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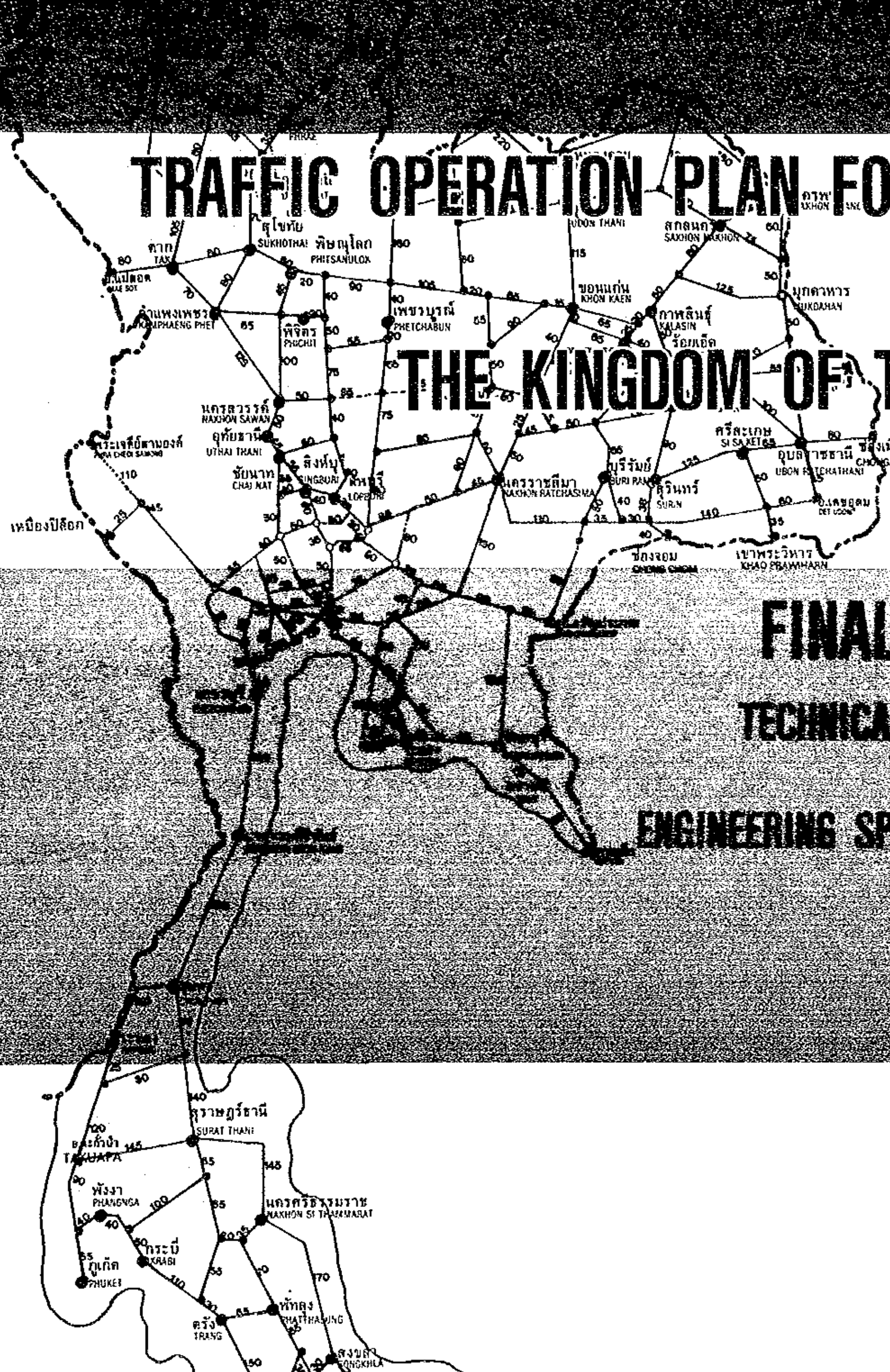
TRAFFIC OPERATION PLAN FOR ROADS IN THE KINGDOM OF THAILAND



FINAL REPORT

TECHNICAL GUIDELINES AND ENGINEERING SPECIFICATIONS

JUNE 1990

PLAN FOR ROADS IN THE KINGDOM OF THAILAND FINAL REPORT

THE STUDY
ON
TRAFFIC OPERATION PLAN FOR ROADS
IN
THE KINGDOM OF THAILAND

FINAL REPORT

TECHNICAL GUIDELINES
AND
ENGINEERING SPECIFICATIONS

JUNE 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF ABBREVIATIONS

GOJ	:	The Government of Japan
JICA	:	Japan International Cooperation Agency
GOKT	:	The Government of the Kingdom of Thailand
MOTC	:	Ministry of Transport and Communications
DOH	:	Department of Highways, MOTC
TED	:	Traffic Engineering Division, DOH, MOTC
MOI	:	Ministry of Interior
OCMRT	:	Office of the Committee for the Management of Road Traffic, MOI
BMA	:	Bangkok Metropolitan Administration
ETA	:	Expressway and Rapid Transit Authority of Thailand
AADT	:	Average Annual Daily Traffic
ADT	:	Average Daily Traffic
CRT	:	Cathod Ray Tube
GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
ITV	:	Industrial Television
OD	:	Origin and Destination
PCU	:	Passenger Car Unit
TIS	:	Thailand Industrial Standard
VTR	:	Video Tape Recorder

CHAPTER 1 MEDIAN DIVIDER, FACILITIES FOR CHANNELIZATION AND ADDED LANE IN THE NEIGHBORHOOD OF AN INTERSECTION

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1.1 TECHNICAL GUIDELINE

1.1.1 Median Divider

1. The median is a highly desirable element on all major roads with four or more lanes.

2. The width of median should be more than the value shown in Table 1.1. However, in unfavorable locations, such as bridges, viaducts (including flyovers) and underpasses, the widths may be reduced to the values in parentheses.

Table 1.1 Width of Median

Unit : m

median	1.50 (1.00)** (minimum)
marginal strip	0.30 (0.25)**
c*	0.50 (0.25)**
lateral clearance	0.80 (0.50)**
appurtenances of road	0.50 (minimum)

Note * : see Figure 1.1.
** : Width in parentheses are applied in the case of bridges, etc.

3. The width of the marginal strip should be 0.30m. In an unfavorable place, such as bridge and viaduct, the width may be reduced to 0.25m.

In this guideline, the raised portion is defined as the median.

Median guard fences should be set on the median, or the surface of the median should be raised to secure directional separation. Marginal strips should be set on both sides of the median.

The function of the median are as follows;

A. To ensure the smooth and safe traffic flow by physically separating opposing traffic.

B. To control undesirable right turning and U-turning vehicles.

C. To provide space for a speed changes lane and a storage of right turning and U-turning vehicles at an intersection.

D. To minimize headlight glare.

E. To provide a safe place for crossing pedestrians.

F. To provide space to install road apparatuses, such as a traffic sign and a traffic signal.

The functions of the marginal strip are as follows;

A. To secure the lateral clearance.

B. To clearly show the edge of carriageway and facilitate visual guidance.

Width of each components of median are shown in Figure 1.1.

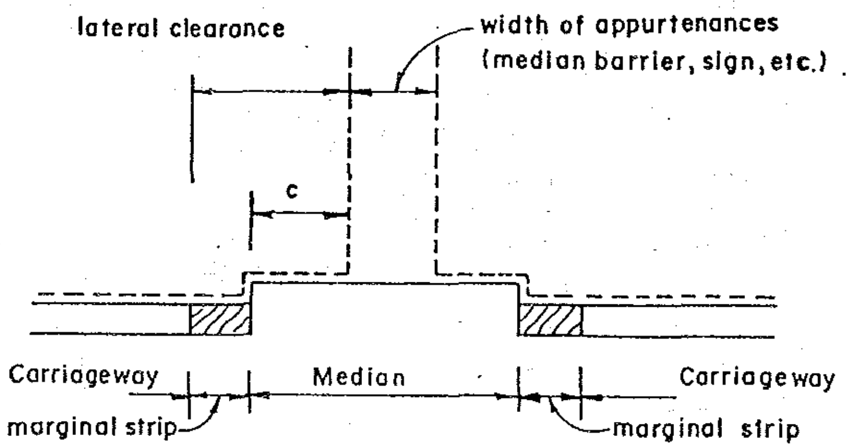


Figure 1.1 The Relation between Median Width, Lateral Clearance and Width of Appurtenances

1.1.2 Facilities for Channelization

(1) Channel

1. When designing a channel, the speed of the design vehicle and various other conditions must be taken into account.

2. For the arrangement of a channel, the traffic volume, method of traffic control, and pedestrian movements should be taken into account, in order to prevent disturbance on traffic flow.

3. The standard width of a channel corresponding to the design vehicles is shown in Table 1.2.

Table 1.2 Width of Channel

Unit : m

Design Vehicle / Outer Radius of Channel	Semi-Trailer (Major Trunk Roads)	Ordinary Motor Vehicle (Other Roads)
13 ≤ R < 14	8.5	5.5
14 ≤ R < 15	8.0	
15 ≤ R < 16	7.5	5.0
16 ≤ R < 17	7.0	
17 ≤ R < 19	6.5	
19 ≤ R < 21	6.0	4.5
21 ≤ R < 25	5.5	
25 ≤ R < 30	5.0	4.0
30 ≤ R < 40	4.5	
40 ≤ R < 60	4.0	3.5
60 ≤ R	3.5	

4. The width of channel should be determined according to the design vehicle, the radius of curvature, and the turning angle. The width should not be too wide or too narrow.

It is desirable to concentrate channels as much as possible in order to minimize the size of intersections and to maintain orderly traffic flow. If a channel width is too wide, traffic flows become disorderly when the traffic volume is heavy. Therefore a suitable width of channel should be provided.

a) Radius of Curvature of Channel

For a left turn channel in rural areas, when there is no restriction in the right of way, the design speed should be the same as for the through lane, and the curve radius should be selected in compliance with the speed. If a channel is independently provided, superelevation should be applied.

For the right turn channel, the radius of curvature would be from 15 to 30m when an intersecting angle is nearly 90 degrees, considering that vehicles have to first stop then proceed at very low speeds. In this case, the inner curve begins approximately 5m before the outer curve, so that it is desirable the tangent length of the outer curve be longer than that of inner curve. (Figure 1.2)

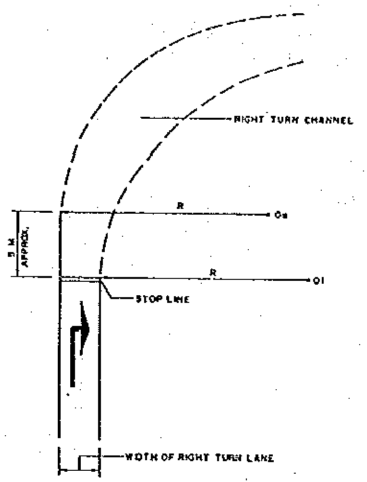


Figure 1.2 Design of Right Turn Channel

On urban streets, where the length of a corner cut has already been determined, the maximum possible radius can be determined on the basis of the width of sidewalk. (Figure 1.3). Right turn channels can be designed in the same way as in a rural area.

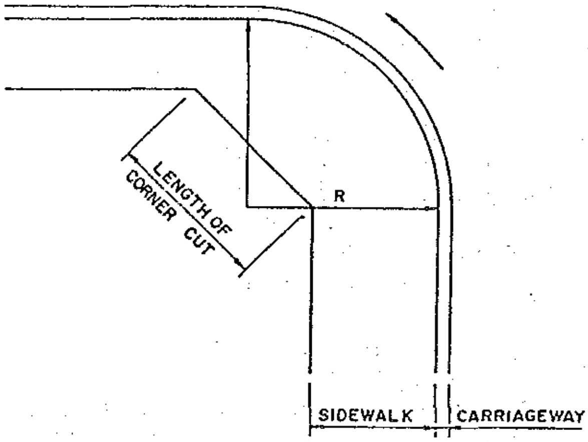


Figure 1.3 Radius of Corner-curb and Length of Corner Cut

b) Width of Channel

The width of a channel should be the values shown in Table 1.2, in conformity to the design vehicle and the radius of curvature. When a channel is separated by an island, with the same pavement condition as the carriageway, a lateral clearance allowance of 0.5m should be provided on both sides of the channel. This lateral clearance allowance may be included in the width necessary for the shoulder, gutter, and setback for channel.

The transition taper of widening is generally provided at the inner side. In this case, a clothoid curve or circular curve should be applied for the transition curve. For a circular curve, the radius of curvature must be 3 to 4 times the inner radius of channel.

c) Treatment for a Channel of Wide Width

If a channel of comparatively small radius is governed by the semitrailer as the design vehicle, the channel width should be wide. In this case, confusion of traffic flows may result from the parallel turning by numerous small-sized vehicles as well as a side contact type of an accident between a large-sized vehicle and a motorcycle could readily occur.

For this type of channel with a wide width, it is necessary to provide a proper channelization, such as zebra markings, to maintain a sufficient lane width for one small-sized vehicle as shown in Figure 1.4, apart from circumstances where a multilane channel is provided if left turning is the main traffic flow.

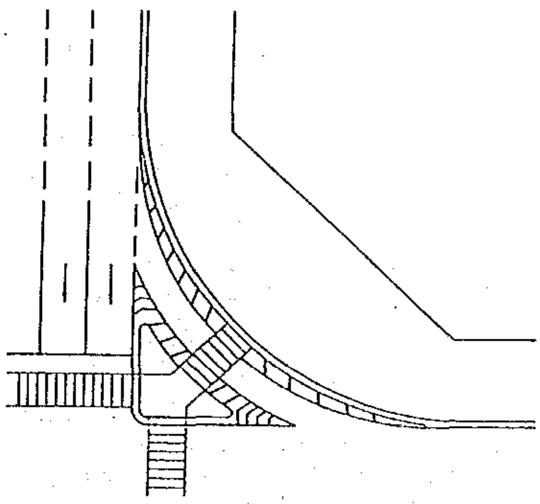


Figure 1.4 Channel of Wide Width

(2) Traffic Island and Separator

1. A traffic island and a separator should be provided to maintain proper and safe traffic flows at an intersection, where channelization is considered.

2. In principle, a traffic island and a separator should be provided with curbs.

3. In the following cases, it is desirable to provide a separator at the approach of an intersection, even though a two-way highway is not separated by a median.
   - where roads with a design speed of 60 km/hr, or higher, intersect each other.
   - where many pedestrians cross a carriageway and the crossing distance is long.

4. For the design, the channel should be located first and then traffic islands and separators would be positioned within the remaining portion. For this case, an appropriate nose offset and setback should be provided.

5. The appropriate width, length, and area of traffic islands or separators should be determined taking their function into full consideration.

6. As a general rule, an alignment will be the combination of a straight line and a circular curve.

7. It is desirable to provide indications with pavement markings, etc. on the approach to a traffic island or a separator.

An at-grade intersection, where traffic is directed into definite paths by islands or separators, is termed as a channelized intersection. An island and a separator are defined areas between traffic lanes to control vehicle movements. Islands and separators also provide areas for pedestrian refuge and traffic control devices.

Islands are generally included in intersection design (channelization) for one or more of the following purposes;

- Separation of traffic flows.
- Control of the angle of traffic conflict.
- Reduction in excessive pavement areas.
- Regulation of traffic and an indication of the proper use of the intersection.
- Protection of pedestrians.
- Protection and storage of turning vehicles.
- Provision of space to install traffic control devices.

Islands serve the following three primary functions. Most islands combine two or all of these functions.

A. Channelization : to control and direct traffic movement, usually turning,

B. Division : to divide opposing or same direction traffic streams, usually through movements,

C. Refuge : to provide refuge for pedestrians.

The minimum radius of curvature of the approach nose of an island would generally be 0.5m. The nose offset (O_1, O_2) and the setback (S_1, S_2, S_3) shown in Figure 1.5 would be provided. These values differ according to the speed of vehicles, the size of an island, location of an intersection (urban or rural area), and the classification of the road. The standard values are shown in Tables 1.3 and 1.4.

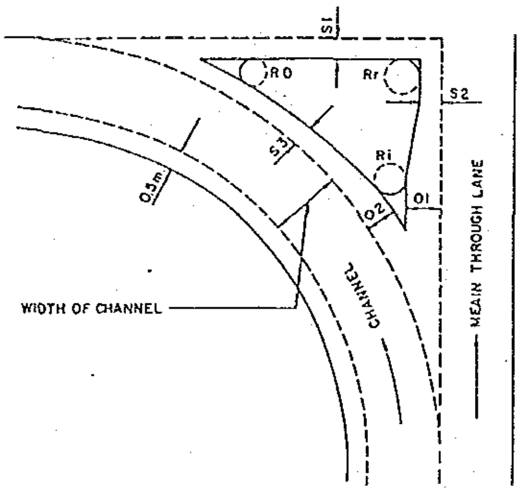


Figure 1.5 Setback and Nose Offset

Table 1.3 Values of Setback and Nose Offset

Unit : m

Design Speed (km/hr)	S_1, S_2	S_3	O_1	O_2
80	1.0	0.5	1.5	1.0
60	0.75	0.5	1.0	0.75
50	0.5	0.5	0.5	0.5

Table 1.4 Radius of Island Nose

Unit : m

R_i	R_o	R_r
0.50 - 1.00	0.50	0.50 - 1.50

The transition of the nose offset should be provided on both sides of the through lane as well as channel for the whole island. In the case of a large island, the rate of transition would be 1/10 to 1/20 on the through lane side, and 1/5 to 1/10 on the channel side.

The provision of a very small island would cause not only problems for drivers but also create a danger of a collision at an island during a rainy night. The minimum dimensions of island and separator are shown in Table 1.5 and Figure 1.6 according to the type. When the prescribed size of island or separator can not be provided in spite of its necessity, pavement markings *should be provided instead of the island or separator.*

Table 1.5 Minimum Dimensions of Island and Separator

	Element	Urban	Rural
(a)	W_a l_a R_a	1.0 m 3.0 m 0.5 m	1.5 m 5.0 m 0.5 m
(b)	W_b l_b R_b Area	1.5 m (W_p + 1.0)m 0.5 m 5.0 m^2	2.0 m (W_p + 1.0)m 0.5 m 7.0 m^2
(c)	W_c l_c	(D + 1.0)m 5.0 m	(D + 1.5)m 5.0 m
(d)	W_d	1.0 m	1.5 m

Note D : Width of Road Appurtenance (m).
W_p : Width of Crosswalk.
W_{a-d} : See Figure 1.6.

Provision of pavement markings on the approach to an island is important from the traffic safety point of view. The minimum transition length of pavement markings should be the value obtained from the following equation, as shown in Figure 1.7.

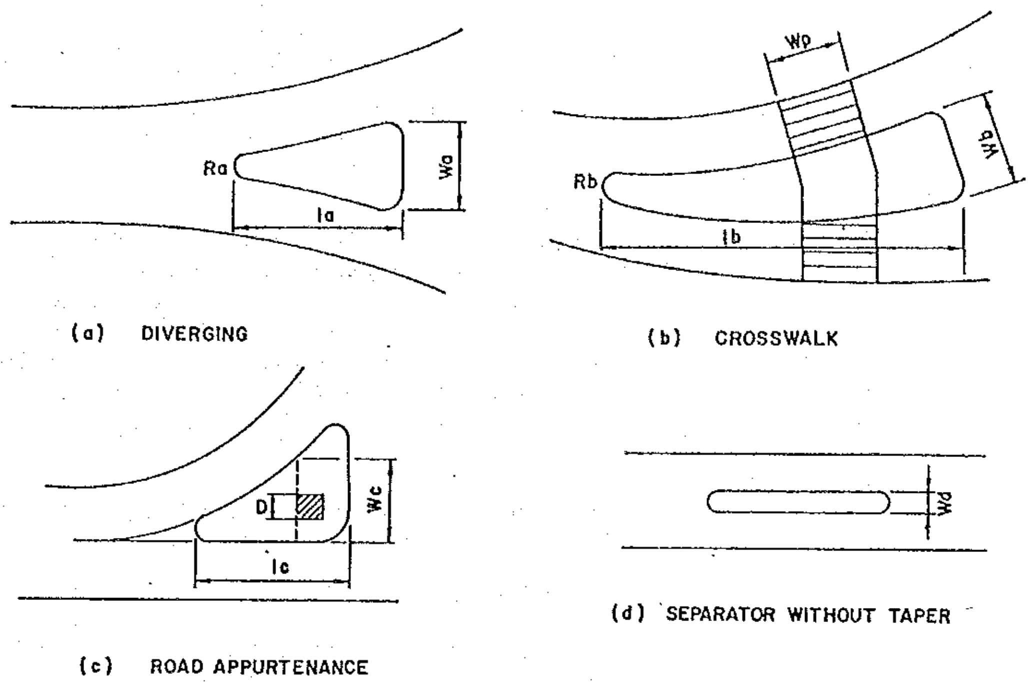


Figure 1.6 Islands and Separators

$l_a = \frac{1}{3}$ VR --- ((a) for diverging)

$l_b = \frac{2}{3}$ VR --- ((b) for one direction shifting)

where;
- l_a, l_b : transition length of marking, in m.
- V : design speed, in km/hr.
- R : radius of approach nose of island, in m.

When the shifting direction is not a main traffic flow in the case of (b), the transition length can be l_a.

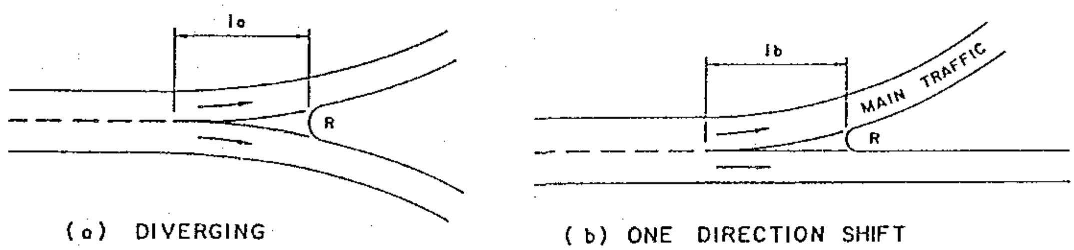


Figure 1.7 Transition Length of Marking of Approach to Island

(3) Passage Method and Corner Cut

a) Passage Method

The passage methods at an intersection are shown in Table 1.6. They differ according to the classification of roads and type of traffic control at an intersection. Since the geometric design of an intersection depends on the passage method, it is necessary to determine the passage method for the intersection design. Table 1.6 shows the standard of passage method of right and left turning vehicles.

Table 1.6 Passage Method of Right and Left Turning Vehicle at an At-grade Intersection

Classification of Road / Condition			Suburban, Rural				Urban			
			Major Trunk	Major	Minor	Access	Major Trunk	Major	Minor	Access
Stop Control	Approach		S4*	T4	T4	T3, T2 or T1	S4*	T3	T2	T1
Stop Control	Exit	Major Road	S4*	T4	T3	T2 or T1	S4*	T3	T2	T1
Stop Control	Exit	Minor Road	-	T3	T3	T2 or T1	-	T2	T2	T1
Signal Control	Approach		S4*	T4	T4	T3, T2 or T1	S4*	T3	T2	T1
Signal Control	Exit		S3*	T3	T2	T2 or T1	S3*	T2	T2	T1

Note -- S : Semi-trailer
T : Ordinary Motor Vehicle

The numbers "1" to "4" associated with S and T in Table 1.6 represent the following passage methods.

1. Occupy the full width of carriageway.
2. Occupy the left side of carriageway without using the opposite lane.
3. Occupy the turning lane and the neighboring lane without using the opposite lane. Instead of the turning lane, the rightmost lane might be used for the right turn or the leftmost lane for the left turn, together with the neighboring lane.
4. Occupy only the turning lane or the rightmost lane for the right turn, and the leftmost lane for the left turn.

* : If there is a difference in the design vehicle used for a major road and a minor road, the design vehicle of the minor road would be used.

Figure 1.8 shows examples of the passage method at an intersection.

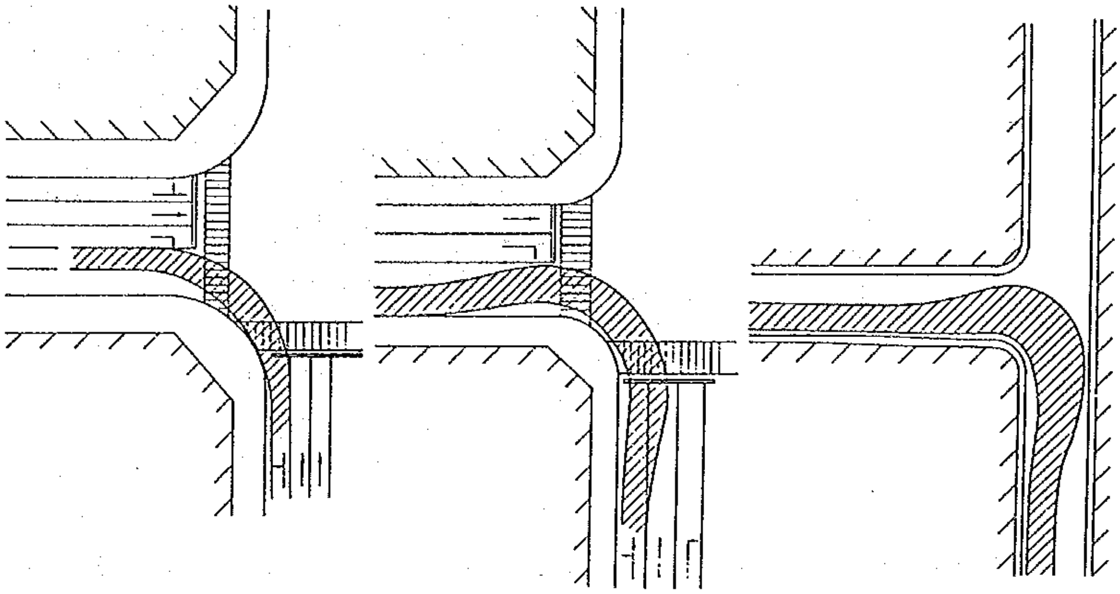


Figure 1.8 Example of Passage Method at an At-grade Intersection

It is necessary to take the followings into consideration.

A. At an approach of a road on the exit side where passage method "1" is adopted, it is necessary to sufficiently set back a stop line.

B. When the vehicle corresponding to the design vehicle is turning right or left at an approach of a multilane road adopting methods "1" to "3", the neighboring lane might be occupied. However, if the division of passage at the approach to the intersection is regulated such as by traffic signs, passing to occupy the neighboring lane should be prohibited.

b) Corner Cut

At an at-grade intersection, it is necessary to provide the corner cut to ensure the safe and smooth flow of traffic and to form a comfortable road space.

It is desirable that the length of a corner cut be determined by examination of the various factors at each intersection, based on the necessary values for the smooth passage of vehicles which will depend on the intersecting angle, the width of sidewalk, the design vehicle, and the passage method (See Figure 1.9). The various factors are as follows; the storage space of pedestrians and bicycles, visibility, and space for landscaping. In urban areas, it is not necessarily practical to calculate the length of corner cut at each intersection (See Figure 1.10). The general standard lengths of corner cut at urban intersections are shown in Table 1.7.

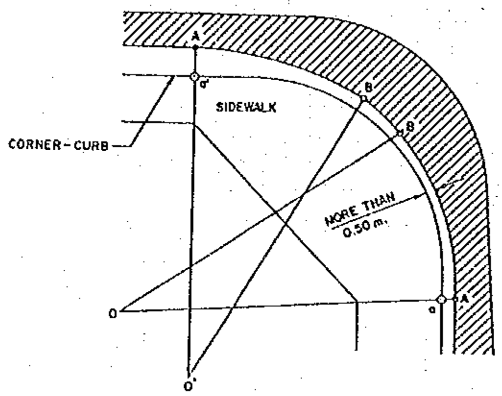


Figure 1.9 Occupied Width by Vehicle and Corner-curb

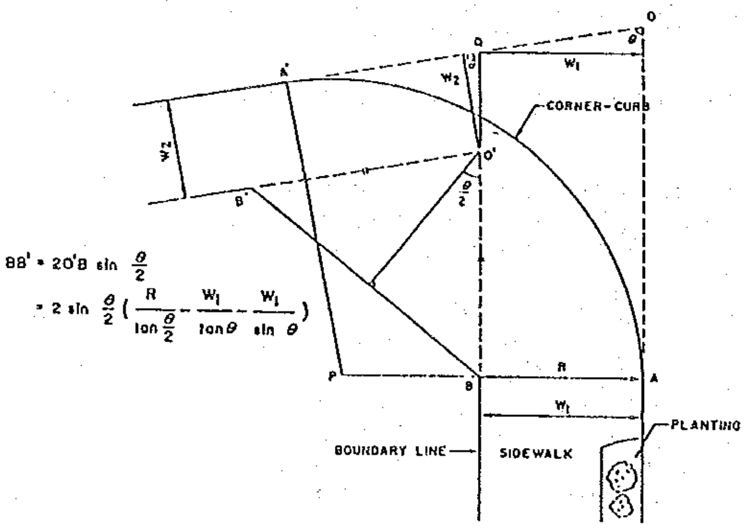


Figure 1.10 Corner Curb and Corner Cut

Table 1.7 Standard Length of Corner Cut

Unit : m

Classification	Major Trunk Roads	Major Roads	Minor Roads	Access Roads
Major Trunk Roads	12	10	5	3
Major Roads	–	10	5	3
Minor Roads	–	–	5	3
Access Roads	–	–	–	3

1.1.3 Added Lane in the Neighborhood of an Intersection

(1) Right Turn Lane

> 1. At an at-grade intersection, a right turn lane should be provided except in the following cases.
>   - Right turn prohibition.
>   - On Minor Roads and Access Roads, when they could be considered to have sufficient capacity in a peak hour.
>   - On a two-lane road with a design speed of 40 km/hr or less, when the design traffic volume is less than 200 vehicles/hour and the right turning rate is less than 20%.
>
> 2. The length of the right turn lane should be determined according to the design speed and the number of vehicles stored in the right turn lane.

a) Providing a Right Turn Lane

Provision of a right turn lane is effective in preventing accidents involving right turning vehicles but it decreases the traffic capacity caused by right turning vehicles.

Therefore, as a general rule, right turn lanes should be provided at all at-grade intersections except in the above mentioned cases. However, on rural roads, it is desirable to provide right turn lanes in order to secure the safety condition, even though the above mentioned rules are applicable.

The right turn lane should be provided independently to the through lane except for the special case when the right turn flow is the main traffic flow. In principle, a through lane should not be used as a right turn lane, since it is necessary to shift right turning vehicles from the through lane to the right turn lane. However, if it is required to make use of a through lane as a right turn lane, due considerations should be made.

b) Length of Right Turn Lane

The length of a right turn lane consists of the length of taper and the storage length. (Figure 1.11)

$$L = l_d + l_s$$

where;
- L : length of right turn lane, in m;
- l_d : length of taper, in m;
- l_s : storage length, in m.

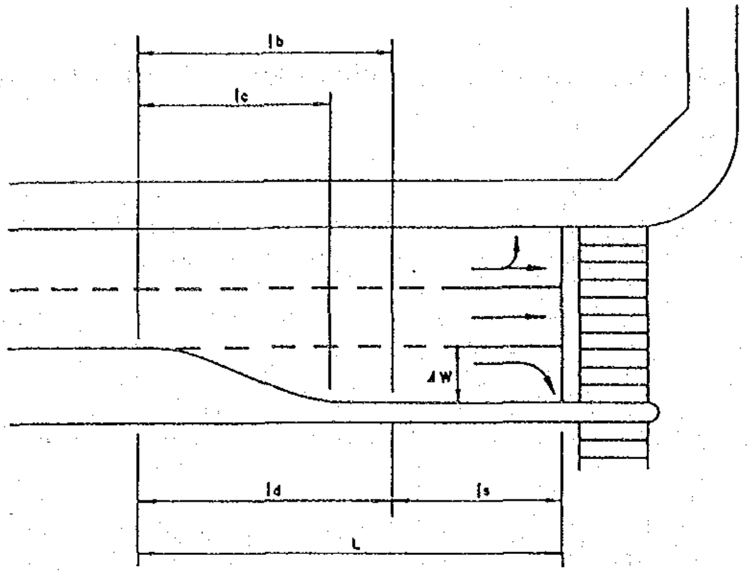


Figure 1.11 Length of Right Turn Lane ($l_b > l_c$)

The length of taper, l_d, is the necessary length not only for the deceleration, but also for the shifting of right turning vehicles smoothly from the through lane to the right turn lane. Therefore the length of taper, l_d, should not be less than either the deceleration or the necessary shifting length.

The minimum length for deceleration, l_b, at an at-grade intersection is shown in Table 1.8. The minimum length, for shifting, l_c, from the through lane to the right turn lane, is obtained from the following equation.

$$l_c = \frac{V \times \Delta W}{6}$$

where;
- l_c : minimum length for shifting, in m.
- V : design speed, in Km/h.
- ΔW : lateral width for shifting, in m. (width of added lane)

Table 1.8 Minimum Length for Deceleration (l_b)

Unit : m

Type (Area) / Design Speed (km/hr)	Major Highway in Rural Area	Urban Highways/and Minor Highway in Rural Area
80	60	45
60	40	30
50	30	20
40	20	15
30	10	10
20	10	10

Therefore, the minimum length of taper, l_d, must be the larger of either the value of l_b shown in Table 9.8 or the value of l_c obtained by the above equation.

$$l_d = \max.\ (l_b,\ l_c)$$

The necessary length of storage is obtained from the following equation.

$$l_s = 1.5 \times N \times S$$

where;
- l_s : storage length, in m.
- N : average number of right turn vehicle per cycle, in veh./cycle.
- S : average space headway, in m. (passenger car, S = 6m, large-sized vehicle, S = 12m)

The average space headway, S, is adjusted by the composition rate of a large-sized vehicle. When this rate is not available, S may be 7m.

At an unsignalized intersection, l_s, is obtained from the following equation taking the fluctuation of traffic volume into account.

$$l_s = 2 \times M \times S$$

where;
- M : average number of right turn vehicles per minute, in veh./min.

When the storage length cannot be calculated at either a signalized or an unsignalized intersection, the storage length should be at least 30m.

The value of l_d and l_s obtained from the above equations are the minimum length of right turn lanes. In rural areas, where high speed traffic is expected, the length of the right turn lane should be as long as possible. In this case, it is desirable the length be at least double the above l_d value.

On the other hand, it is often difficult to maintain in urban areas the desirable length of right turn lane as mentioned above. When it is necessary to reduce the length of right turn lane, the taper length (l_d) should firstly be reduced, whereas it is desirable to provide the necessary storage length (l_s).

c) Right Turn Lane at Newly Constructed At-grade Intersection

Generally, the prediction of traffic volumes at newly constructed at-grade intersections may not be precise. It is therefore desirable to secure spaces for future improvements of right turn lanes, if this is feasible.

d) Multi-Right Turn Lanes

When the right turning volume of traffic is heavy and multi-right turn lanes are planned, the storage length is obtained by dividing the necessary length of storage l_s, at a singular right turn lane by the number of right turn lanes.

When multi-right turn lanes are provided, it is necessary to pay special attention to the segregation of right turning traffic and opposing through traffic, and the method of providing a median. In this case, an exclusive right turn signal phase should be provided. In addition, the number of lanes at the exit section must be more than the number of right turn lanes.

(2) Left Turn Lane

1. In the following cases, a left turn lane or left turn roadway should be provided.
   - where an intersecting angle is not more than 60 degree and the left turn traffic volume is heavy.
   - where the left turn traffic volume is very heavy.
   - where the speed of left turning vehicles is high.
   - where the left turn traffic volume is heavy and there are many pedestrians crossing the carriageway at the left turning exit.
   - for special cases when provision of a left turn lane is warranted.

2. The length of the left turn lane should be determined according to the design speed and the number of storage vehicles.

The provision of a left turn lane must be made independently to the through lane. The same should be applied to the right turn lane.

The length of the left turn lane, L, shown in Figure 1.12, consists of the length of taper, l_d, and the storage length, l_s. The length of the left turn lane is determined by the same method as the length of right turn lane.

The left turn roadway shown in Figure 1.13 is defined as the left turn channel separated by a traffic island. The left turn roadway may be used either independently or as an approach-end treatment for the left turn lane or deceleration lane.

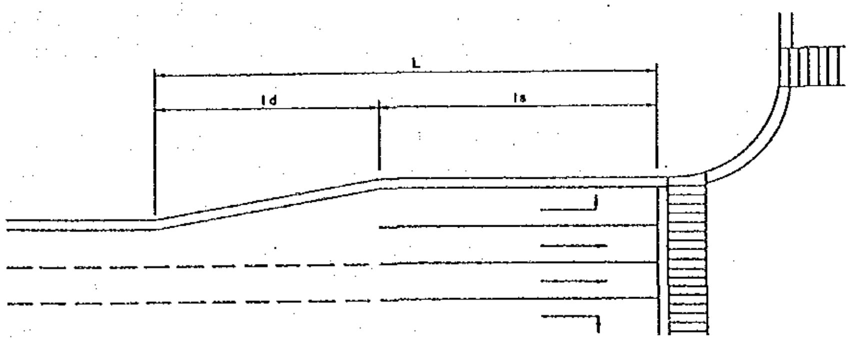


Figure 1.12 Left Turn Lane

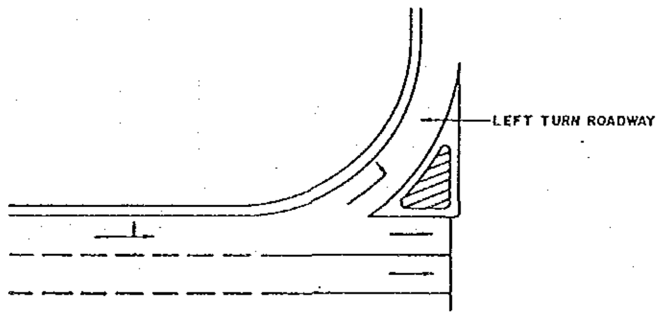


Figure 1.13 Left Turn Roadway

(3) Speed Change Lane

1. In the following cases, a deceleration lane should be provided.
   - where there are decelerating or diverging traffic from the Major Trunk Roads with full or partial access control.
   - where the necessity is warranted.

2. In the following cases, an acceleration lane should be provided.
   - where there are accelerating and merging traffic into the Major Trunk Roads with full or partial access control.
   - where the necessity is warranted.

3. The lengths of the speed change lane vary according to the characteristics of roads, the difference between design speed of the through lane and that of the speed change lane, the method of traffic control, etc. The standard lengths of speed change lanes are shown in Table 1.9.

The items prescribed in this section should generally be applied to the speed change lanes provided at an at-grade intersection.

Table 1.9 Standard Length of Speed Change Lane (excluding taper)

Unit : m

Type (Area) / Speed (km/h) / Design Speed (Km/h)	Length of Deceleration Lane						Length of Acceleration Lane					
	Major Highway in Rural Area			Urban Highway and Minor Highway in Rural Area			Major Highway in Rural Area			Urban Highway and Minor Highway in Rural Area		
	To Stop	To 20km/h	To 40km/h	To Stop	To 20km/h	To 40km/h	From Stop	From 20km/h	From 40km/h	From Stop	From 20km/h	From 40km/h
80	60	50	30	45	40	25	140	120	80	90	80	50
60	40	30	20	30	20	10	100	80	40	65	55	25
50	30	20	-	20	15	-	60	50	-	40	30	-
40	20	10	-	15	10	-	40	20	-	25	15	-
30	10	-	-	10	-	-	20	-	-	10	-	-

The standard length of the speed change lane should not be less than the value shown in Table 1.9.

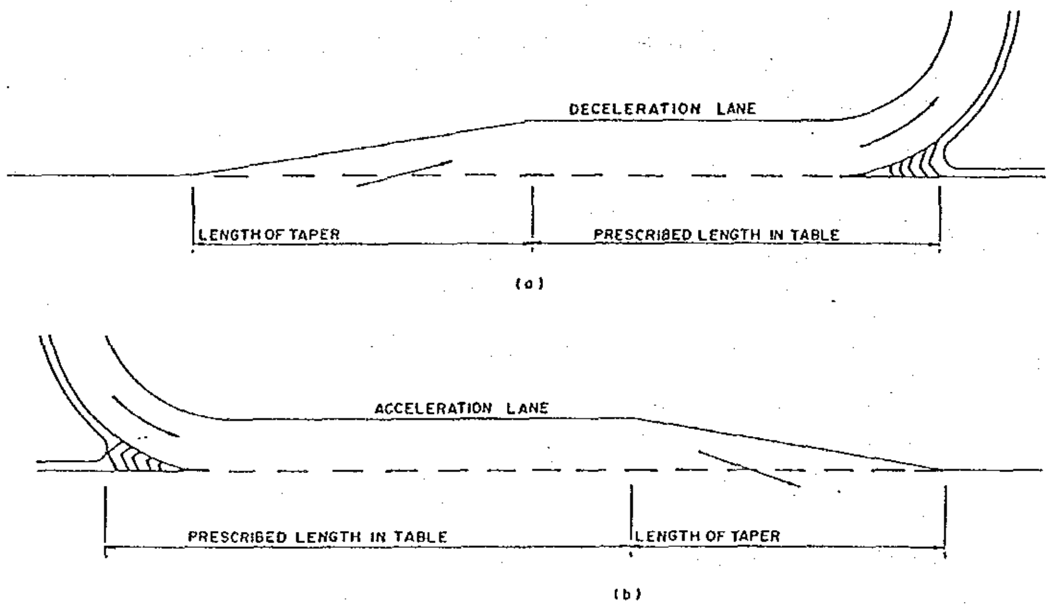


Figure 1.14 Speed Change Lane

(4) Cross Section in the Neighborhood of an Intersection

1. When the turning lane or the speed change lane is provided at an intersection, the width of a lane other than the turning or the speed change lane may be reduced to 3.0m on Major Trunk Roads and Major Roads in urban areas. On other roads, the width may be reduced to 2.75m.

2. The standard width of the turning lane and the speed change lane is 3.0m.

3. When the turning lane or the speed change lane is provided at an intersection, an appropriate transition run-off should be provided, in conforming to the design speed.

4. The value of lane widths should be as shown in Table 1.10, conforming to the classification of road.

Table 1.10 Lane Width at an At-grade Intersection

Unit : m

Type (Area)	Road Class	Lane width of Mid-block Section	Width of Through Lane in the Section Provided Added Lane	Width of Added Lane
Urban	1. Major Trunk Roads	3.5	3.5 or 3.25	3.25, 3.0 or 2.75 (2.5)**
	2. Major Roads	3.25 [3.5]*	3.25 or 3.0	
	3. Minor Roads	3.0	3.0 or 2.75	
Sub-urban Rural	1. Major Trunk Roads	3.5	3.5	
	2. Major Roads	3.25 [3.5]*	3.25 [3.5]*	
	3. Minor Roads	3.0	3.0	
	4. Access Roads	3.0	2.75	

Note -- * : Lane width in [ ] will only be applied when necessary.

** : In an unavoidable case, width shown in ( ) can be applied for a right turn lane in urban area.

a) Lane Width

It is often difficult to acquire land in the neighborhood of an urban street, when provision of an added lane or the through lane is desired. In this case, the width of the through lane may be reduced by 0.25m by decreasing the design speed by 20km/h at the intersection. This means that it is desirable to provide an added lane even if this means reducing the widths of through lanes, stopping lanes, and medians at an intersection.

The standard width of an added lane is 3.0m. However the width of a right turn lane in urban areas may be reduced to 2.5m when the composition rate of heavy vehicles is low and the above mentioned width cannot be attained by reducing the width of sidewalk, etc.

b) Widening for the Right Turn Lane

Even if the width of a right turn lane cannot be attained on existing roads because of several restrictions, segregation of right turning vehicles at an intersection is still effective from the traffic management point of view. In this case, however, it is desirable to widen the lane by shifting the center line by 1.5m, if this is possible, and to secure the space for right turning vehicles without providing lane line markings, as shown in Figure 1.15.

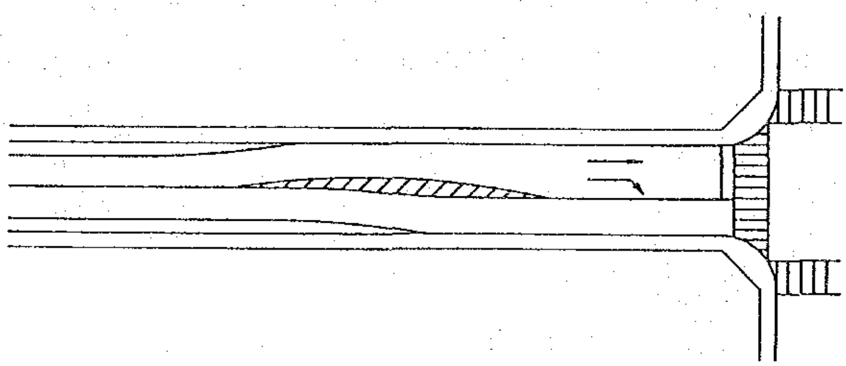


Figure 1.15 Widening for the Right Turn Lane

c) The Number of Lanes

As a general rule, the number of lanes at an exit of an intersection must be the same as the number of through lanes at its approach. This number of through lanes is equal to the total number of lanes minus the number of right and left turn lanes.

When it is necessary to reduce the number of lanes at an exit of an intersection to be less than at its approach, the number of through lanes at an approach should be also decreased. In this case, extra through lanes at the approach may be used for the turning lanes.

The shifting of lanes within an intersection must be avoided by laying out the lanes at the exit section of an extension line of through lanes at the approach section. In a situation where the through lane at the approach is shifted as shown in Figure 1.16 in order to provide the right turn lane, the lane at the exit should be laid out as an extension of the shifted through lane at the approach.

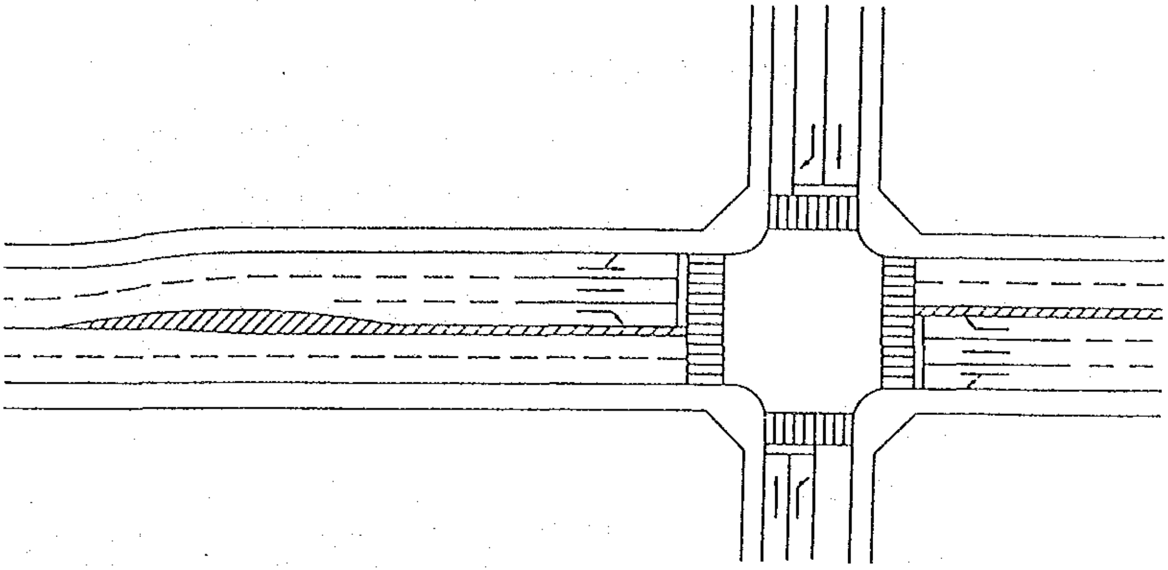


Figure 1.16 Through Lane at an Exit Section Corresponding to the Shifted Lane at an Approach

d) Lane Shift

The section length of lane shift for providing the added lane at an at-grade intersection should be determined according to the design speed, the urban or rural status of the area, and the horizontal alignment.

When lane shift is required at the approach of an intersection in order to provide the added lane, the standard section length of lane shift at its tangent section should be the larger value either calculated by the equation or the minimum value shown in Table 1.11. The standard value of a tangent section may be a good guide to the lengths of lane shift at a curved section.

Table 1.11 Section Length of Main Through Lane Shift

Unit : m

Area / Design Speed (km/h)	Suburban, Rural		Urban	
	Calculation Formula	Minimum Value	Calculation Formula	Minimum Value
80	$\frac{V \cdot \Delta W}{2}$	85	–	–
60		60	$\frac{V \cdot \Delta W}{3}$	40
50	$\frac{V \cdot \Delta W}{3}$	40		35
40		35		30
30		30		25
20		25		20

Note -- ΔW : Lateral value of lane shift in m.
V : Design speed in km/hr.

1.2 ENGINEERING SPECIFICATION

1.2.1 Example of Traffic Control Devices Improvements

In this section, some examples of traffic control devices improvement are presented as references for improvements of various shape of intersections.

(1) Y-Shaped Intersection (1) (see Figure 1.17)

a) Before Improvement

1) Major problems

A. This intersection is an acute angle intersection. The distance between stop lines were very long and no guide marking was provided in the intersection. Hence, the travel path through the intersection was not clear.

B. The approach section from 'A' was one lane, but there were relatively heavy right turn traffic volumes. Hence, right turn vehicles (A - C) often disturbed the through traffic flow.

C. Two crosswalks were installed on B road and C road and were close together. This resulted in pedestrians trying to cross both crosswalks as a single movement. This condition was particularly dangerous for students and pupils.

D. Sidewalks were installed only on one side of A road and B road.

b) After Improvement

1) Improvement of the geometric design

Sidewalks on A road and B road were installed together with widening of the road space. On the other hand, a sidewalk was installed on C road by reducing the lane width.

2) Traffic operational measures

A. A right turn lane was provided on A road by shifting the location of the stop line forward.

B. Guide markings were provided in the intersection in order to control the traffic flow.

C. Two crosswalks on B road and C road was combined into one crosswalk. Also, an exclusive signal phase for pedestrians was provided in order to allow pedestrians to cross the whole length of the crosswalk.

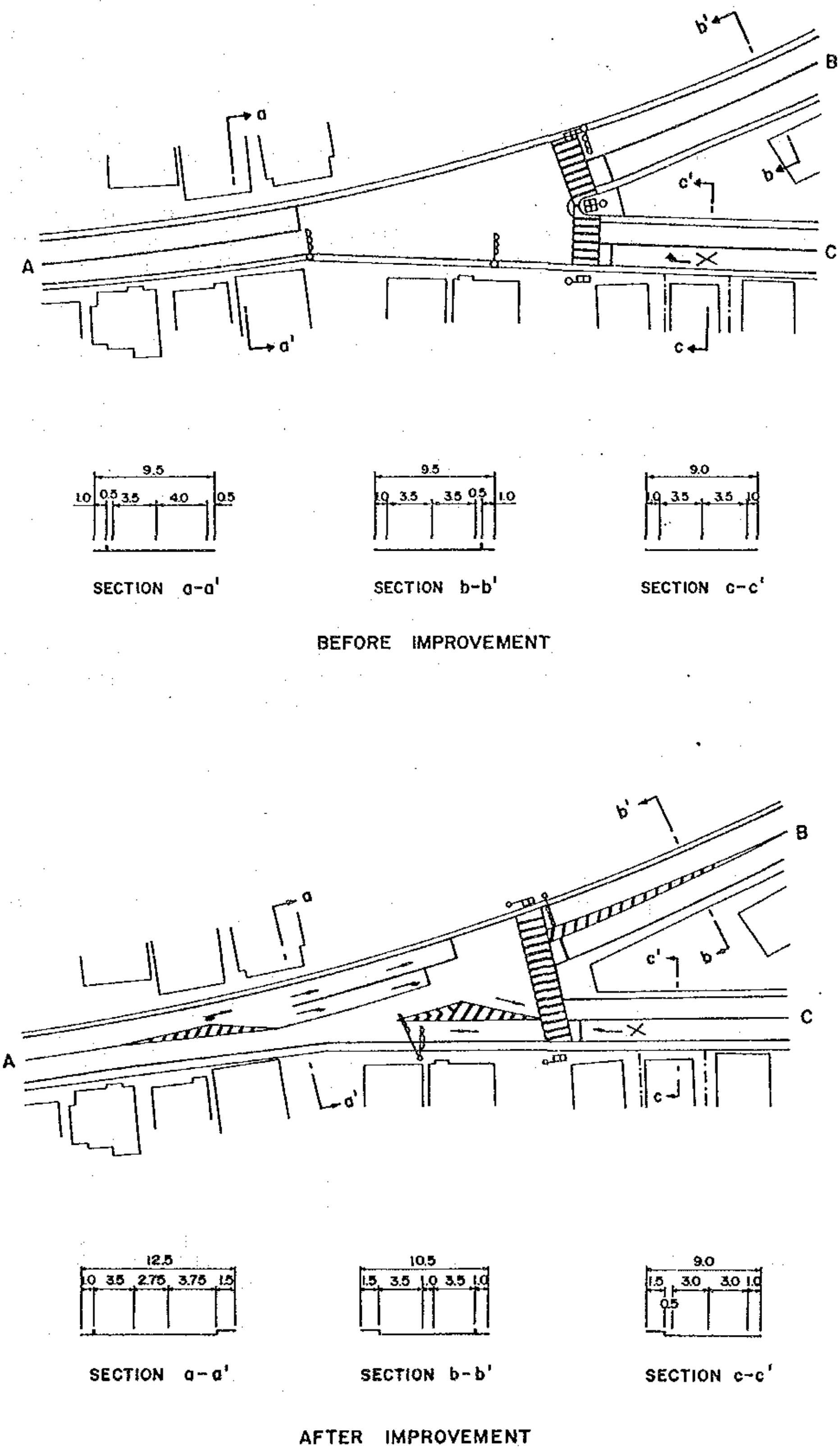


Figure 1.17 Y-Shaped Intersection Improvement Plan (1)

(2) Y-Shaped Intersection (2) (see Figure 1.18)

a) Before Improvement

1) Major problems

A. This intersection is located on a curved section.

B. Even though the right turn traffic volumes are heavy at 'A' approach, no exclusive right turn lane was provided. Hence, right turn vehicles often disturb the through traffic flow.

C. The same situation was found for left turn vehicles at 'B' approach.

D. The distance between stop lines at 'A' and 'B' approaches was very long.

E. The crossing length of a crosswalk on 'C' approach was very long.

F. There was no waiting space for pedestrians at approaches to the crosswalk on 'C' approach. In addition, no sidewalk was installed on both sides of the road C. Hence, pedestrians were forced to wait before crossing on the carriageway.

b) After Improvement

1) Improvement of the geometric design

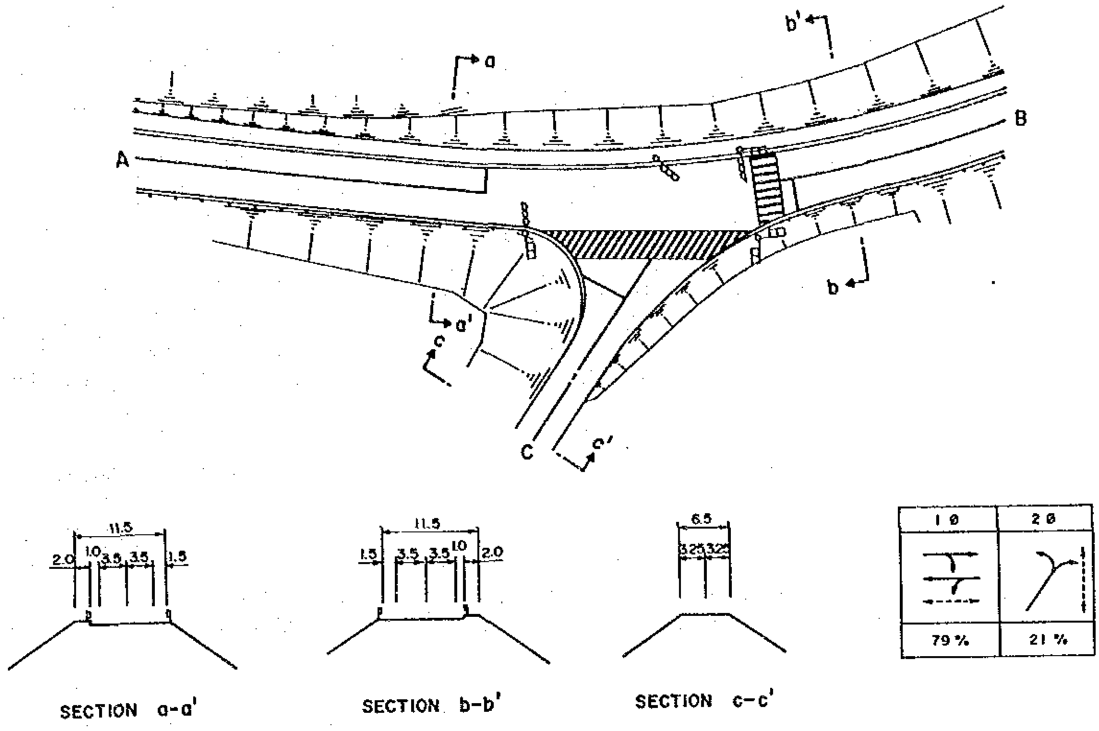
A sidewalk was installed on one side of C road by widening the road space. At the same time, lane width was also widened.

2) Traffic operational measures

A. An exclusive right turn lane was provided on 'A' approach in order to segregate right turn vehicles from the through traffic flow.

B. An exclusive left turn lane was provided on 'B' approach in order to segregate left turn vehicles from the through traffic flow.

C. The crosswalk on 'C' approach was shifted away from the intersection in order to reduce the crosswalk length.



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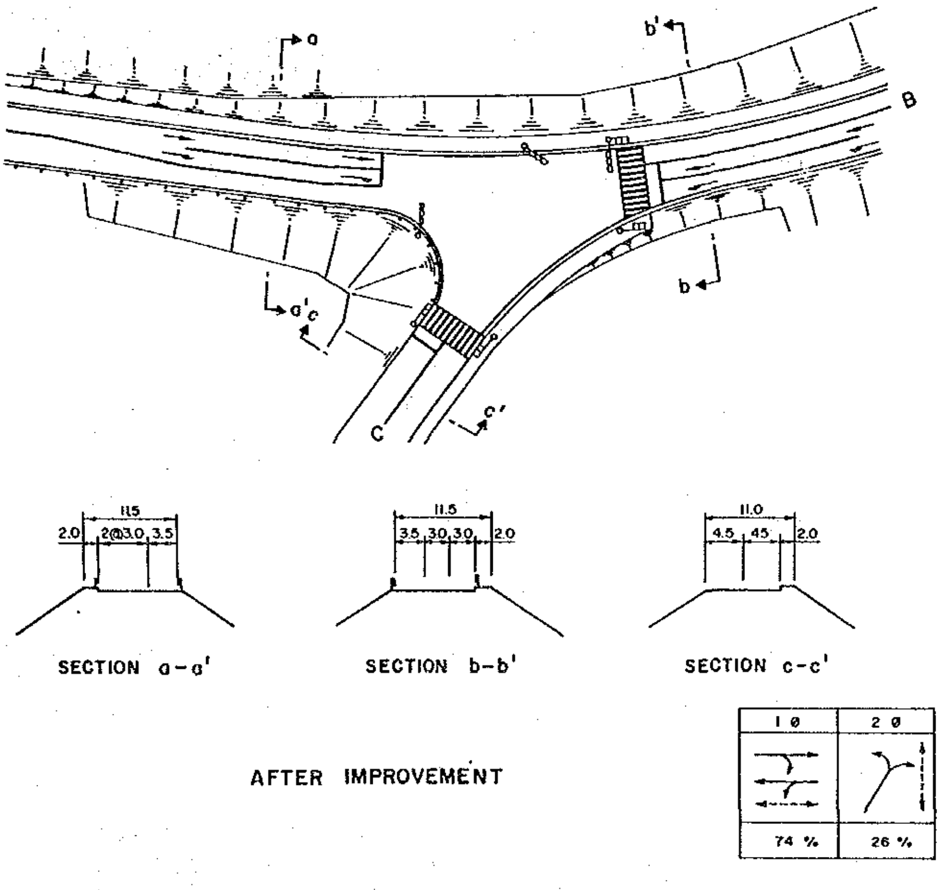


Figure 1.18 Y-Shaped Intersection Improvement Plan (2)

(3) T-Junction (1) (see Figure 1.19)

a) Before Improvement

1) Major problems

A. Traffic volumes on approach 'B' reached 900-1000 vehicles/hr during peak periods. In addition, the composition of left turn vehicles on approach 'B' was quite high at 30-40%. However, since the approach was only one lane, traffic capacity was insufficient.

B. No sidewalk was installed to connect the crosswalk on C road.

C. Two stop lines were provided in the intersection and at the crosswalk for the through traffic lane on 'A' approach. This caused the confusion to drivers as regards stopping location.

D. There were two left turn traffic lanes on 'C' approach including the side road; however, the exit was only one lane. This caused conflicts at the merging section. In addition, since the distance between the stop line on 'C' approach and the crosswalk on A road is quite long, vehicles tended to accelerate, which caused a danger to crossing pedestrians.

E. Many rear-end collisions occurred on 'A' approach and 'B' approach.

b) After Improvement

1) Improvement of the geometric design

A. B road was widened and an exclusive left turn lane was provided. Also, sidewalks were improved.

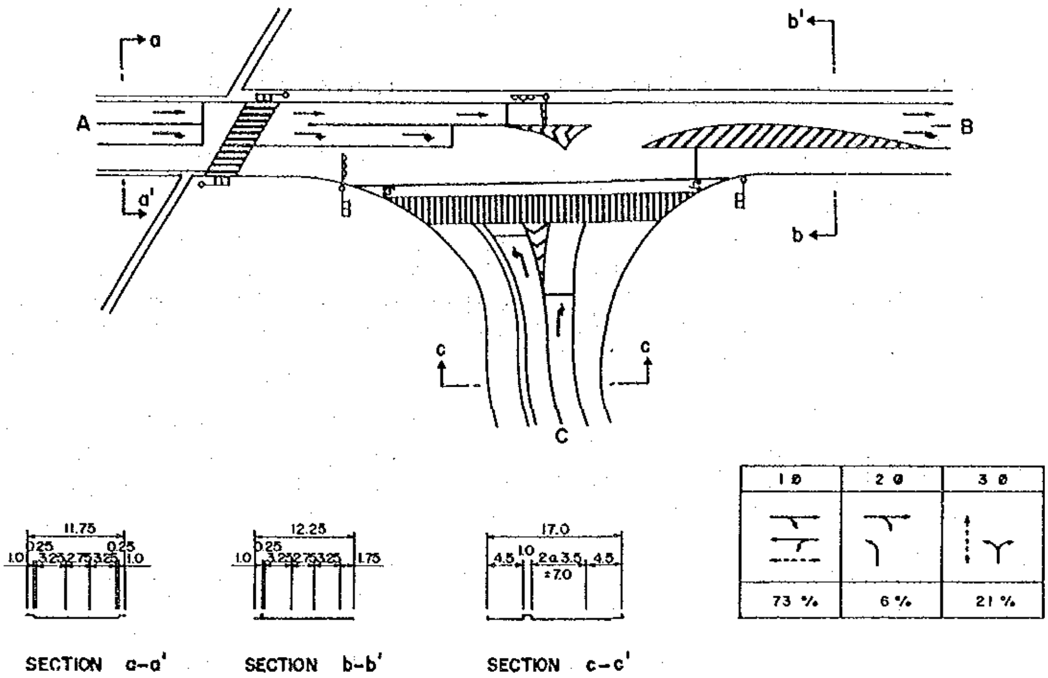
B. A traffic island was installed in order to segregate left turn traffic from the 'C' approach and the side road.

2) Traffic operational measures

A. Guide markings in the intersection was improved.

B. The crosswalk on A road was shifted to the intersection by using a traffic island and a stop line in the intersection was removed.

C. Second phase of the signal was modified as an exclusive signal for the right turn and left turn, in order to prevent rear-end collisions, caused by traffic queues at downstream intersection of B road.



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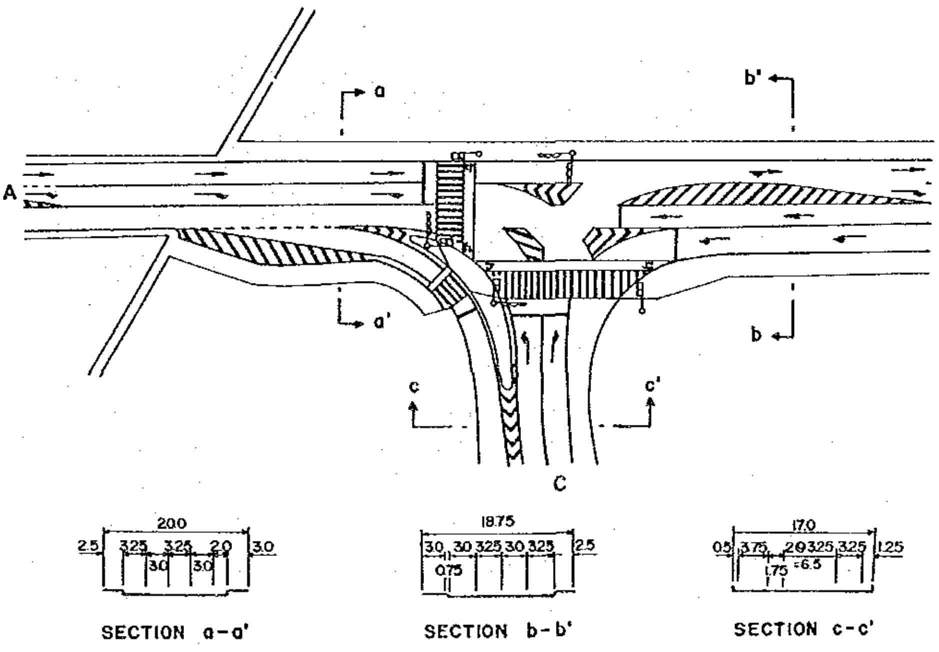

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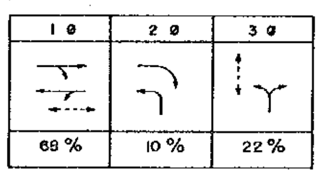


Figure 1.19 T-Junction Improvement Plan (1)

(4) T-Junction Improvement Plan (2) (see Figure 1.20)

a) Before Improvement

1) Major problems

A. The radius of corners were very large and the crosswalk and a stop line on C road were located rather far from the intersection center; hence the intersection area was large.

B. Due to the large intersection area, the velocity of right turn vehicles tended to be high. Hence there was traffic safety problem for pedestrians crossing the crosswalk on B road.

C. No guide marking was provided in the intersection; hence travel path was not clear.

D. Many rear-end collisions and right turn accidents occurred mainly due to the unclear travel path through the intersection.

b) After Improvement

1) Improvement of the geometric design

A. The intersection area was reduced by applying appropriate corner radii and shifting the location of the crosswalk and a stop line on 'C' approach to the inner area of the intersection.

B. By using the spare areas generated by modifying the corner radius, sidewalks were improved and roadside trees were planted.

2) Traffic operational measures

A. The crosswalk on 'B' approach was shifted to 'A' approach in order to avoid conflicts between right turn vehicles from 'C' approach and crossing pedestrians.

B. The crosswalk and a stop line on C road were shifted close to the intersection.

C. An exclusive right turn lane and a left turn lane were provided at 'C' approach.

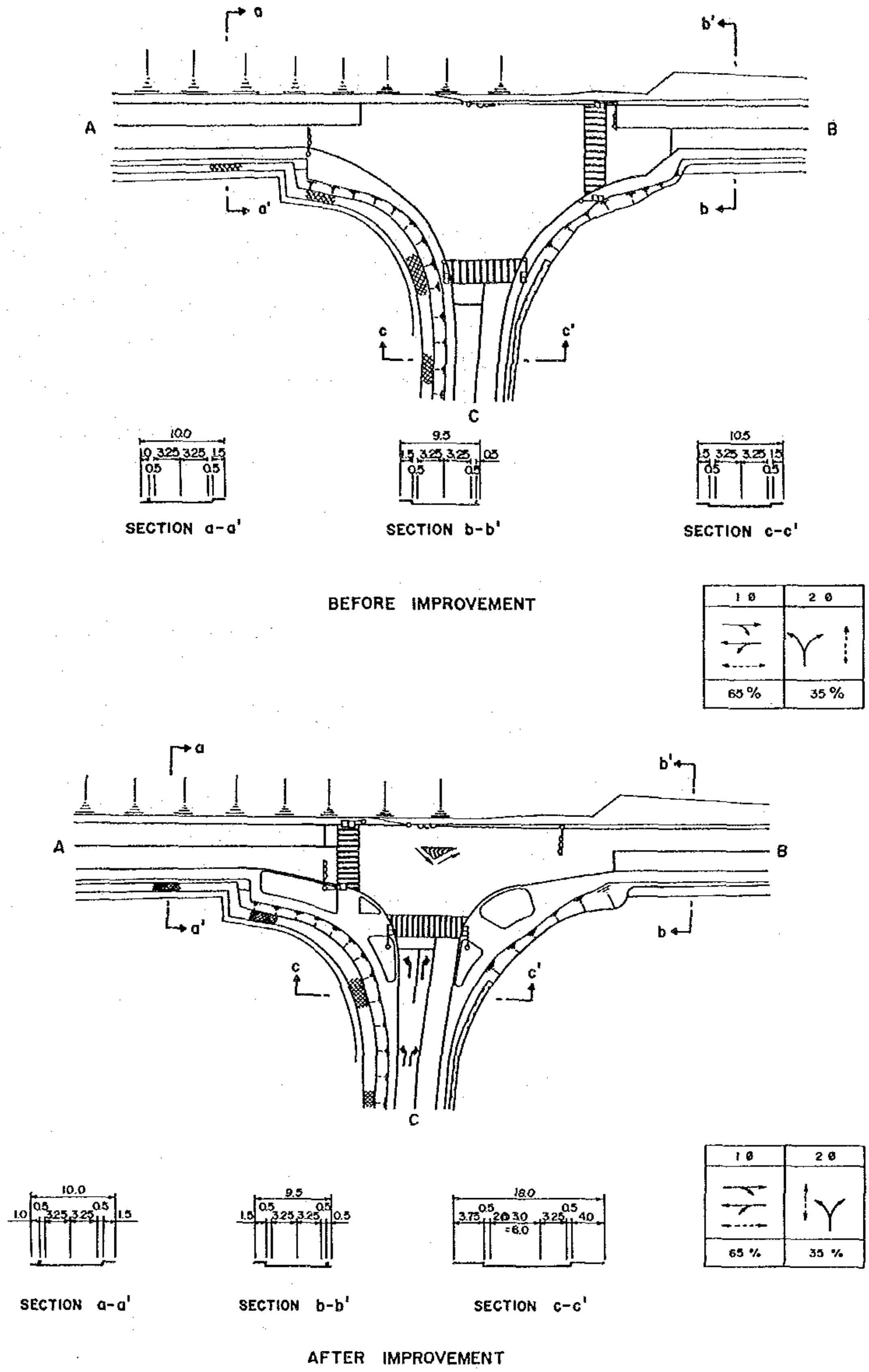


Figure 1.20 T-Junction Improvement Plan (2)

(5) X-Shaped Intersection (see Figure 1.21)

a) Before Improvement

1) Major problems

A. A - C direction is the main road, while right turn and left turn from B road and C road is high.

B. The crossing angle of this intersection is acute and the distance between stop lines are long. However, no guide marking was provided at the intersection; hence the travel path for vehicles was not clear.

C. No right turn lane was provided for every approach; hence right turn vehicles often disturbed the through traffic flow.

b) After Improvement

1) Improvement of the geometric design

A. The intersection area was reduced by providing left turn channels on 'B' and 'D' approaches.

B. An exclusive right turn lane was provided on 'B' approach by reducing the width of the sidewalk.

2) Traffic operational measures

A. Exclusive right turn lanes were provided on 'A', 'B' and 'C' approaches.

B. Guide sign markings for right turn were provided in order to clarify the travel path through the intersection.

C. Free turning was allowed for left turn vehicles from 'B' approach.

D. Bicycle crossings were provided on 'B' and 'C' approaches.

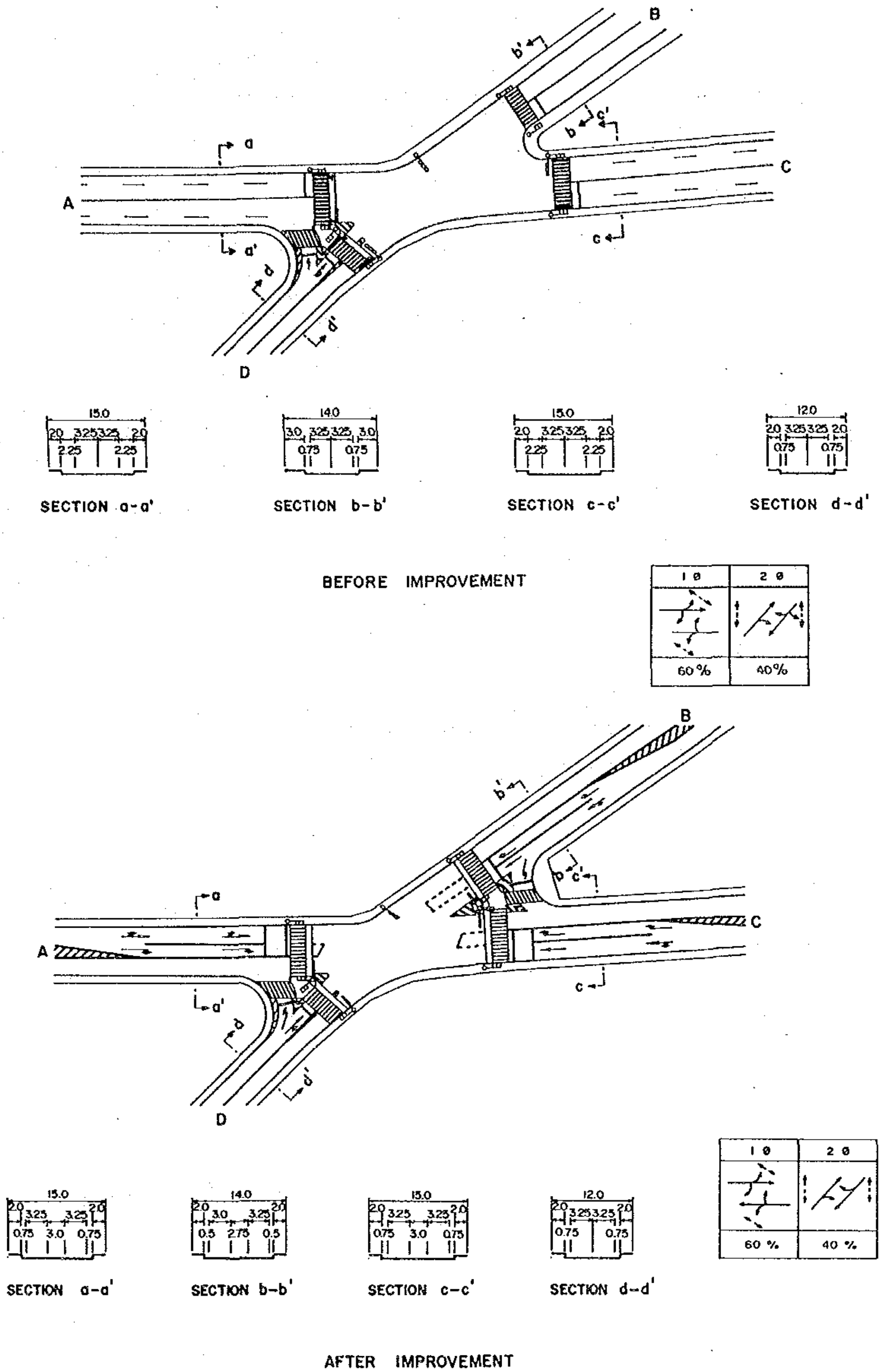


Figure 1.21 X-Shaped Intersection Improvement Plan

(6) Ordinary 4-Leg Intersection (see Figure 1.22)

a) Before Improvement

1) Major problems

A. The main traffic flow was A - C direction.

B. No exclusive right turn lane was provided on 'A' and 'C' approaches, which caused chronic congestion. In addition, some accidents between through vehicles and right turn vehicles occurred.

b) After Improvement

1) Improvement of the geometric design

Since pedestrian volumes at this intersection were limited, the width of sidewalks on A road and C road were reduced by 50cm. Then, lane width in these direction were widened in order to provide spaces for right turn vehicles.

2) Traffic operational measures

An exclusive right turn phase was provided for right turn traffic of 'A' and 'C' approaches.

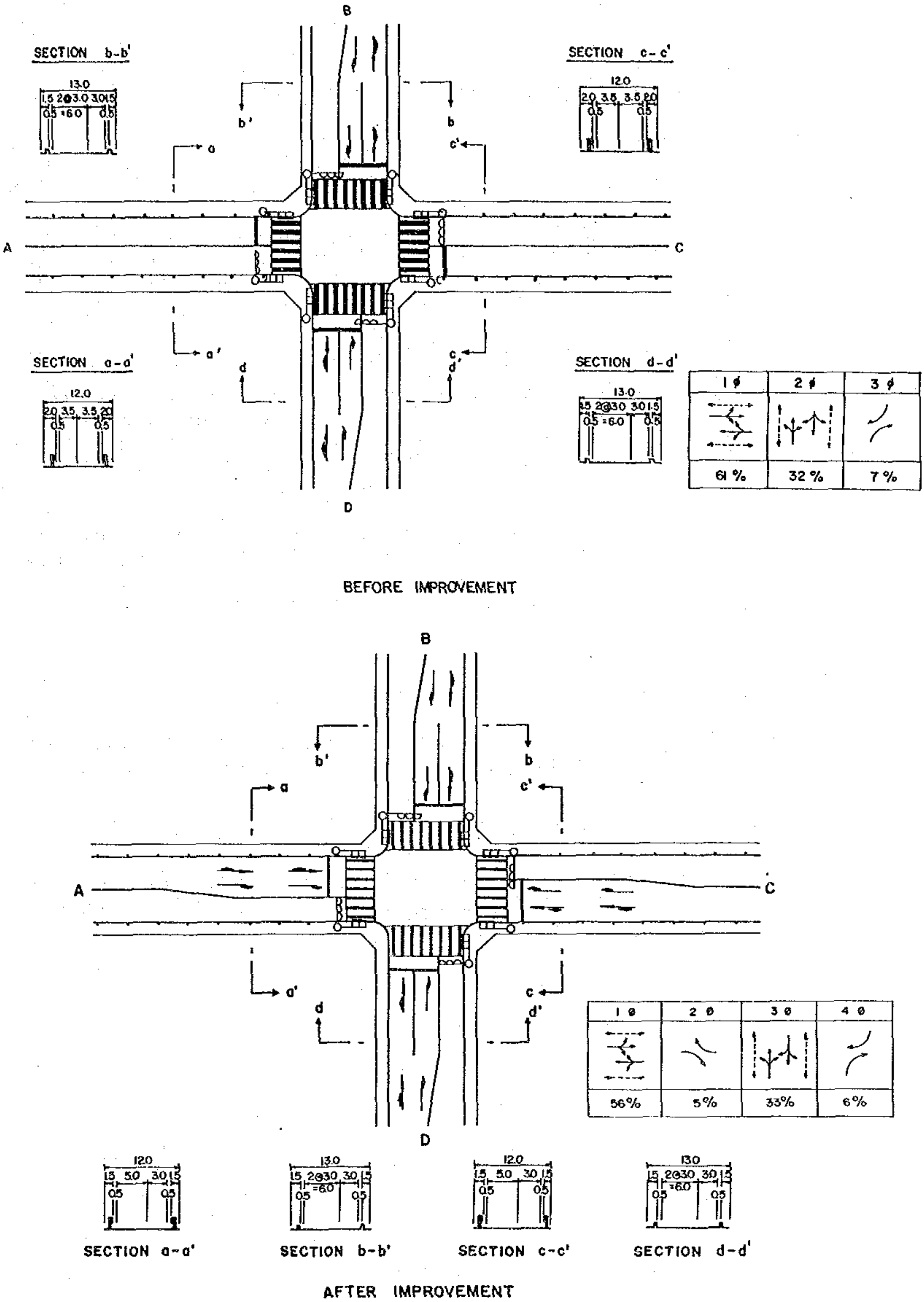


Figure 1.22 Ordinary 4-Leg Intersection Improvement Plan

(7) Staggered Intersection (see Figure 1.23)

a) Before Improvement

1) Major problems

A. Right and left turn ratio from minor roads 'B' and 'D' were very high at about 40% of total traffic volume entering from these two roads during the morning peak period.

B. Many pedestrians cross the main road.

C. No exclusive right turn lane was provided on the main road (A road and C road) even though approaches of both roads were two lanes. Hence, right turn vehicles on those roads disturbed through traffic flow, which caused the traffic congestions.

D. No guide marking was provided in the intersection. Hence, the running path was not clear, particularly through and right turn vehicles from 'B' and 'D' approaches, and conflicts occurred.

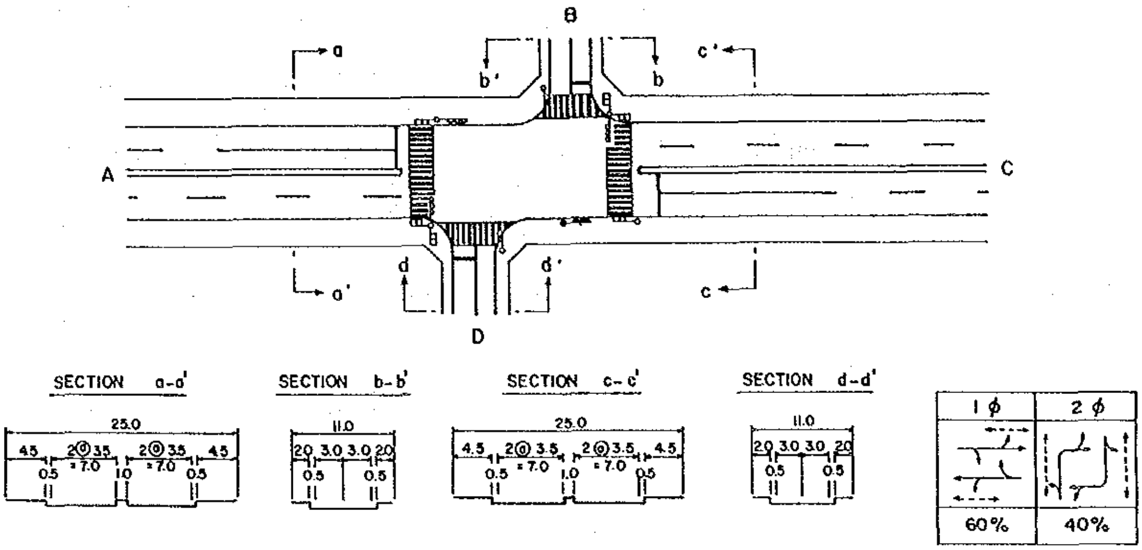
b) After Improvement

1) Improvement of the geometric design

Exclusive right turn lanes were provided on 'A' and 'C' approaches by removing part of the median and reducing the lane width.

2) Traffic operational measures

Guide markings were provided in the intersection in order to clarify the running path of vehicles, particularly vehicles entering from minor roads.



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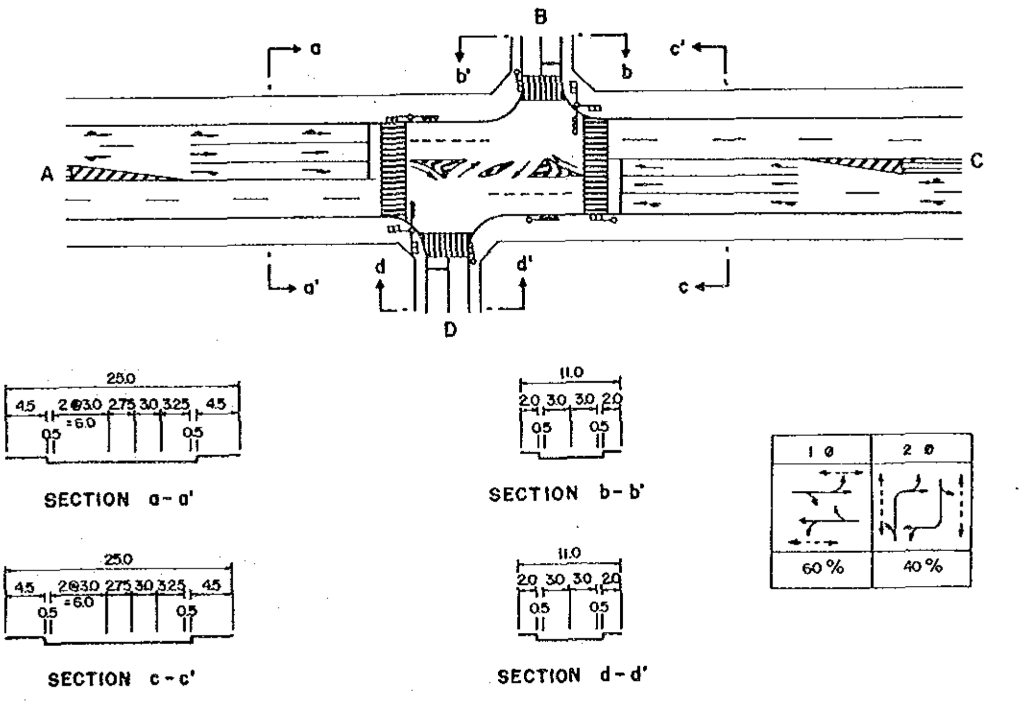


AFTER IMPROVEMENT

Figure 1.23 Staggered Intersection Improvement Plan

CHAPTER 2 CLIMBING LANE, PASSING LANE AND MOTORCYCLE LANE

CHAPTER 2 CLIMBING LANE, PASSING LANE AND MOTORCYCLE LANE

2.1 CLIMBING LANE

2.1.1 Technical Guideline

1. The provision of a climbing lane is desirable, if necessary, for a road section with upgrades exceeding 5% (or 3% in the case of an express highway or a highway with a design speed of more than 100 km/hr).

2. Decision as to where a climbing lane is required can be considered in conjunction with the reduction of running speed of heavy vehicles by up-grade and the traffic capacity.

3. It is desirable the lane width of a climbing lane to be 3.0m.

(1) Necessity of a Climbing Lane

Basically, the design speed at an upgrade section is considered to maintain the average running speed of passenger cars, whereas only a half of the design speed is supposed to be maintained by trucks. However, at an upgrade road section with heavy traffic volume as well as a higher composition rate of trucks/trailers, slow moving trucks/trailers largely affect the orderly traffic flow. This can lead to the reduction of traffic capacity, traffic safety and driving comfort.

In this case, it is desirable to provide a climbing lane in order to maintain the design capacity, traffic safety and driving comfort, by excluding slow moving vehicles from the main traffic flow. In addition, it is also desirable to carry out economical and safer route locations for the following cases by providing a climbing lane;

A. To avoid a long detour, high embankment or deep cutting, resulting from route alignment in order to keep the critical length of grade.

B. To prevent improper overtaking by passenger cars and to secure safe driving conditions.

(2) Condition of Provision

For planning of a climbing lane, the following points should be taking into account;

- Service level
- Grade value
- Length of grade
- Design traffic volume/traffic capacity
- Composition rate of heavy vehicles

Generally, when both value and length of grade are considered, it is desirable to refer to a running speed diagram. In a case where the traffic capacity becomes less than the design traffic volume due to the existence of an upgrade section, it is necessary to provide a climbing lane.

For express highways, it is desirable to consider the provision of adequate climbing lanes at proper locations, in order to maintain a smooth traffic flow.

In addition, provision of proper climbing lanes on other types of road are also desirable in order to reduce the construction cost and to secure safe traffic flow.

(3) Road Section Requiring Climbing Lane

The necessity of a climbing lane can be determined in conjunction with the reduction of running speed of heavy vehicles and the traffic capacity. In other words, a road section where heavy vehicles cannot operate by the allowable minimum running speed due to vertical alignment, causing insufficiency of the traffic capacity requires provision of a climbing lane.

Also even though the traffic capacity is sufficient, it is recommended to provide a climbing lane when heavy vehicles cannot operate by the allowable minimum running speed and especially when the design speed is relatively high. Too much differences in traveling speeds of ordinary vehicles and heavy vehicles could reduce the service level.

In Japan, simulation studies have been conducted for the effects of a climbing lane. From the results of these studies, provision of a climbing lane is justified for the following cases with running speed and traffic capacity being judging criteria.

A. Running speed of heavy vehicles at an upgrading road section become less than the allowable minimum running speed shown in Table 2.1, and the hourly designed traffic volume of a road section is more than the hourly designed traffic capacity at an up-grade section.

   However, if the length of such section is less than 200m, a climbing lane may not be necessary.

Table 2.1 Allowable Minimum Running Speed

Design Speed (km/hr)	Allowable Minimum Running Speed (km/hr)
120	60
100	55
80	50
60	40
50	35

B. Running speed of heavy vehicles at an up-grading road section become less than the allowable minimum running speed for a distance of more than 1,000m, even though the hourly designed traffic volume of a road section is less than the hourly designed traffic capacity at an up-grade section.

However, provision of a climbing lane may not be necessary under one of the following conditions for a road section with the design speed of 80 km/hr or less and the daily designed traffic volume of 20,000 vehicles or less.

- Vertical gradient is 3% or less.

- Vertical gradient is 4% or less and the up-grade section length is 5 km or less.

(3) Method to Identify Road Section Requiring Climbing Lane

In order to identify a road section where the provision of a climbing lane is required, it is necessary to find out a road section where the running speed of heavy vehicles are less than the allowable minimum running speed, by utilizing the running speed curve of heavy vehicles in accordance with the designed vertical alignment.

a) Climbing Capacity of Heavy Vehicles

The climbing capacity of heavy vehicles can be obtained from the climbing capacity curve as shown in Figure 2.1. In this figure, the power of a typical type of heavy vehicle per weight is set as 10 PS/ton, while the maximum running speed is assumed to be 80 km/hr. However, if the design speed is determined as 60 km/hr or 50 km/hr, the maximum speed should be set as 60 km/hr and 50 km/hr, respectively.

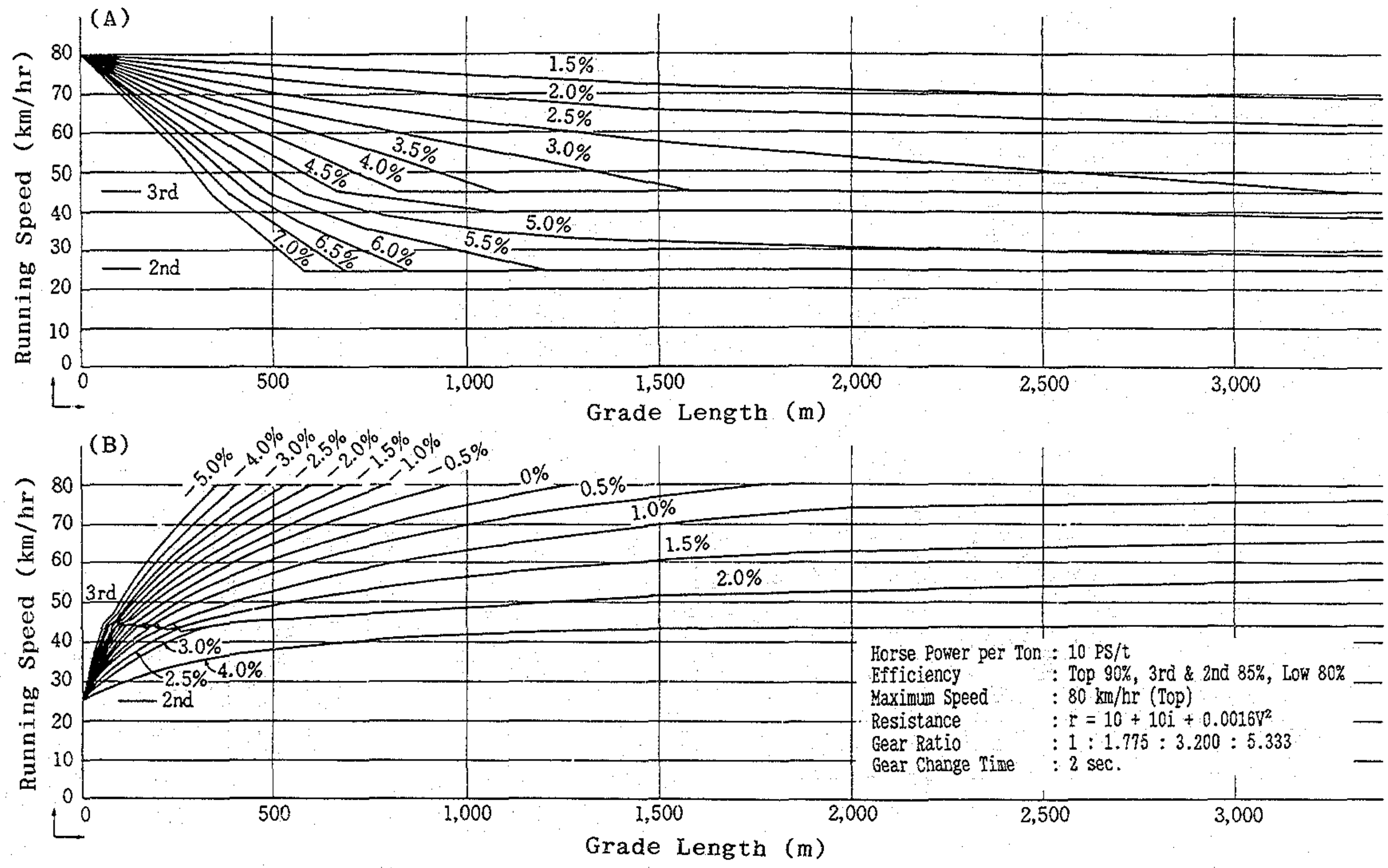


Figure 2.1 Climbing Capacity of Heavy Vehicles

b) Vertical Curve

A vertical curve is defined as the continuation of straight gradient by dividing it. The method for the division and the segregation of gradient are as follows.

A. A vertical curve of less than 200m in length is replaced by the gradient of both sides of a vertical curve in half by half.

B. If an absolute value of the difference between the gradient of both sides is less than 0.5%, a vertical curve of 200m or more in length is replaced by the gradient of both sides of a vertical curve in half by half,

C. If an absolute value of the difference between the gradient of both sides is not less than 0.5% and the length of a vertical curve is 200m or more, 1/4 each side of a vertical curve is replaced by the gradient of both sides, while 2/4 of center part of a vertical curve is considered as a grade section with the gradient calculated as an average value of the gradient of both sides.

An example of the replacement of a vertical curve as well as the speed curve of heavy vehicle is shown in Figure 2.2.

c) Method to Calculate Traffic Capacity at Upgrade Section

The traffic capacity at an upgrade section can be calculated by the same method applied to an ordinary road section, which is described in Chapter 3 of this Volume. However, for this calculation, the heavy vehicle equivalent passenger car unit should be adjusted according to the gradient.

As a reference, 7,000 veh/day and 20,000 veh/day are assumed as the standard value of the traffic capacity for 2-lane road and 4-lane road, respectively.

(4) Element of Climbing Lane

a) Cross Section

Since a climbing lane is utilized mainly by slow moving vehicles, the width of lane is set as 3.0m. However, for express highways or highways with a design speed of more than 100 km/hr, it is desirable to provide a space equal to the marginal strip of the main carriageway, between the main carriageway and a climbing lane, as shown in Figure 2.3.

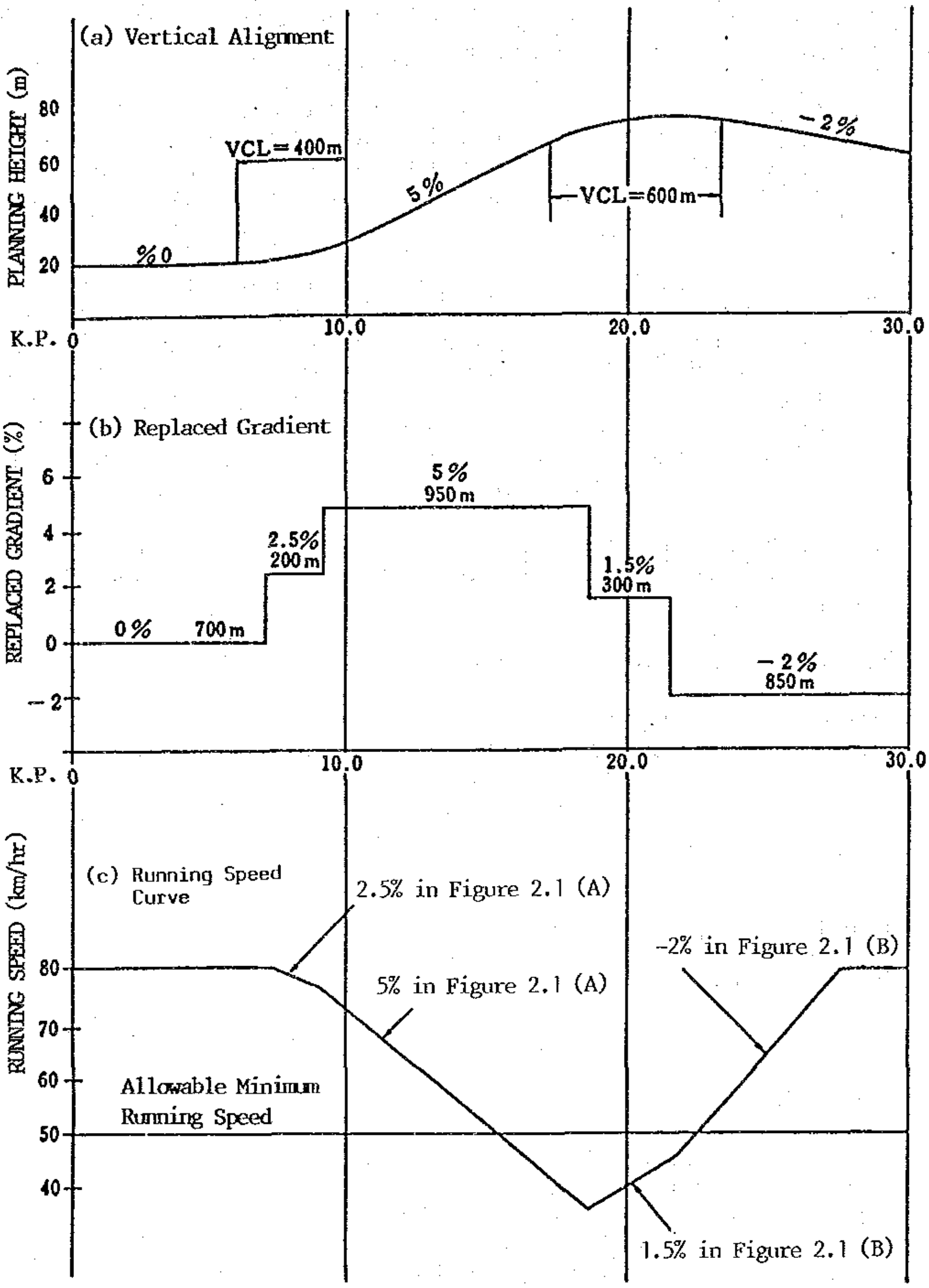


Figure 2.2 Example of Running Speed Curve of Heavy Vehicles

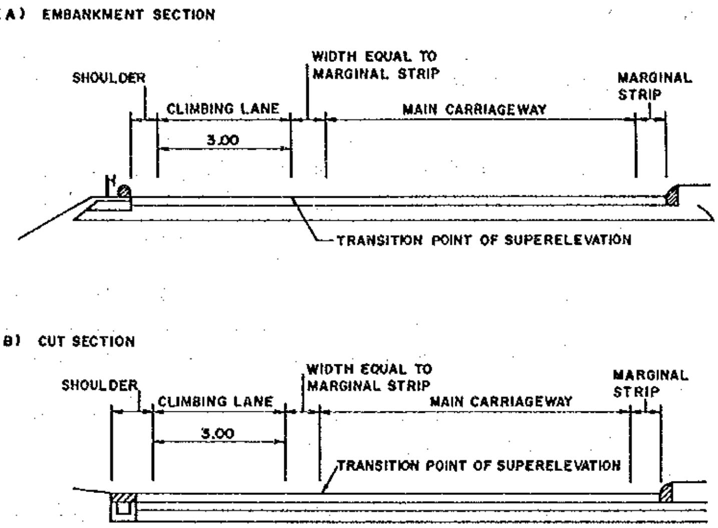


Figure 2.3 Cross Section of Climbing Lane

b) Superelevation

According to the superelevation of the main carriageway, it is desirable to determine the superelevation of a climbing lane, as shown in Table 2.2.

Table 2.2 Superelevation of Climbing Lane

Superelevation of Main Carriageway (%)	10	9	8	7	6	5	4	3	2
Superelevation of Climbing Lane (%)	5	5	4	4	4	4	4	3	2

2.2 PASSING LANE

2.2.1 Technical Guideline

1. The provision of a passing lane is desirable, if necessary, for a two lane road, where passing of a slow moving vehicle is difficult over a long distance.

2. For the selection of a location to provide a passing lane, the following points should be taken into account;
   - To secure sufficient sight distance at both diverging and merging points.
   - To consider the relation with access roads, intersections and roadside condition.

3. Either an overtaking lane method or a slower traffic lane method should be selected which will take into due consideration the road condition, traffic characteristics, etc.

4. It is desirable to provide a passing lane within each 5 to 7 km along a two lane road.

5. The lane width of a passing lane should principally be the same as the lane width of the main carriageway.

6. It is desirable the standard length of a passing lane (excluding taper length) to be 800m for an overtaking lane method and 500m for a slower traffic lane method. This length can be reduced to 500m and 300m respectively, if circumstances are unavoidable.

(1) Necessity of Passing Lane

A platoon headed by a slow moving vehicle is often formed on road sections with passing difficulties or with passing prohibitions over long distance. This leads to the reduction of traffic capacity and driving comfortability. In addition, this situation may lead to improper overtaking by frustrated drivers. This is one cause of severe traffic accidents, such as head-on collisions.

It is therefore necessary to conduct economical and safe route alignments as well as traffic operation plans. This provides opportunities for faster traffic to pass at certain locations within a road section in order to secure the smooth and safe traffic flow in circumstances where there is difficulty of passing along the entire length of road.

(2) Location of Passing Lane

It is desirable to provide a passing lane on a road section where passing is difficult over a long distance and a platoon is likely formed by a slow moving vehicle.

For the selection of a location for a passing lane, it is necessary to consider the following points;

A. Sight distances at both diverging and merging points of a passing lane in order to maintain effective usages of a passing lane.

B. It is desirable to avoid locations where parking vehicles or access traffic are expected due to the existence of an access road and an intersection, or roadside land use.

It is also desirable to select locations where the existence of structures, such as bridges, are limited.

(3) Provision Method

Figure 2.4 indicates the provision methods for a passing lane.

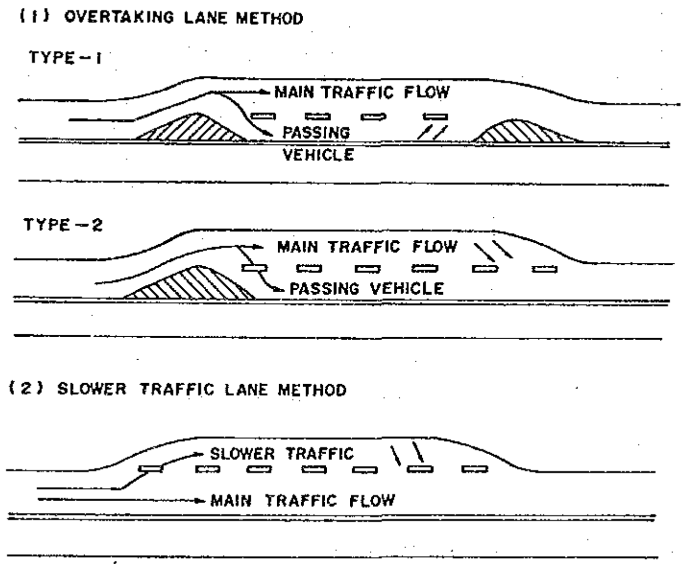


Figure 2.4 Provision Methods of Passing Lane

The concept of the overtaking lane method is that faster vehicles overtake slow moving vehicles using an inner lane. For this method, two types of merging method can be considered.

The slow traffic lane method adopts the same concept for the climbing lane but slow moving vehicles only utilize the outer lane (slow traffic lane) while other vehicles can maintain an orderly driving speed.

These two methods both have advantages and disadvantages, as summarized in Table 2.3. Hence it is necessary to select a suitable method in due consideration of road conditions and characteristics of traffic flow.

Table 2.3 Advantages and Disadvantages of Two Method

Item	Overtaking Lane Method	Slower Traffic Lane Method
Alignment	* Longer taper length at merging section. * Section to shift the main carriageway is required.	* Shorter taper length at merging section.
Existence of Roadside Facility	* Restriction of entrances/ exit to roadside facility is required.	* Possibility of parking vehicles on slower traffic lane.
Required Land	* More land is required.	* Less land is required.
Driver's Behavior	* No problem since same method as 4 lane road.	* No problem since same method as climbing lane.
Safety	* Smooth operation can be expected (Type 1). * Some consideration are required at merging section (Type 2).	* Some consideration are required at merging section.
Effectiveness of Passing	* Faster vehicle overtake slower vehicles as they wish.	* Unable to overtake if slower vehicles do not utilize slower traffic lane. * Overtaking from the left side might be taken place.

(4) Element of Passing Lane

The width of a passing lane is principally the same as the main carriageway lane width

a) Overtaking Lane Method

Figure 2.5 illustrates a typical cross section of an overtaking lane method.

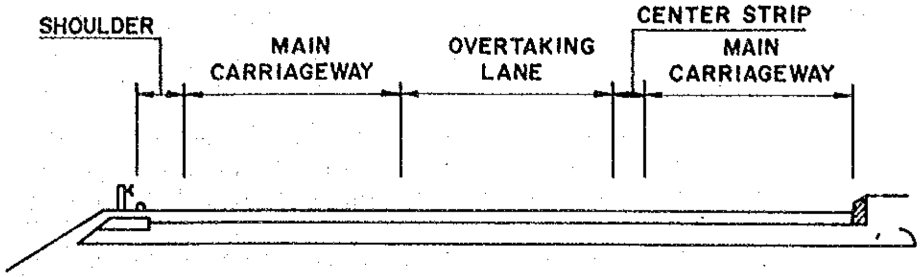


Figure 2.5 Typical Cross Section of Overtaking Lane Method

The standard length of a passing lane, excluding taper length, is 800m. However this length can be reduced to 500m in an unavoidable circumstance. The standard taper length is shown in Table 2.4.

Table 2.4 Standard Taper Length for Overtaking Lane Method

Unit : m

Design Speed (km/h)	80	60	50	40
Diverging Section	45			
Merging Section	175	130	90	75

In addition, it is also necessary to provide a center strip between a passing lane and an opposing lane to secure sufficient lateral clearance between overtaking vehicles and opposing vehicles.

b) Slow Traffic Lane Method

Figure 2.6 illustrates a typical cross section of a slow traffic lane method.

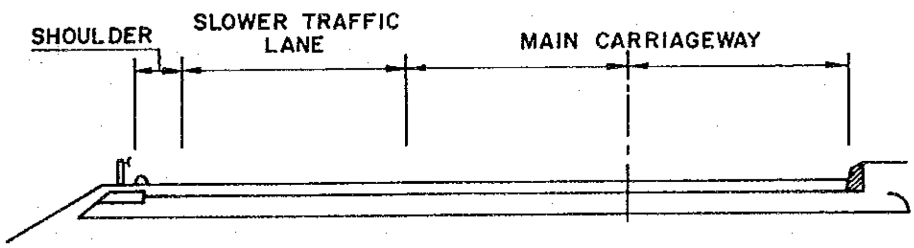


Figure 2.6 Typical Cross Section of Slow Traffic Lane Method

The standard length of a slow traffic lane, excluding taper length, is 500m. However this length can be reduced to 300m in an unavoidable circumstance. The standard taper lengths are 45m at a diverging section and 60m at a merging section.

2.3 MOTORCYCLE LANE

2.3.1 Technical Guideline

1. Provision of a motorcycle lane is desirable at a road section with one of the following traffic conditions.

   1) Average traffic volume, excluding motorcycle, is more than 2,000 per day and motorcycle traffic volume is more than 1,000 per day.

   2) Average traffic volume, excluding motorcycle, is more than 2,000 per day and motorcycle traffic volume is more than 500 per day, where the running speeds of vehicles are considerably high.

(1) General

The composition rate of motorcycles are as high as 40 to 50% in Thailand, especially in urban and suburban areas. These high compositions of motorcycle traffic may cause a disturbance for an orderly vehicle traffic flow. Traffic accidents involving motorcycles are therefore also likely and these are generally serious because motorcycle riders wear no protection. As the majority of motorcycles in Thailand are of a small size (80 to 125 cc), they are a very popular transport mode for the general public. It is therefore virtually impossible to control the operation of these motorcycles on major highways.

It is therefore necessary to introduce some measures to exclude motorcycle traffic on major highways. For this purpose, provision of a motorcycle lane is desirable.

(2) Condition of Provision

Traffic volumes of vehicles, composition rates of motorcycles and running speeds of vehicles excluding motorcycles should be considered to determine whether the provision of motorcycle lanes is warranted.

Motorcycle traffic often decreases the traffic capacity of a road because of their comparative slower speeds than other vehicles and their unstable riding. The degree of obstruction caused by motorcycle to the other vehicle traffic sharply increases as the traffic volume increases. It is a fact that a motorcycle is equivalent to one passenger car from the standpoint of traffic capacity when the passenger car volume per hour is 200 to 250 on a two lane road. This volume corresponds to approximately 2,000 vehicles per day. This traffic volume could be a threshold to the vehicle volume. As with the case of pedestrians, a situation in which vehicles pass pedestrians every 30 seconds is assumed to be dangerous. Such a situation is created by 120 motorcycles per hour or 1,000 motorcycles per day. Even when the motorcycle volume per day does not reach 1,000, if the running speed is considerably high and it endangers motorcycle riders, a motorcycle lane should be provided at a lower volume of about 500 motorcycles per day.

(3) Occupied Width of Motorcycle

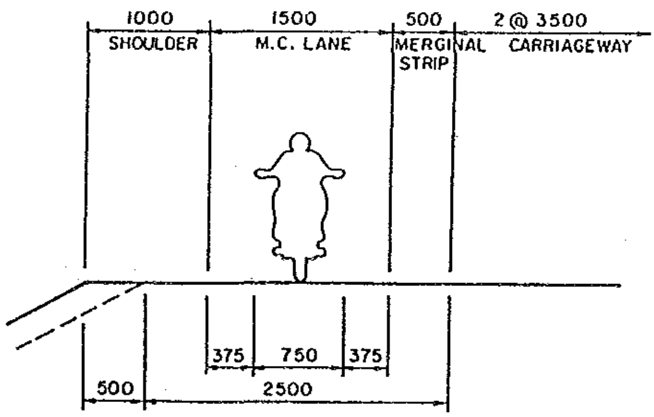
The concept of a motorcycle lane is very new to Thailand. There is therefore no definite figure which relates to the occupied width of a motorcycle.

At present, the maximum width of a motorcycle is regulated at 1.1m according to the Ministerial Regulation No. 5 (1981), while the maximum width of a motorcycle produced in Thailand is 0.75m.

0.75m is therefore assumed to be the maximum width of motorcycle. In addition, the leaning width of a motorcycle operation is considered to be 0.25m on both sides. Reference is made to the leaning width of a bicycle. Hence, the occupied width of motorcycle is determined to be 1.25m.

(4) Cross Sectional Element for Motorcycle Lane

In order to determine the cross sectional element for a motorcycle lane, several matters, such as comfortability of riding on a motorcycle lane, effects for the main traffic flow, safety, construction cost, etc., were taken into account. Then, the cross sectional elements for motorcycle lanes, illustrated in Figure 2.7, is proposed in the Study.



Unit : m

Figure 2.7 Cross Sectional Element for Motorcycle Lane

CHAPTER 3 TRAFFIC SIGNAL

CHAPTER 3 TRAFFIC SIGNAL

3.1 TECHNICAL GUIDELINE

3.1.1 Summary of Warrants

1. Pretimed Signal

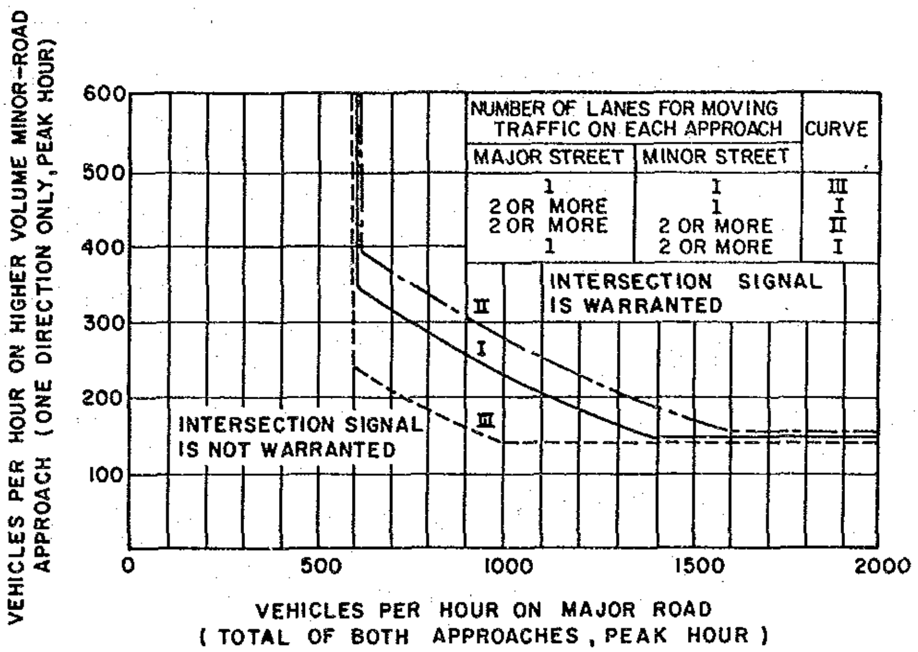


Figure 3.1 Warrant for Traffic Control by Pretimed Signal

2. Semi-Traffic-Actuated Signal

Table 3.1 Warrant for Traffic Control by Semi-Traffic-Actuated Signal

	Vehicle per hour on major road (total of both approaches)	Vehicle per hour on higher-volume minor road approach (one direction only)
Peak hour traffic volume	900 or more	100 or more

3. Pedestrian Signal

Table 3.2 Warrant for Traffic Control by Pedestrian Signal

	Vehicle per hour on the street (total of both directions)	Pedestrian per hour on the crosswalk crossing the road
Peak hour traffic volume	650 or more	200 or more

4. Traffic Accident Prevention

Table 3.3 Warrant for Traffic Accident Prevention by Traffic Signal

	Accidents Preventable by Traffic Signals
Number of Accidents within a 12-month Period	5 or more

3.1.2 Function of Traffic Signal

(1) Purpose of Traffic Signal Installation

Traffic signals assign alternately the right-of-way to the competing traffic movements at the intersection by light of red, amber and green, and thus they ensure an orderly flow of traffic. Traffic signals have following advantages when they are well-designed, effectively placed and properly operated.

A. They can maintain orderly traffic flows and increase the traffic capacity of the intersection.

B. They can reduce the total delay of vehicles at heavy traffic intersection, and relieve vehicles on minor road and pedestrians from suffering extraordinary delay to cross the main road.

C. They can reduce the frequency of certain types of accidents.

Following three sub-sections present detailed explanations as to the aforesaid features of traffic signals.

(2) Traffic Capacity of Signalized Intersection

It is obvious that the signalization at low-traffic-volume intersection reduces the traffic capacity of the intersection. But when the traffic volume at an intersection exceeds a critical volume, traffic signals can increase the capacity of traffic at the intersection as far as the intersection is not saturated with traffic.

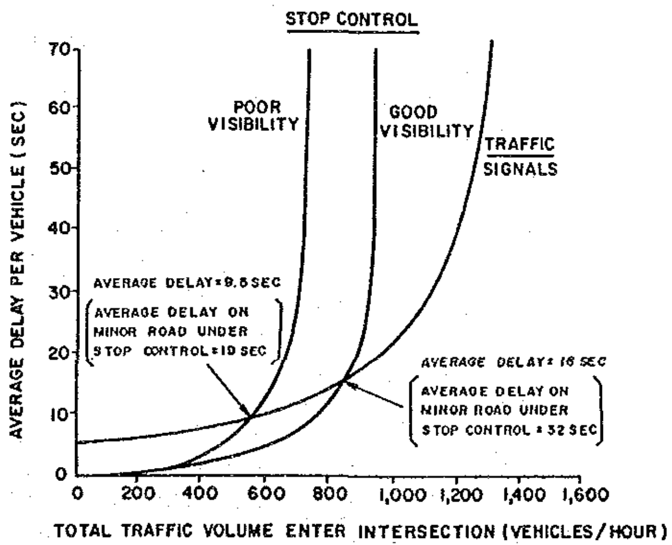
The maximum number of crossing vehicles per hour during the green phase of the signal is called as "saturation flow rate". Although the saturation flow rate varies with the number of lanes and volumes of right and left turning vehicles, or pedestrians at the intersection, the constant value of 2,000 PCU per hour for one lane can be applied practically for any intersection. The quotient obtained by dividing the design traffic volume at each approach by its saturation flow rate shows the ratio of the "effective green time" to the cycle length required for handling the design volume.

Usually, one phase covers two approaches or more and the maximum of the above ratios of these approaches, is called the "degree of saturation of the phase". The sum of the saturation degrees of all phases is called the "saturation degree of the intersection".

The saturation degree of an intersection is the ratio of the sum of the minimum necessary green periods of all phases to the cycle length; if this value exceeds 1.0, it means that the intersection is over-saturated in the view of traffic capacity, and that the intersection cannot handle the design volume. In this case, more sophisticated countermeasure should be considered, such as coordinated signal control system, grade separation or one-way system.

(3) Delay at Signalized Intersection

Signal control can eliminate the delays to minor-road vehicles waiting for acceptable gaps, but it will cause vehicles on a major-road to suffer some delays while waiting for a green light. It should be noted that the substitution of a signal for stop control by traffic signs and markings does not always reduce the total intersection delays. Relation between traffic volume entering an intersection and an average delay is shown in Figure 3.2, in which it is evident that at reasonably low levels of traffic volume, the stop control is preferable to the signalized control when the total delay at the intersection is a primary concern.



Source :
F.V. Webster and J.G. Wardrop, "Capacity of Urban Intersections", Sixth International Study Week Traffic Engineering, Saltzburg, 1962.

Figure 3.2 Relation Between Traffic Volume Entering Intersection and Delay of Vehicle

(4) Effect of Traffic Signals for Safety Improvement

Installation of traffic signals usually reduces accidents substantially, though rear-end collisions tend to increase slightly in many cases. However, the installation of two or more signal displays to each approach can prevent the increase of rear-end collisions.

Pedestrian signal displays with sufficient duration for crossing are useful to prevent pedestrian accidents. Separated vehicular turning phases together with provision of exclusive right turn lanes are effective in avoiding right turn vehicle accidents.

According to the experimental works conducted in the Phase I Study at the intersections on Route 336 of DOH road where traffic signals were installed, the number of traffic accidents was reduced by about 50%. This reduction rate agrees generally with the experiences in other countries.

3.1.3 Warranting Conditions

In the Study, warrants on installation of traffic signals are proposed for the following three types of systems: i.e., pretimed signal, semi-traffic-actuated signal, and pedestrian signal. A criterion of installing signals for accident prevention is also proposed.

In these warranting conditions, traffic volumes are defined by number of vehicles, instead of PCU. Even though the number of motorcycles on certain DOH road sections are very high, it is difficult to employ PCU as an unit for the warranting conditions, because no detailed studies related to the PCU value as well as the intersection delay have been carried out in Thailand. Hence, detailed studies are necessary to determine the warranting conditions for traffic signals defined by PCU.

However, as a reference, the motorcycle PCU value of 0.5 for an urban road and 0.75 for a rural road may able to be used for justification of traffic signals at unsignalized intersections with heavy motorcycle traffic volume.

(1) Warrant of Pretimed Signals

A pretimed signal is operated by a fixed-timing program which is determined by taking into account the traffic volume of approaches, the traffic composition and the geometric characteristics of the intersection.

On condition that traffic volume remains within a certain level at intersections, it is possible to handle the traffic smoothly by traffic regulations such as stop control. When traffic volume exceeds this level, it becomes difficult to guarantee a smooth flow of traffic and the resulting traffic congestion may induce traffic accidents.

According to the simulation carried out for a non-signalized intersection where the major road has 4 lanes and minor road has 2 lanes, the maximum traffic capacity at the intersection can be calculated by the following equation.

$$M = \frac{Ne^{-rL}}{1 - e^{-rL'}}$$

Where;

- M : Vehicles per hour on higher-volume minor-road approach (one direction only, vehicles/hr.)
- N : Vehicles per hour on major road (total of both approaches, vehicles/hr.)
- r : N/3600 (vehicles/sec.)
- e : Base of the natural logarithm
- L : Headway of vehicles at the intersection from major road (sec.)
- L': Headway of vehicles at the intersection from minor road (sec.)

The value of L in the equation means the critical vehicular gap (headway) on a major road for a vehicle entering or crossing at an intersection. Supposing that 85 percentile running speed is about 50-60 km/hr., the value of L is estimated at about 6 seconds. In addition, according to practices in several countries, this value might be 7 seconds, when the average speed of vehicles on a major road is 80 km/hr., while this value might be changed for urban roads to 5 seconds.

Value of M is the maximum traffic capacity in the case for stop control at the intersection where major road has 4 lanes and minor road has 2 lanes. At the other types of intersections, the value of M is obtained by considering the fact that the wider the road is, the smoother the flow of vehicles becomes. Figure 3.1 shows warranting condition for pretimed signal proposed in the Study. The followings are basic conditions for utilization of this figure.

- Traffic volume in this figure are vehicle numbers.

- Peak hour in this figure means a simple peak hour in a day.

- If the peak hour of major and minor roads are different, it is desirable to utilize both peak hour traffic volume to determine the necessity of a pretimed signal from an optimistic point of view.

(2) Warrant of Semi-Traffic-Actuated Signals

A semi-traffic-actuated signal utilizes vehicle detectors only on the minor approaches. This type of control may be applied at the intersections where vehicles on minor approaches cannot cross the major road safely without traffic signals.

In the Study, warranting conditions for semi-traffic-actuated signal were worked out based on experiences in Japan, and the results are shown in Table 3.1.

(3) Warrant of Pedestrian Signals

As for a traffic signal of which primary objective is to control crossing pedestrians, it is necessary to consider the volume of pedestrian traffic, the carriageway width and the vehicular traffic volume of approaches.

In the Study, the subject is focussed on the road whose carriageway is from 9 to 12 m wide with pedestrian crosswalks. In such roads, a minimum traffic volume that makes pedestrian crossing difficult is said to be from 650 to 700 vehicles/hr.

Table 3.2 shows warranting conditions for pedestrian signals which were determined by taking the empirical examples of other countries into account. In addition, the minimum duration of signal phase for crossing pedestrians can be calculated by the following equations.

A. Intersection/crosswalk with limited number of pedestrians for each cycle.

$$T = \frac{L}{V}$$

where;
- T : Minimum duration required for pedestrians to cross carriageway (sec.)
- L : Length of crosswalk (m)
- V : Velocity of pedestrian (m/sec.) Usually, 1 m/sec. is utilized as the velocity

B. Intersection/crosswalk with a number of pedestrians for each cycle.

$$T = L + \frac{P}{F \times W}$$

where;
- T : Minimum duration required for pedestrians to cross carriageway (sec.)
- L : Length of crosswalk (m)
- P : Number of waiting pedestrians for each cycle (person)
- F : Flow rate of crossing pedestrians (person/m/sec.)
- W : With of crosswalk (m)

There is no uniform figure for the flow rate of crossing pedestrians; however, based on experiences in Japan, the following values can be utilized as the flow rate depending on walking purposes.

* for commuting - 0.92
* for shopping - 0.69
* for amusement - 0.72
* other purpose - 0.52

(4) Warrant for Traffic Accident Prevention

When a traffic signal is installed at an intersection, rear-end collisions may increase but the accidents such as head-on collisions, pedestrian accidents, etc. may be reduced. There are some evidences to suggest that a substantial number of accidents can be prevented by traffic signals. The traffic signals are essential when other less restrictive measures fail to reduce the accidents.

In the Study, to ensure the traffic safety at intersections with the history of traffic accidents, warranting conditions based on accident data are proposed in reference to the examples in other countries, as shown in Table 3.3.

3.1.4 Selection of Signal Control Systems

There are two types of traffic control system, i.e., the independent control and the coordinated control.

(1) Independent Control System

The independent control by traffic signals, in principle, may be applied to intersections where the section distance between neighboring intersections is generally long for the platoon of the traffic to disperse over the section.

A. Pretimed control

- Single-program control
- Multi-program control

B. Traffic-actuated control

- Semi-traffic-actuated control
- Full-traffic-actuated control

The pretimed control operates with a time table in which the cycle length and intervals are predetermined and fixed. The single-program control, the most simple control system, applies constant parameters around the clock. The multi-program control, on the other hand, is operated by variable parameters of cycle length and intervals. These parameters change throughout the time of the day, and the switchover of parameters are carried out automatically by the built-in clock.

The traffic-actuated control is the type in which the length of the green period varies according to the fluctuation of traffic volume on approaches. The change in traffic volume is detected by using traffic detectors. In this system, the length of green period is prolonged by detecting vehicles on approaches.

The one in which the time intervals of all signals are changed in accordance with traffic flows on all approaches, is called "full-traffic-actuated control", and the other in which only a traffic fluctuation on a minor approach is reflected upon the allocation of time splits of the signal is called "semi-traffic-actuated-control".

The following is the summary of selection method for independent control types.

A. Where crossing roads are major roads and their traffic volume are relatively high, the multi-program control is proper.

B. Where an arterial road with high traffic volume and a minor road carrying low traffic volume cross each other, the semi-traffic-actuated control is proper. In this case, it is necessary to install a push button signal for pedestrians to cross the major road. If pedestrian crossings are frequent on the major road (more than 1 person per 1 minute), the multi-program control is generally desirable.

C. Where two roads of which traffic volume are relatively low intersect, the single-program control is proper. However, if there are few crossing pedestrians (less than 1 person per 1 minute), the full-traffic-actuated control may be desirable. When the full-traffic-actuated control is adopted, it is necessary to install push button signals for pedestrians.

(2) Coordinated Control System

The coordinated control system is effective and applicable to extensively developed road network in urban areas, since linked traffic signals can be coordinated according to traffic flows.

A. Pretimed control

- Single-program control
- Multi-program control

B. Traffic-actuated control

- Semi-traffic-actuated control
- Full-traffic-actuated control

C. Traffic-adjusted control

The operational characteristics of the pretimed control and the traffic-actuated control is almost as same as the independent control system, although several linked traffic signals are controlled by this system.

The traffic-adjusted control is a type in which the length of green timing varies according to the fluctuation of traffic volume in the specific location of linked section or area. The progressive system and the area traffic control system is under this control system.

3.1.5 Placement of Signals

Current placing of traffic signals are prescribed in "General Specification for Road Traffic Signals and Flushing Traffic Signals, DOH, 1980" (hereafter referred to as the "DOH specification of signals").

According to this DOH specification of signals, the placement of signal displays is set out as indicated in Figure 3.3. The placement is planned on the premise that the type of signal is pedestal or overhang type. This signal placing method is characterized by nearside positioning of primary signal (hereafter called Method A).

On the other hand, the placing method indicated in Figure 3.4 is of far-side positioning of primary signal which is overhang type (hereafter called Method B). Method B has several advantages, i.e., smaller number of signal displays needed, better visibility from approaching vehicles and less expensive installation cost.

Method A is widely prevailing in Thailand, but its inferior visibility from high speed approaching vehicles encourages the adoption of overhang type signals, and accordingly, superiority of Method B can be stressed. Therefore, the introduction of Method B is recommended at intersections where approaching speeds are high, and require visibility from a distance.

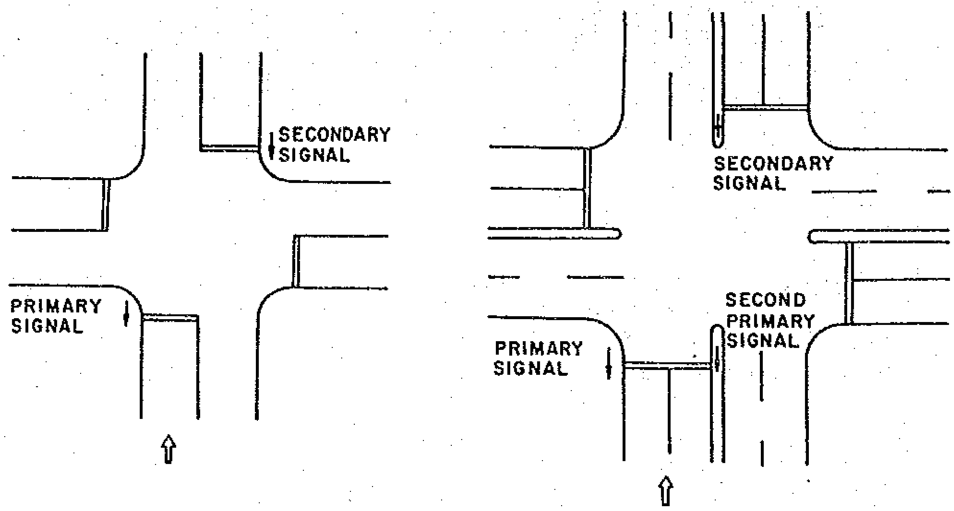
Following paragraphs explain the signal placing method (Method B) for practical application.

(1) Signals for Vehicular Traffic

a) Primary Signal

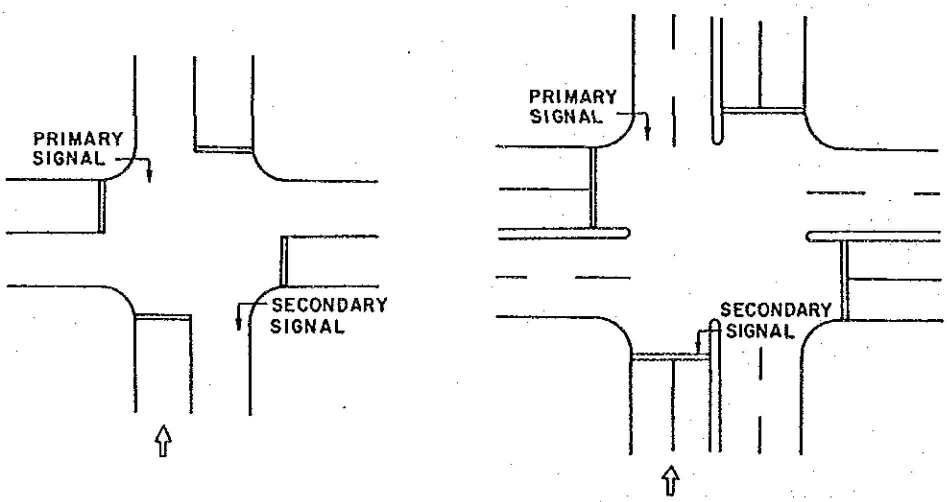
A. To be installed at far-left location of the intersection, facing exactly opposite to the running direction.

B. When an approach is split and channelized by traffic islands, each channelized lane is to be considered as an approach



(a) Small Intersection (b) Large Intersection

Figure 3.3 Standard Placement of Signal Display (Method A)



(a) Small Intersection (b) Large Intersection

Figure 3.4 Standard Placement of Signal Display (Method B)

b) Secondary Signal

A. To be installed at near-right location of the intersection. Generally, it is attached to backside of the primary signal for the opposite direction.

B. To be installed at median strips, when the approach has more than 3 lanes and the median strip is 1 m wide or more.

C. Secondary signal for the minor road is omissible when the width of the minor road is less than 5.5 m, heavy vehicles are few and visibility is well secured.

c) Advance Notice Signal

When necessary due to insufficient sight distance at locations such as a curved section, advance notice signals are required at about 50 m on this side of a spot where primary signal or secondary signal can be seen. It is desirable that an advance notice signal is of flashing amber color beacon, and attached with a sign to indicate existence of traffic signals ahead.

(2) Pedestrian Signal

The pedestrian signal should be positioned so as to provide maximum visibility at the beginning of the crossing, and to avoid to be an obstacle in the pedestrian flow. Placement at far-side right or left end of the crossing area may meet this requirement.

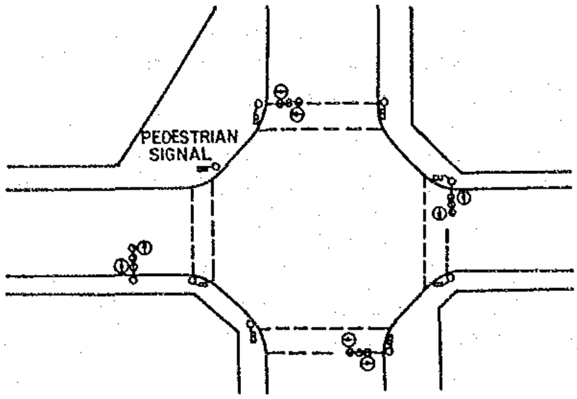
(3) Enhancement of Visibility

Visors should be used on all signal displays to aid in directing the signal indication specifically to approaching traffic, as well as to reduce the impaired visibility resulting from external light entering the optical units.

Also, when the visibility of signals are obstructed by the sunlight at dawn or sunset, following betterments should be taken into consideration; i.e., use of backplates, relocation of primary signals, and installation of secondary signals.

Based upon the aforementioned instructions, typical placement plans of traffic signals at intersections are shown in Figure 3.5.

(a) Typical Intersection



(b) Deformed Intersection

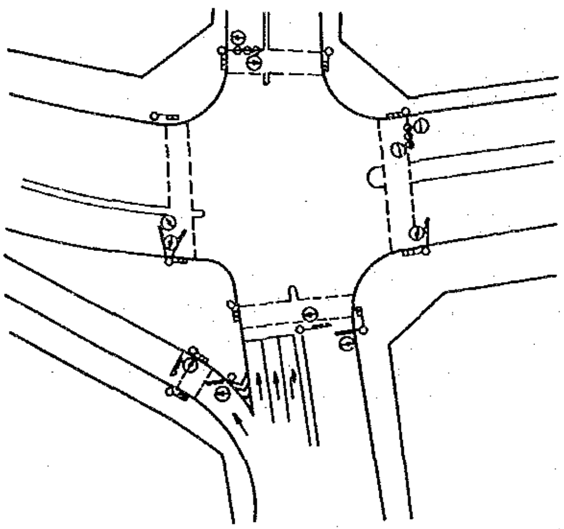


Figure 3.5 Example of Signal Arrangement