 (considering access point exit). Note that the first three digits, which describe the ramp terminal condition, are identical in both descriptions.

Using this system, it may be possible to identify all of the design situations that are practical or significant, and then develop distance equations for each of these cases. Assuming that the six groups of factors described in Tables 1 and 2 represent all the factors needed to define any ramp terminal-access point situation, there are a finite number of combinations or situations which they could produce. Many combinations could quickly be eliminated because they would represent impossible or highly improbable situations. Those remaining could be further analyzed and distance equations developed.

The following sections of this paper discuss the development of equations for some of the most common situations, and illustrate their use with sample problems.

IDENTIFICATION OF DESIGN ELEMENTS

The preceding section discussed primarily the problems involved in defining or describing the many ramp terminal-access point design situations encountered by highway designers. In the course of developing this material approximately 60 of the most common and significant design cases were identified. Essentially, these consist of ramp terminal-access point relationships associated with simple diamond and full cloverleaf interchanges.

The immediate objective at this point in the research was to identify the design elements that would influence the proper spacing between a crossroute ramp terminal and the nearest crossroute access point. If these elements were known for a particular design case or situation, they could be combined into equation form, and the equation could be solved for various traffic volume and route speed conditions.

Adhering to this procedure, 60 design situations were studied individually to determine the design elements which were critical for each case. Basically, this involved a logical process which considered: (a) the traffic movements that were permitted or possible under each situation, (b) the various maneuvers which these movements might logically make, and (c) the manner in which the highway designer (from a standpoint of traffic efficiency and safety) would desire these movements to be made.

As this analysis continued through the various design situations, certain elements kept reappearing, whereas others were eliminated, replaced, or combined. Table 3 describes the major design elements which were determined as being applicable in these cases. Despite the fact that these elements were evolved from an analysis of only 60 design situations, there are two facts which suggest that this list may be nearly complete: (a) the extent to which many of them kept recurring in one design situation after another, and (b) the 60 situations that were studied represent probably the most common and important design cases.

The following section discusses the development of equations using these design elements as equation components.

TABLE 3

DESIGN ELEMENTS INFLUENCING SPACING BETWEEN CROSSROUTE RAMP TERMINALS AND ACCESS POINT

L	=	allowable distance between ramp terminal and nearest crossroute access point
R_R	=	radius of ramp at crossroute connection
R_{AR}	=	radius of right turn to or from access point
R_{AL}	=	radius of left turn to or from access point
S_1	=	required storage distance for right turns at a signalized intersection
S_2	=	required storage distance for left turns at a signalized intersection
S_3	=	required storage distance for through traffic at a signalized intersection
S_{L2}	=	required storage distance for left turns with no signal control (function of gaps in the opposing traffic stream)
w	=	width of access point roadway
N	=	number of lanes in one direction on crossroute
M_L	=	distance required to merge (converge separate streams of traffic into a single stream) traffic to the left (i. e., ramp traffic to through traffic)
W	=	distance required to weave (cross) traffic streams moving in the same general direction
G	=	distance traveled while seeking a suitable gap in adjacent lane traffic
C	=	distance traveled while actually changing lanes
D	=	distance required to decelerate from design speed of crossroute to design speed of turning radius at ramp terminal or access point or to stop condition
T	=	appropriate signing distance including perception and reaction time and required deceleration distance

DEVELOPMENT OF EQUATIONS

Once the controlling design elements had been determined, the establishment of equations became a simple matter of combining the pertinent elements for each particular design situation. The equations were then tested by applying them to design problems such as those illustrated in the following chapter. In every case tested, the distances obtained appeared to be reasonable in relation to the volumes and speeds which were assumed. Appendix B contains a list of references for the various design elements used in this study.

There are certain basic principles which, in effect, set the "ground rules" for the use of the equations and describe the conditions of their application. A listing and discussion of these principles are contained in the following paragraphs:

1. Method of measurement—the allowable distance, L, is measured along the crossroute from the centerline of the access point roadway to the near edge (projected) of the ramp roadway, or, in the case of a free-flow ramp terminal, to the gore.

2. Multiple values—when more than one equation can be written for a particular designation, the equation resulting in the largest total value for L should be used, thereby satisfying the most critical condition.

3. Adjustments for specific conditions—the calculated allowable distance may be adjusted for: unusual vertical or horizontal alignments; certain volume and traffic characteristics peculiar to the area (such as those found on commuter routes); frontage conditions regulating signal and sign placement; physical barriers such as bridge abutments, retaining walls, and piers.

4. Equation conditions relating to signalized intersections—whenever storage distance at a signalized intersection (either ramp terminal or access point) is an equation component, the equation for L should be written for the last car to be stored at the intersection on the end of the red signal phase. For example, the deceleration distance used in this particular equation should be measured to the end of the stored vehicles and not to the intersection stopline.

5. Equation components relating to speed—in determining the numerical value for any component which is partially or solely a function of speed, the design speed of the facility should be used.

6. Vehicle maneuvers—an important consideration in selecting elements comprising equations is that the driver of the vehicle be required to make only one decision or accomplish only one element at a time. For example, when seeking a gap in a stream of adjacent traffic (preceding a lane change maneuver), the driver should not at the same time be required to decelerate in order to enter a ramp terminal or access point. Thus, the equations developed reflect maximum consideration of traffic safety as well as high standards of design.

7. Intersection capacity analysis—should be made to determine storage and laning requirements at major intersections.

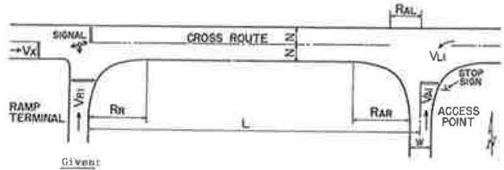
Possibly the most important principle of all, underlying the application of these equations is that they be used as guides only, and as such, must be tempered with sound engineering judgment.

APPLICATION OF EQUATIONS TO DESIGN PROBLEMS

Equations developed during the course of this research are applied to three different design situations. Route volumes, speed data, and locational and physical characteristics which would normally be available to the design engineer are supplied as "givens" in these examples. The design situations have also been identified by the coding or classification system discussed in this report.

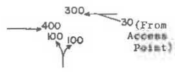
Within a single design situation, it may be possible to write two or more equations, any of which might yield the controlling distance under certain volume and speed conditions. These equations generally correspond to the various traffic movements possible in a particular design case.

EXAMPLE 1 - CODE NO.'S 343264 Access Point Exit
343666 Access Point Entrance



Given:

Rural Area
Design speed of CROSS ROUTE = 70 MPH
10% commercial vehicles
N = 1 lane
W = 20'
R_R = 150'-50'-150' (5' offset)
R_{AR} = 150'-50'-150' (5' offset)
R_{AL} = 50'
V_X = 400 DHV
V_{RI} = 200 DHV
V_{AI} = 50 DHV
V_{LI} = 20 DHV



Traffic volumes (DHV) at Ramp Terminal

To Find: L

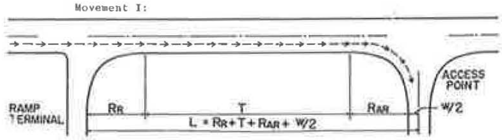
STEP 1 - Examine possible movements between RAMP TERMINAL and ACCESS POINT and select the most critical.

Movement I: From eastbound CROSS ROUTE (V_X) to a right turn at the ACCESS POINT. (Code 343264)

Movement II: Left turn from the ACCESS POINT (V_{AI}) to a stop at the RAMP TERMINAL - CROSS ROUTE signalized intersection. (Code 343666)

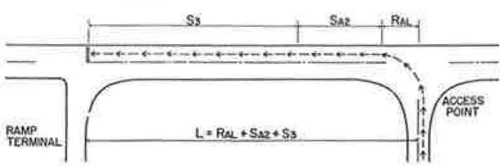
STEP 2 - Write equations for critical movements.

Movement I:



S_{A2} = Storage distance for left-turn from ACCESS POINT
R_{AL} = Left-turn Radius from ACCESS POINT
R_R = Ramp Radius
T = Appropriate signing distance (including perception and reaction time, and deceleration distance)
R_{AR} = Right turn Radius from ACCESS POINT
W = Access Point roadway width
S_3 = Storage distance for through traffic at RAMP TERMINAL - CROSS ROUTE signalized intersection

Movement II:



NOTE: An examination of the design volumes to be stored in determining S_{A2} or S_3 indicates that these combined distances will be much less than the appropriate signing distance (T) in Movement I.

Therefore, it appears that the equation for L in Movement I will result in the appropriate distance from RAMP TERMINAL to ACCESS POINT.

STEP 3 - Determine Value - Guides for equation unknowns.

Movement I:

1) T = Perception and reaction time + Deceleration distance.
T = 2.5 seconds at design speed of CROSS ROUTE (70 MPH) + Deceleration from CROSS ROUTE design speed (70 MPH) to Right-turn radius design speed (15 MPH).
T = (2.5 seconds x 103 ft./sec.) + 450'
T = 710'

2) R_R = R_{AR} = Tangent distance for 150'-50'-150' three-centered curve with $\Delta = 90°$ and a 5' offset.
R_R = R_{AR} = 85'

STEP 4 - Compute L for critical movement.

Movement I: $L = R_R + T + R_{AR} + \frac{W}{2}$

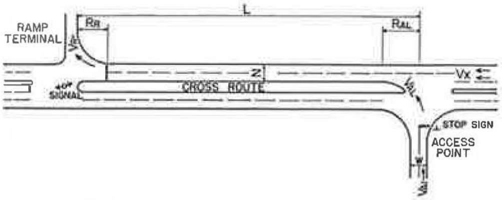
$$L = 85 + 710 + 85 + \frac{20}{2}$$

$$L = 890'$$

CONCLUSION: If a 10% tolerance in the computed Value-Guides is assumed, the length which satisfies the most critical condition is found in the range of:

L = 820' to 960'

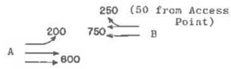
EXAMPLE 2 - CODE NO'S. 247365 Access Point Exit
247766 Access Point Entrance



Given:

Urban Area
Design speed of CROSS ROUTE = 40 MPH
10% commercial vehicles

N	2 lanes
W	20'
R_R	50'
R_{AL}	50'
V_X	920 DHV
V_R	250 DHV
V_{AL}	80 DHV
V_{AI}	100 DHV



Traffic Volumes (DHV) at Ramp Terminal

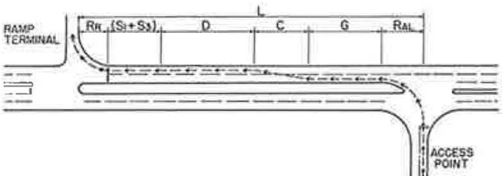
To Find: L

STEP 1 - Examine possible movements between RAMP TERMINAL and ACCESS POINT and select most critical one.

Movement I: Left turn (V_{AL}) from the ACCESS POINT to a right turn (V_R) at the RAMP TERMINAL.

STEP 2 - Write equation for critical movement

Movement I:



$$L = R_{AL} + G + C + D + (S_1+S_3) + R_R$$

R_{AL} = Left-turn radius from ACCESS POINT
G = Dist. travelled while seeking a gap in adjacent lane
C = Dist. travelled while changing lanes
D = Deceleration distance to stop condition
(S_1+S_3) = Storage dist. for right-turn and through traffic
R_R = Ramp Radius

STEP 3 - Determine Value - Guides for equation unknowns

Movement I:

1) Determine phasing and related green time at the CROSS ROUTE - RAMP TERMINAL intersection by means of a capacity analysis.

Phase A	A	green = 25%
Phase B	A, B	green = 65%
		amber = 10%
60 sec. cycle		TOTAL = 100%

2) Determine $(S_1 + S_3)$ for approach B :

$$(S_1 + S_3) = 1000\ (1.10) \times 2 \times 25 \times (1 - 0.65) \times \frac{60}{3600 \times 2} = \frac{1000\ (55)\ (0.35)}{120} = \underline{160'}$$

3) Deceleration distance from CROSS ROUTE design speed of 40 MPH to stop condition:

D = 300'

4) Distance travelled while changing lanes:

C = 3 seconds at CROSS ROUTE design speed of 40 MPH

$C = 3 \times \frac{40}{60} \times 88 \quad C = \underline{175'}$

5) Distance travelled while seeking a gap in adjacent land:

G = 5.8 seconds at average speed[1] of 27.5 MPH

$G = 5.8 \times \frac{27.5}{60} \times 88 \quad G = \underline{235'}$

STEP 4 - Compute L for critical movement:

Movement I: $L = R_{AL} + G + C + D + (S_1 + S_3) + R_R$

$L = 50 + 235 + 175 + 300 + (160) + 50$

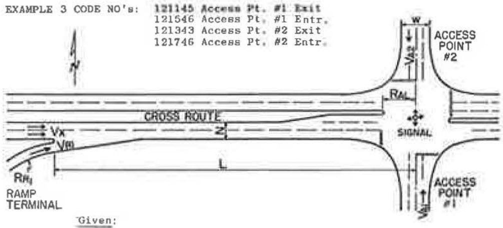
$L = 970'$

[1] Average speed = ½(design speed of CROSS ROUTE + design speed of left-turn radius at ACCESS POINT) = $\frac{40 + 15}{2} = 27.5$ MPH

CONCLUSION: If a 10% tolerance in the computed Value - Guides is assumed the length which satisfies the most critical condition is found in the range of:

L = 885' to 1055'

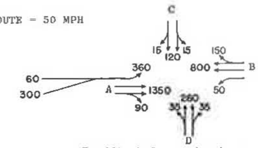
EXAMPLE 3 CODE NO's: 121145 Access Pt. #1 Exit
121546 Access Pt. #1 Entr.
121343 Access Pt. #2 Exit
121746 Access Pt. #2 Entr.



Given:

Intermediate Area
Design speed of CROSS ROUTE = 50 MPH
5% commercial vehicles

N	2 lanes
W	40'
R_{R1}	230'
R_{AR}	30'
R_{AL}	50'
V_X	1200 DHV
V_{R1}	600 DHV
V_{R2}	300 DHV
V_{A1}	350 DHV
V_{A2}	150 DHV



Traffic Volumes (DHV) at ACCESS POINT

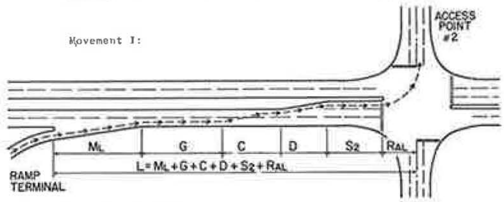
To Find: L

STEP 1 - Examine possible movements between RAMP TERMINAL and ACCESS POINT and select most critical.

Movement I: From entrance RAMP TERMINAL (V_{R1}) to a left turn at the ACCESS POINT #2 (Code no. 121145)

STEP 2 - Write equations for critical movements.

Movement I:



M_L = Merging distance
G = Distance travelled while seeking a gap in adjacent lane
C = Distance travelled while changing lanes
D = Deceleration distance to stop condition
S_2 = Storage distance for left turn
R_{AL} = Left turn radius at ACCESS POINT #2

STEP 3 - Determine Value - Guides for equation unknowns.

Movement I:

1) Determine phasing and related green time for CROSS ROUTE - ACCESS POINT intersection by means of a capacity analysis:

Phase A	A	green = 30%
Phase B	A, B	green = 40%
Phase C	C, D	green = 15%
		amber = 15%
		TOTAL = 100%

2) Determine S_2 for approach A :

$$S_2 = 360\ (1.05) \times 2 \times 25 \times (1-0.30) \times \frac{60}{3600 \times 1}$$

$S_2 = \frac{360\ (52.5)\ (0.70)}{60} \quad S_2 = \underline{220'}$

3) Distance required for ramp traffic to merge to the left (M_L):

$M_L = (20' - 8') \times 50{:}1$ Taper

$M_L = 12 \times 50 \quad M_L = \underline{600'}$

4) Distance travelled while seeking a gap in adjacent lane (G):

G = 7 seconds at CROSS ROUTE design speed of 50 MPH[1]

$G = 7 \times \frac{50}{60} \times 88 \quad G = \underline{515'}$

5) Distance travelled while changing lanes (C) :

C = 3 seconds at CROSS ROUTE design speed of 50 MPH

$C = 3 \times \frac{50}{60} \times 88 \quad C = \underline{220'}$

6) Deceleration distance from CROSS ROUTE design speed of 50 MPH to stop condition (D) :

D = 400'

STEP 4 - Compute L for critical movement:

Movement I: $L = M_L + G + C + D + S_2 + R_{AL}$

$L = 600 + 515 + 220 + 400 + 220 + 50$

$L = 2005'$

CONCLUSION: If we assume a 10% tolerance in the computed Value - Guides the length which satisfies the most critical condition is found in the range of:

L = 1810' to 2200' (for Code 121145)

CONCLUSIONS AND RECOMMENDATIONS

This study has demonstrated that a design aid to determine the proper spacing between interchange ramp terminals and crossroute access points can be developed. This design aid takes the form of distance equations that can be solved for various traffic volume and route speed values. A method or system for describing the possible design situations has also been developed and has produced equations for 60 of the most common and important cases. The equations comprise the design elements controlling the proper spacing for each individual design case.

The results of this limited-scope study suggest two major areas of further research:

1. An extension of the research initiated by this study in which all possible ramp terminal-access point design situations are identified, possibly through the use of the descriptive system developed herein. Equations could then be developed for all practical cases and published in chart or graphic form for use by highway designers. This material would have particular application in establishing highway department access policies toward local land developers. Ultimately, the material might be put into a form that could be used by local planning agencies in planning street systems and land uses in interchange areas.
2. Continued research on the values used for design elements comprising the equations. Lane changing distance requirements, lane speeds through interchange areas, signing distances, refinement of weaving standards, and merging distance requirements are some of the areas in greatest need of research.

In conclusion, it would seem appropriate to reiterate one of the basic principles underlying the development of these equations or value guides. They, like any other chart, graph, or design aid, are to be used as guides only, and not as a replacement of sound engineering judgment.

REFERENCES

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