Palestine Polytechnic University

College of Engineering & Technology
Civil & Architectural Engineering Department

Graduation Project

Evaluation and Redesign of Certain Intersections In Hebron City

Project Team

Al-ATA AL-ATAWNEH **MOHAMMAD AL-ASAFRAH**

RA'FAT GHRAYIEB

Project Supervisor
ENG. FAYDI SHABANEH

Hebron – Palestine

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Certification

الإهداء:

إلى من امتزجت دمائهم بثرى هذه الأرض و علقت ذكراهم بالوجدان. . . لشهداء فلسطين.

إلى الأعز و الأغلى على القلب . . . إلى والدي.

إلى من حزن لحزني وفرح لفرحي . . . إلى أصدقائي الأعزاء.

نهدي هذا العمل

فريق العمل:

العطا العطا ونه
محمد العصافرة
رأفت اغريب

نكر و تقدير:

تقدم بالشكر العظيم إلى إدارة جامعة بوليتكنيك فلسطين على الدعم و التوجيـه و نخـص بالذكر دائرة الهندسة المدنية و المعمارية.

ما نتقدم بالشكر إلى العاملين في مكتبة جامعة بوليتكنيك فلسطين لما قدموه لنا من مراجع م الاستفادة منها.

ما نتوجه بالشكر الكبير و الامتنان إلى الأستاذ المهندس القدير فيضي شبانة الذي قدم لنا لدعم و المشورة الصائبة و المعلومة الدقيقة و جزاه الله كل خير.

ما نتوجه بالشكر الجزيل إلى جميع محاضري سم هندسة المساحة و المبـاني و نخـص بالذكر الأستاذ المهندس القدير كمال غطاشة "ونسأل الله الشفاء العاجـل لـه"، والأسـتاذ لمهندس خليل كرامة، كما لا ننسى الأستاذ احمد الشريف لما قدموه لنا من مساعدة.

ما نتقدم بالشكر إلى بلدية الخليل لما قدمته لنا من معلومات.

ر نشكر كل من مد لنا يد العون لإنجاح هذا الجهد المتواضع.

Evaluation and Redesign of Certain Intersections In Hebron City

Work Team

Al-ATA AL-ATAWNEH **MOHAMMAD AL-ASAFRAH**

RA'FAT GHRAYIEB

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Abstract:

This project is evaluation and redesign of certain intersections in Hebron city, this project aim to redesign a certain intersections in Hebron city. Intersections are that connect between the vital places in Hebron, this project is an application for engineering and technical specification that have to considered in highway design, the project aims to achieve its main goal with comfortable intersections, minimum tired, minimum cost, minimum accidents occurs on this intersections, minimum cost and time of execution. The project has two parts: fieldwork and office work, the plans of the project contains horizontal plan, profile, and intersections design. Cross-sections.

Certification

Palestine Polytechnic University

PPU

Hebron-Palestine

The Senior Project Entitled:

Evaluation and Redesign of Certain Intersections In Hebron City

Prepared by

AL-ATA AL-ATAWNEH **MOHAMMAD ALASAFRAH**

RA'FAT GHRAYIEB

In according with the recommendation of the project supervisors and the acceptance of all examining committee members, this project has been submitted to the department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Engineering.

Project Supervisors **Department Chairman**

Examining committee members

Evaluation and Redesign of Certain Intersections In Hebron City

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CHAPTER ONE

INTRODUCTION

1-1 General:

Road is away for vehicles and for other types of traffic over which they lawfully pass. It includes all area comprising the road way and all structures pertaining to the road within the limits of the defined boundary or right of way. Highway engineering is one of the important branches of engineering. It deals with the construction, design and maintenance of roads of different kinds.

The history of roads dates back to the period before the advent of recorded history. With desire to hunt animals for food, the ancient man began to form tracks to facilitate his movements. As civilization advanced, the growth of agricultural took place and human settlements began to be formed. The introduction of the wheel (approx. 3500 B.C) and the domestication of animals saw the advent of chariots and carts.

Roads are vitally important to a country's economic development. The construction of a high quality road network directly increases a nation's economic out put by reducing journey times and costs, making a region more attractive economically. The actual construction process will have the added effect of stimulating the construction market.

So the movement on the roads must be smooth specially on intersections, a highway intersection is required to control conflicting and merging streams of traffic so that delay is minimized this is a achieved through choice of geometric parameters that

control and regulate the vehicle paths through the intersection. These determine priority so that all movements take place with safety.
The major aim of intersection to provide vehicle drivers with a road layout that will minimize confusion. The need for flexibility dictates the choice of must suitable junction type. The selection process requires the economic, environmental and operational effects of each proposed option to be evaluated.

The principle at the basis of the design of intersection is that it should reflect the pattern of movement of the traffic. The heaviest traffic flows should be afforded the easiest paths. Visibility, particularly for traffic exiting the minor junction, is a crucial factor in the layout of intersection low visibility can increase the rate of occurrence of serious accidents as well as reducing the basic capacity of the intersection itself.

Our primary goals in geometric design are to have a facility that will move people safety and as efficiently as possible. Our objective is to design intersection facilities to meet the requirements of driver and vehicle. This is not straightforward though. Take driver as an example. Not all the drivers respond to an object in the travel-lane of a highway in the same time. This is because our perception-reaction times are different. Because of the variability in human and vehicle characteristics, appropriate values for these factors affecting design need to be selected.

1-2 Categories of the Intersections:

The intersection area is apart of every connecting road or street, in this area must occur all crossing and turning movements. The general types of intersections:

- **<u>Intersections at- grade:</u>**
  1. **Three legs or simple intersection:**

     These intersections are cheapest and least elaborate. The intersection road ways have been joined by circular arcs in order to provide pavement under vehicles turning of right, and this intersection of road carrying little traffic except signs may be deemed necessary.

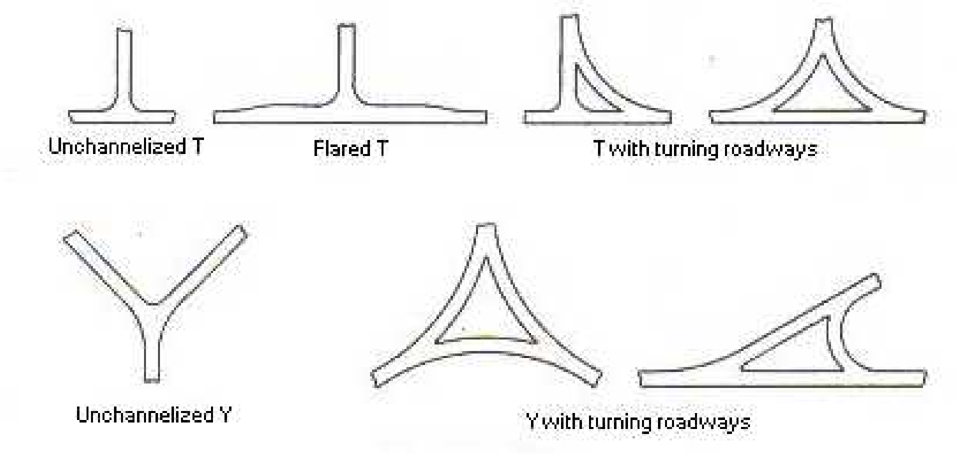

Fig. 1-1 Three legs Intersections [1]

2. Four legs intersection:

In this intersection the vehicles meet at unfavorable angles may demand channelization. Flared intersection design involves (1) widening the entering traffic lanes to permit deceleration clear of through traffic and (2) widening the leaving lanes to provide for acceleration and merging. However the number of accident less, and increased the capacity of the intersection.

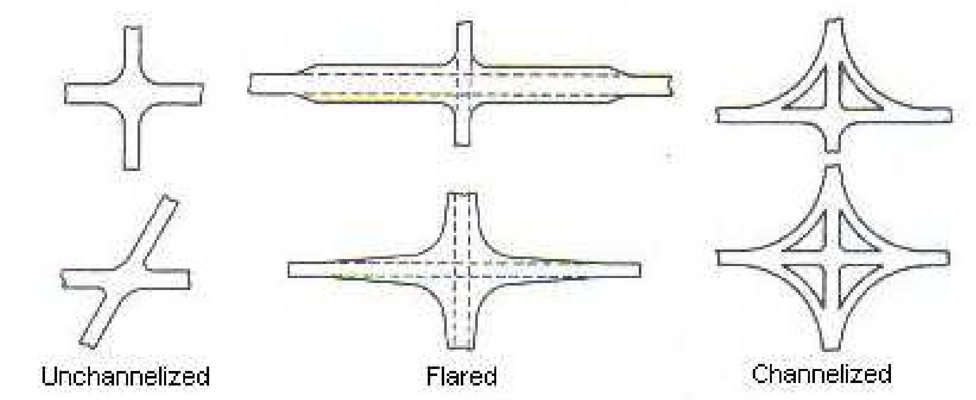

Fig. 1-2 Four legs Intersections [2]

[1] From Reference No. 1
[2] From Reference No. 1

3. Rotary:

A rotary intersection, called a "roundabout" in England, is sometimes placed at the confluence of three or more intersection legs. Basically, it’s a one–way road around a central island .It operates as a series of curved weaving sections placed end to end. At low traffic volumes, rotaries may minimize delay by substituting weaving for direct crossing of vehicle paths. However at higher volumes or where traffic signals are required to reduce congestion rotary is used.

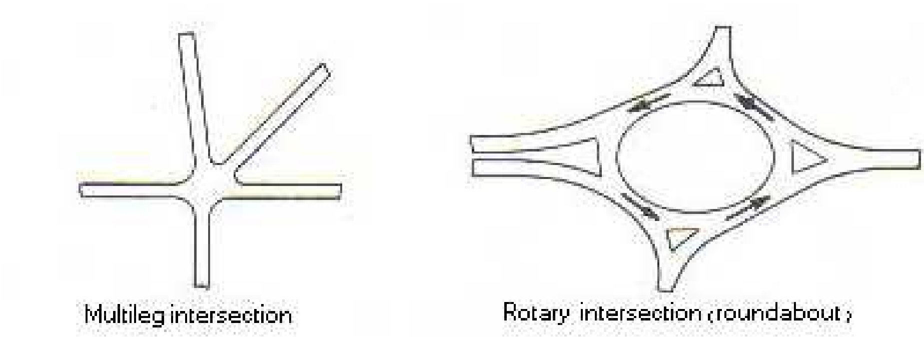

Fig. 1-3 Rotary Intersections [1]

- **Interchange or Separated grade intersections:**

Interchanges involves selecting the conformation best suited when density of traffic occurs to a particular situation, considering such factors as topology of the site, traffic projections and character, land availability, impact on the surrounding area and overall environment, economic viability, and financial constraints it is a difficult task.

The functions of interchanges are (1) to provide grade separation between two or more traffic arteries and (2) to make possible the easy transfer of vehicles from one artery to the other or between local streets and the freeway.

General classes of freeway interchange:

a. Diamond	b. Partial cloverleaf
c. Cloverleaf	d. Directional
e. T or trumpet	f. Through freeway with Rotary

[1] From Reference No. 1

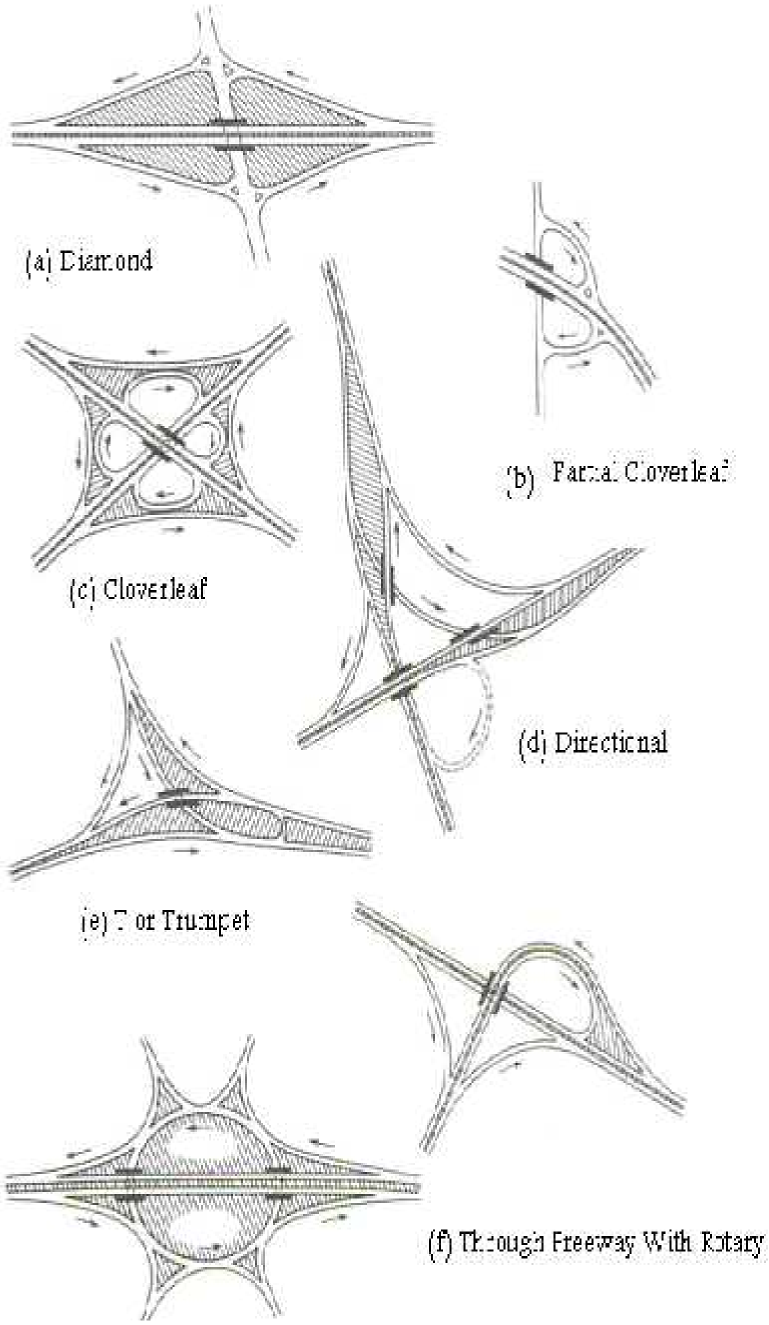

Fig. 1-4 General classes of freeway interchanges [1]

[1] From Reference No. 1

1-3 Objectives of the project:

The project is Examination of some intersections in Hebron city. The best intersections that allow all movements take place with safety. The main aims of the project are to examine and geometry design of these intersections. The secondary objectives of the project are:

1-Rehabilitation of exist intersections.
2- Provide vehicle drivers with a road layout that will minimize confusion.
3- Design the light marking and traffic signs of the intersections.
4- Improved view of traffic for pedestrians.

1-4 Methodology:

1-Limitation the subject of the project, which is examination of some intersections in Hebron city, Beer-Almahger, Alsaheb, and Jabal-Abu-rumman intersections.
2- Reconnaissance study of the project sites and areas.
3-Search about the existing planning which done for these intersections, because the existing maps and aerial photos may be of great help, contour maps show the terrain features and relief of the area, aerial photographs show up to date metric plane details.
4-Write reconnaissance survey report, which summarizes all the collected information, including a description of the intersections.
5- Search in references and books from the Library.
6-Surveying fieldwork, which include the traverses of the intersections locations by using the “Total station” instrument, and traffic counting of the cars which passes through the intersections in peak hours and other times in several days.

7-Study the geometric standards of design intersections, and study the engineering specifications of the intersections to be redesigned.

8- Study the traffic signs and lighting of the intersections.

9- Prepare the final planning and starting to write the project.

1-5 Structure of the Project:

This project is presented in seven chapters. The first chapter entitled “Introduction” outlines general for the intersection engineering, classification of the intersection, objectives of the project, structure of the project, methodology, the discouragements and the difficulties, previous studies.

The second chapter entitled “Traffic Volume”. In this chapter, we count cars, which pass through the intersection in peak hours and in several days. In this chapter, the number of lanes can be estimated.

The third chapter entitled “Field Work Surveying”. In this chapter we will be briefly described the surveying field work which usually done to design any intersection from surveying point of view.

The fourth chapter entitled “Geometric Design of intersections” in this chapter we know what is the standards of geometric design the intersections for design Speed, design cross sections elements (width and number of lanes, shoulders, medians, gutters, sidewalks, etc.). And sight distance.

The fifth chapter entitled “Traffic signs marking and lighting” consists of distribution the lights and traffic signs marking of the intersection.

The sixth chapter entitled "Traffic Lights" consist the types, locations, advantages and disadvantages of traffic lights.

The seventh chapter entitled “Conclusion and Recommendation "consists of summary, recommendations.
Final we write the appendixes, which, the first Computation of traverse and field surveying, the second appendix is the Standard Design; the third appendix is AutoCAD Planning.

1-6 The Present Situation of the Intersection:

We have studied the intersection which connecting the main street of Hebron city. After the field study of the intersection and all field works, the intersections have many defects, for this reasons the intersection needs rehabilitation. The main of these defects are:

1- The width of intersection is not enough for capacity of the present and future traffic volume.

2- The presence of buildings and walls, which located near the intersection, prevents the widening of the intersection, where widening of the intersections needs to compensate of the neighboring citizens by large amount money, which rise the cost of the project.

3- The design of the intersections dose not complies with the geometric standards in the design for stopping sight distance, design speed, superelavation.

4- Shoulders, pedestrian routs (paths), and pavement of intersection are not available.

5- Traffic signs and light of the intersection are not available.

6- A large number of accidents took place on intersections.

7- Some parts of intersection are not paved or in bad conditions.

1-7 The Discouragements and the Difficulties:

1- The location of the intersection in densely populated area, and the large number of details around the intersection, so the design and widening of the intersections with the geometric standards will be very difficult

2-In our project it is very necessary to use the Total station to make the field surveying, and the total station at PPU should be calibrated.

3- Difficulties in collecting data from official departments.

4-The weather conditions during fieldwork and traffic counting, is not stable.

5-The references about intersections rare.

1-8 Previous Studies:

After visiting Hebron municipality there were no clear idea about the design of any intersection especially the one's we are interested in our project. The information we got is that defined the width of the branch at intersection, the intersection is designed according to the situation of the land properties and existing buildings and road in the area without taking into consideration any rules and specifications for design such as safety stopping distance and sight distance.

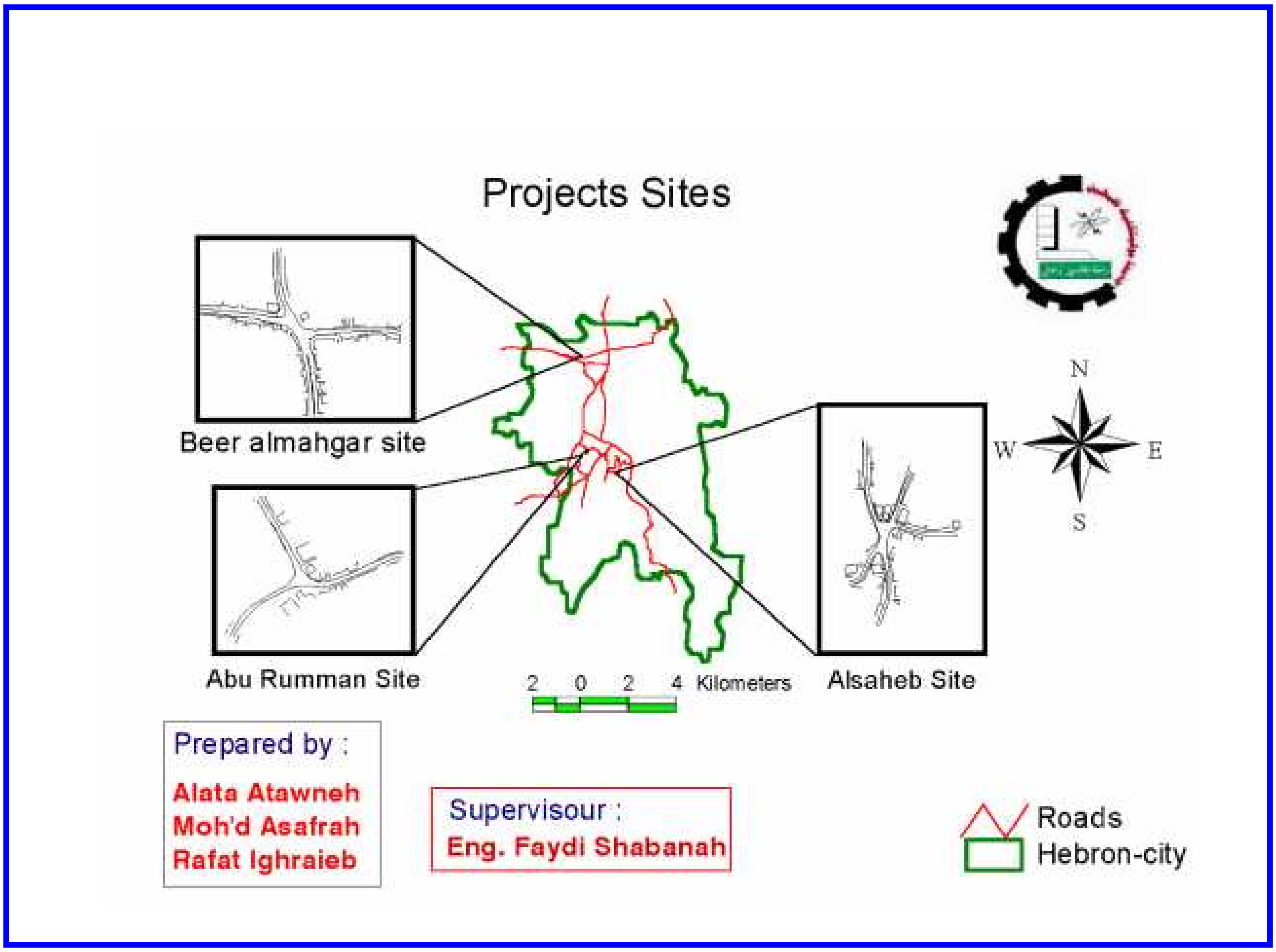

Fig. (1-5) Three Site of the Project

CHAPTER TWO

Traffic Volume

2-1 Introduction:

Knowledge of traffic characteristics is useful to the highway engineer in developing highway and transportation plans, performing economic analyses, and establishment geometric design criteria, selecting and implementing traffic control measurement and evaluating the performance of transportation facilities.

Traffic volume is defined as the number of vehicles that pass through a point along a roadway or traffic lane per unit of time. A measure of the quantity of traffic flow, volume is commonly measured in unit of vehicles per day, vehicles per hour, and vehicles per minute.

Measures of traffic volume are of special significance to the highway engineer, average daily traffic (ADT) and design hourly volume (DHV). The average daily traffic is the number of vehicles that pass a particular point on a roadway during a period of 24 consecutive hours averaged over a period of 365 days.

ADT is a fundamental traffic measurement needed for the determination of vehicle-miles of travel on the various categories of rural and urban highway systems. ADT values for specified road section provide the highway engineer, planner, and administrator with essential information needed for the determination of design standards.

The design hourly volume (DHV) is a future hourly volume that is used for design. It is usually the thirtieth highest hourly volume of the design year. Traffic volumes are much heavier during certain hours of the day or year and it is for these peak hours that the highway is designed.

2-2 Traffic and Road Capacity:

2-2-1- Road Capacity (R.C.):

The term highway capacity indicates the ability of a roadway to accommodate traffic. There are several terms in use which indicate the capacity and the most commonly used as follows:

a) Basic Capacity:

It is the maximum number of passenger's cars that can pass at a given point on the road during one hour under the most ideal conditions.

b) Possible Capacity:

It is the maximum number of vehicles that can pass a given point on the roadway during one hour under the prevailing roadway and traffic condition. It is less than the capacity, since the one or more of the above conditions can not be fulfilled.

c) Practical Capacity (P.C):

It is the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under the existing roadway and traffic conditions without unreasonable delay or restriction to driver's freedom to maneuver.

d) Design Capacity (D.C):

The design capacity is to be assumed equal to or less than the practical capacity.

2-3 Periods of the Counting:

The accounting of vehicles in variable period is very important to get the high accuracy of the information, the main interval of accounting are:

1- Counting in peak hours.

2- Counting in variable hours in one day.

3- Counting in holidays.

4- Counting when is closing some roads.

2-4 Objectives of Study Traffic Volume:

1- Existing traffic:

Traffic currently using an existing highway that is to be improved.

2- Normal traffic growth:

Traffic that can be explained by anticipated growth in state or regional population.

3- Diverted traffic:

Traffic that switches to a new facility form nearby roadway.

4-Converted traffic:

Traffic changes resulting from change of mode.

5-change of destination traffic:

That has changed to different destinations, where such change is attributable to the attractiveness of the improved transportation and not to change in land use.

6- Development traffic:

Traffic due to improvements on adjacent Land in addition to the development that would have taken place.

7- Induced traffic:

Traffic that doesn't previously exist in any form, but results when new or improved transportation facilities are provided.

2-5 The internal counting consists of the following subdivisions:

1-Home interviews.
2- Truck studies.
3-Taxi studies.
4- Public transit information.

Interviews are made on a predetermined schedule and form, are provided for tabulating the necessary information. The information required is for the day preceding the home interview. This information includes the number of occupants in a household, occupation. Number making the trip, use of private or public transportation, origin and destination, purpose of the trip.

2-6 Methods of survey:

Tow methods employ for carrying out volume counts:
(a) Manual Recording Method.
Manual methods employ field checkers to record the volumes of flow on forms or charts specially prepared for the purpose.

(b) Use of Automatic Recorders.
Automatic records photoelectric cell detectors or magnetic detectors are used as permanent and fixed equipments for a few control stations and rubber-tyre detectors are employed at other stations for short periodic counts.

2-7 Normative specifications:

The ministries of public work in Jordan specifications are used in West Bank, for this reasons we must take the considerations to find the number of vehicles, which used in design by compensation of the main factors to convert the big vehicles to equivalent vehicles. These factors are (the small cars number*1, the number of the busses * 2.5, a number the trucks *3).

To know the number of vehicles in day is equal the summations of vehicles divided by the number of counting hour's number of vehicles per hour.

To rehabilitation and design the road to simulation the present and future volume traffic during to twenty year, to calculate the number of lane to simulation the future and present volume traffic during twenty year, we must be multiple the average daily traffic (ADT) by peak factor, the peak factor is equal 2.5.

To know the numbers of vehicles are used in the design must be compensation the main factors to convert the big vehicles to small vehicles. These factors are (the small cars number*1, the number of the busses * 2.5, a number the trucks *3).

To calculate the average vehicles in hour (AVH) if not have available accuracy information about peak hour design hour volume (DHV) then we can find the DHV by use this equation:

D.H.V = K*(A.D.T)…………… (3-1).

Where K= Constant between (0.12 – 0.24)

To calculate the number of lane simulation the present and future traffic volume during twenty year we must multiply the average daily traffic (ADT) by the peak factor (peak factor=2.5).

The design capacity is defined by the maximum number of vehicles passing through point during one hour under the true conditions. The design capacity is range between (700- 1200 vehicles/hour), and it depends on the design speed for the road and the degree of the road.

2-8 Traffic Volume on Intersection:

The starting point for any junction design is thus the determination of the volume of traffic incident on it together with the various turning, merging and conflicting movements involve. The basis for design will be the flow estimate for some point in the future – the design reference flow (DRF). It is an hourly flow rate. Anything from the highest annual a hourly flow to the fiftieth highest hourly flow can be used. For urban roads, use for thirtieth highest flow is usual, with the fiftieth highest is used on interurban routs.

Use of these figures implies that, during the design year in question, it can be anticipated that the design reference flow at the junction will be exceeded and a certain level of congestion experienced. If however , the highest hourly flow was utilized, while no overcapacity will be experienced, the junction will operate at well below its capacity for a large proportion of the time, thus making such a design economically undesirable with its scale also having possible negative environmental effects due the due the intrusion resulting from its sheer scale .(If the junction is already in existence then the DRF can be determined by manual counts noting both the composition of the traffic and all turning movements).

2-8-1 Deriving design reference flows from base line traffic figures:

2-8-1-1 Existing Junction:

At existing junctions, it will be possible to directly estimate peak hour and daily traffic flows together with all turning movements. In order for the measurements to be as the representative as possible of general of the peak flow levels, it is desirable to take them during a normal weekday (Saturday to Thursday) within a natural month (April, May , June , September ,or October) . Factoring up the observed morning and evening peak hour flows using indices given in the national road. Traffic forecasts can lead to the derivation of DRF for the design year (normally 15 years after opening). Flow patterns and proportion observed in the past year can be extrapolated in order to predict future patterns movements.

2-8-1-2 New Junction:

In a situation where a junction is being design for anew road or where flow patterns through an existing junction are predicted to change significantly because of change to the general network ., flows must be derived by use of a traffic modeling process which will generate estimates of 12,16 or 24 hours link flow for a future chosen design year. AADT flows are then obtained by factoring the 12, 16, or 24 hour flows. The AAHT is then calculated (AADT / 24) and then factored to represent the appropriate highest hourly flow using derived factors. Tidal flow is then taken into consideration; generally at 60/40 spilt in favor of the peak hour direction is assumed. Turning proportion are also guesstimated so that the junction can be designed.

2-8-1-3 Short-term variations in flow:

Traffic does not usually arrive at a junction at a uniform or constant rate. During a certain periods, traffic may arrive at a rate higher than the DRF. At other period lower . If the junction analysis for a priority junction/roundabout is being done with the aid of one of the Transport Research Laboratory’s computer programs (PICADY/ARCADY) , such variation can be allowed for using a “ flow profile “ . Atypical profile should involve the inputting of peak time flows in 15-minute intervals. When calculations are being completed by hand for apriority junction /roundabout ,such short terms variations may be taken into consideration by utilizing an a hourly flow equal to 1.125 time the DRF.

In the case of a priority junction, this adjustment should be applied to the design flows on both the minor and major arms. In the case of roundabout intersection, this factored flow will impact not only on the entry flow to the roundabout but also the circulating flows within the intersection.

2-8-1-4 Conversion of AADT to highest hourly flow:

Particularly on urban highways, where peal are less marked, the thirtieth highest flow may be most appropriate. On an interurban route, the fiftieth highest might apply On recreational routes where peaks occur infrequently, the two hundredth highest may be the value most consistent with economic viability. The general implication is that where the design flow is exceed some degree of congestion will result, but this is preferable and economically more justifiable to the situation where congestion will never occur and the road is under capacity at all time .

2-8-2 Major & minor Priority Intersection:

A priority intersection occurs between two roads; one termed the “major” road and other the “minor” road. The major road is the one assigned a permanent priority of traffic movement over that of the minor road. The minor road must give priority to the major road with traffic from it only entering the major road when appropriate gaps appear. The principal advantage of this type of junction is that the traffic on the major rout is not delay.

The principal at the basis of the design of priority intersection is that it should reflect the pattern of movement of the traffic. The heaviest traffic flows should afforded at the easiest paths. Visibility, particularly for traffic existing the minor junction is a crucial factor in the layout of the priority intersection. Low visibility can increase the rate of occurrence of serious accidents as will as reducing the basic capacity of the intersection itself.

Priority intersections can be in the form of simple “T-junctions, staggered junctions or crossroads, though the last form should be avoided where possible as drivers existing the minor road can misunderstand the traffic priorities. This may lead to increased accidents.

Diagrammatic representations of the three forms are given in Fig (2-1)

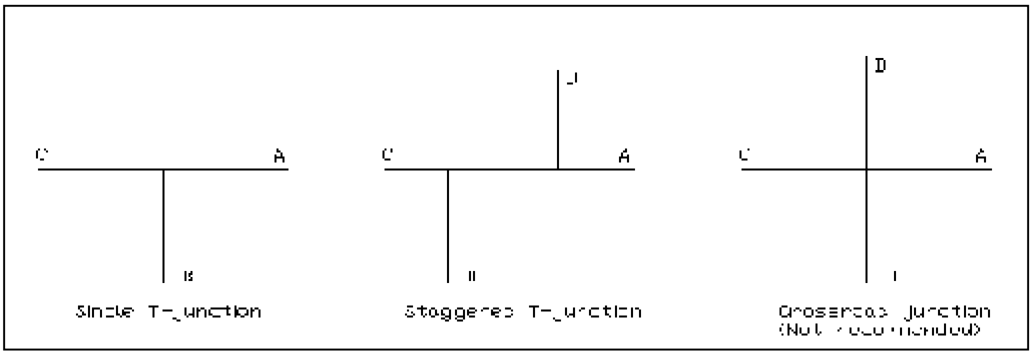

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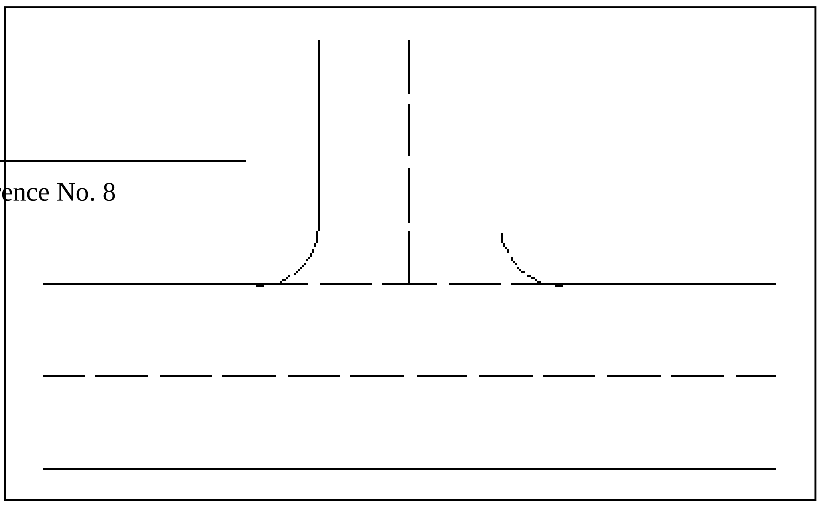
Fig. 2-1 Three forms of priority intersection. [1]

Within the two main junction configuration mentioned above (T-junction/staggered junction), there are three types of geometric layout foe a single carriageway priority intersection:

Simple Junction:

A T-junction or staggered junction without any ghost or physical islands in the major road and without channeling islands in the minor road approach (Fig 2-2).



[1] From Reference No. 8

Fig. 2-2 Simple T-junction. [1]

Ghost island junction:

Usually a T-junction or staggered junction within which an area is marked on the carriageway, shaped and located so as to direct traffic movement Fig.(2-3).

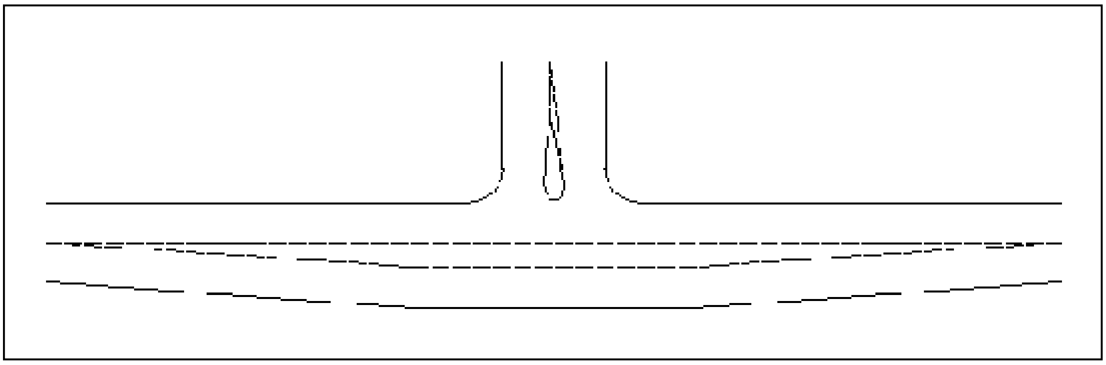


Fig. 2-3 Ghost island junction. [2]

[1] From Reference No. 8
[2] From Reference No. 8

Single Lane Dualling:

Usually a T-junction or staggered junction within which central reservation islands are shaped and located so as to direct traffic movement Fig(2-4).

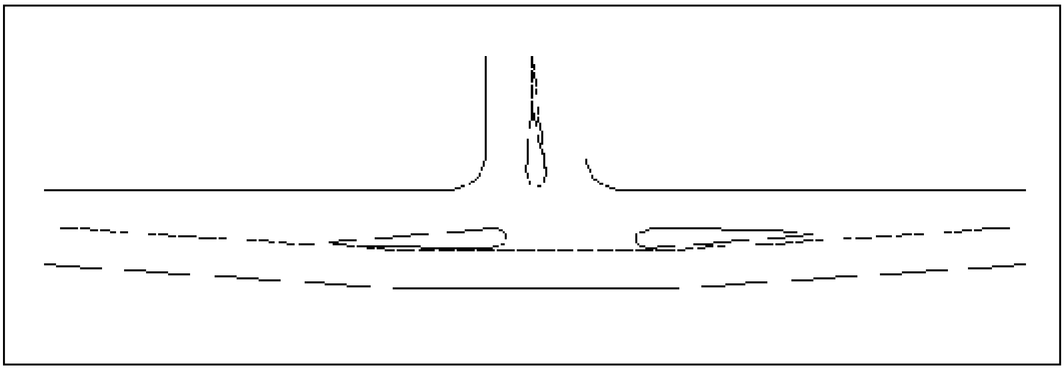


Fig. 2-4 Single lane Dualling.[1]

2-8-3 Roundabout intersections:

Introduction

In order to control merging and conflicting traffic flows at intersection, a roundabout performs the following two major functions:

(1) It defines the priority between traffic streams entering the junction, usually in the basis that traffic wanting to join the circulatory flow must give way to the traffic to their right already circulating in the roundabout. (In the UK and Ireland traffic circulates in the clock wise direction.)

(2) It causes the diversion of traffic from its preferred straight-line path, requiring diverse to slow down as they enter the junction.

[1] From Reference No.8

In order to work efficiently, sufficient gaps must appear in circulating flows on the roundabout that diverse then accept. Traffic on the entry arms can thus enter, circulate and then leave at their desired arm. Its operation has, therefore, certain similarities to that of a priority intersection and, the design procedure in both has certain similarities. The situation is more complex in the case of a roundabout intersection as there is no clear identifiable major road traffic flow that can be used as a basis for designing the junction, with the circulating flow depending on the operation of all entry arms to it.

If properly design, the angles at which traffic merges/diverges will be small. This, combined with the relatively slow traffic speeds on the roundabout will help reduce accident rates.

When traffic flows at intersection are relatively low, adequate control can be attained using the priority option. As flow level increase, however, with this intersection type, delays/ queue lengths become excessive and some alternative from is required. While grade-separated junctions may be the proffered option at high flow levels, the expense involved may be prohibitive. For this reason, particularly in an urban setting, at-grade roundabouts signalized intersections become viable junction options at levels of flow above those suitable for priority control.

If the cost of the land is an important factor, traffic signals will preferred as land requirements for a standard 3 or 4-arm conventional roundabout would be greater. However, right turning vehicles can cause operational difficulties at signal-controlled junctions, particularly where volumes within this phase are large

Roundabouts have difficulty dealing with unbalanced flows, in which case signalization may be preferable. In situations where flows are relatively well balanced, and where three or four entry arms exist, roundabout copes efficiently with the movement of traffic. Where the number of arms exceeds four, however, efficiency may be affected by the failure of diverse to understand the junction layout. It may also prove difficult to correct this even with comprehensive direction signing. In addition to their ability to resolve conflicts in traffic as efficiently as possible, roundabouts are often used in situations where there is:

- A significant change in road classification/type.
- A major alteration in the direction of the road.
- Changes form an urban to a rural environment.

2-9 Counting and design of traffic volume:

The following tables clarify different period time of vehicles counting at three intersections Beer al-mahjagar, Abu-Rumman and Al-Saheb:

Table 2-1 Time period of counting

Site	Monday 18/4/2005	Saturday 23/4/2005	Sunday 24/4/2005	Tuesday 26/4/2005	Wednesday 27/4/2005	Thursday 28/4/2005	Friday 29/4/2005
Beer Al-mahgar	8:20-9:30	13:00-14:00	7:00-8:00	7:00-8:00	13:00-14:00	11:00-12:00	11:30-12:30
Abu-Rumman	10:00-11:00	13:15-14:15	9:00-10:00	8:30-9:30	8:30-9:30	7:00-8:00	13:00-14:00
Al-Saheb	11:20-12:20	11:50-12:50	14:30-15:30	10:00-11:00	7:00-8:00	9:00-10:00	15:30-16:30

The traffic accounting in above table is not enough, because we must account the vehicles in period in one year.

As shown in table (2-1) we were counting the vehicles at intersections as shown in table (2-2).

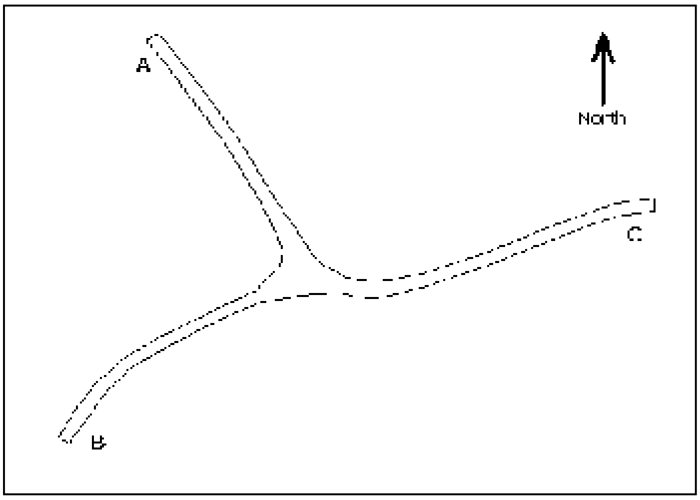


Fig 2-5 Abu-Rumman site

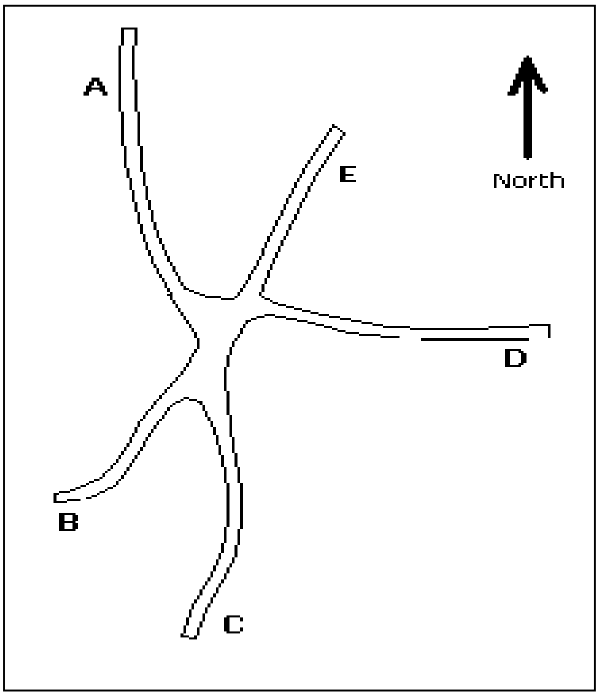


Fig 2-6 Al-Saheb site

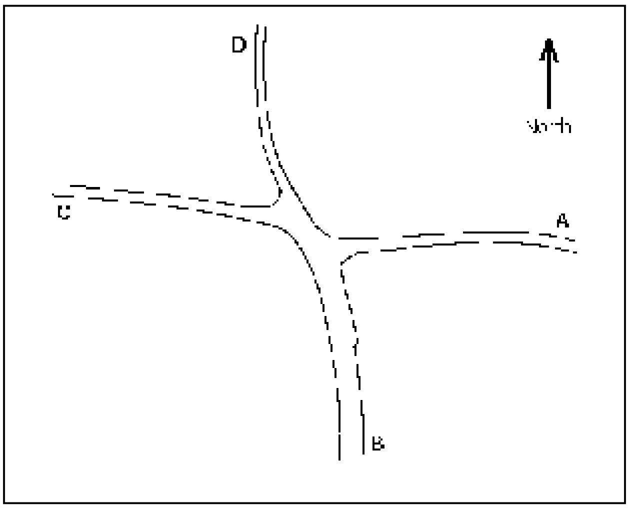


Fig 2-7 Beer Al-mahgar site

Table 2-3 Time period of counting in a year.

Site	App	Car	Bus	Truck	AVH	A D T	A D T*	DH V	Lane #
Beer Al-mahgar	A	241	28	7.7	319	7659	19149	3063.77	4
	B	280	27	6.3	353	8482	21206	3392.91	4
	C	95	18	5.1	148	3542	8854.3	1416.69	4
	D	147	16	20	239	5739	14349	2295.77	4
Abu-Rumman	A	258	28	11	349	8366	20914	3346.29	4
	B	124	23	10	201	4814	12034	1925.49	4
	C	265	30	9	352	8451	21129	3380.57	4
Al-Saheb	A	219	23	4.4	279	6689	16723	2675.66	4
	B	17	4.7	4	38	915.4	2288.6	366.171	2
	C	40	11	11	94	2263	5657.1	905.143	2
	D	75	13	2.7	108	2589	6471.4	1035.43	2

	E	80	8	2	102	2438	6094.3	975.086	2

A D T*= average daily traffic at 20 year.

1. AVH = (car+ bus*2 + truck*3)

   AVH = (241+ 28*2 + 7.7*3) = 319

2. ADT= AVH * 24

   ADT = 319 * 24 = 7659

3. ADT*= 2.5 * ADT

   ADT* = 2.5 * 7659 = 19149

4. DHV = 0.16 * ADT*

   DHV = 0.16 * 19149 = 3063.77

5. # of lane = DHV / 850

   # of lane = 3063.77 /850 = 3.604 = 4 lanes

In west bank roads are third degree, then the capacity design are depended on 850 vehicles/ hour.

CHAPTER THREE

Field Work Surveys

3-1 Introduction:

In the evaluation or reconstruction of existing roads and the establishment of new ones, surveys are required for the development of project plans and the estimation of costs. The performance of good surveys requires well-trained engineers who have an understanding of the planning, design, and economic aspects of highway location and who are sensitive to the social and environmental impacts of roads development.

In our project the surveys fields work include two main stages:
* First stage Traverse field work, which is constructed from five main stations as link Traverse.
* Second stage, Land surveys of “beer al-mahjar” intersection and all details on it such as building, pavement…etc.

3-2Observation Standard deviation

All surveying measurements are subject to errors from varying sources. For example when measuring an angle, the major error sources include instrument placement and leveling, target placement, circle reading, and target pointing .Although great care may be taken in measuring an angle, these error sources will nonetheless render in exact results. To appreciate fully the need for adjustments, surveyors must be able to identify the major measurements error sources, know their effects on the measurements, and understand how they can be modeled.

3-3 Error Source in Horizontal Angles:

Whether a total station instrument is used, errors are presents in every horizontal angle measurements. These errors are:

3-3-1 Reading Errors:

Reading error occur with digital instruments, there size being dependant on the sensitivity of the particular electronic angular resolution system. Manufacturers of digital reading instrument quote the expected combined pointing and reading precision for an individual direction measured face left and face right with there instruments in terms of standard deviation . Typical values range from (+1”) for the more a precise instruments, to (+10”) for the less expensive one’s . These errors are random, and their effects on an angle are depending on the measurement method and the number of angle repetition.

$$\pm_{\sim r} = \pm \frac{\pm_{r} \sqrt{2}}{\sqrt{4}}$$

- From paper sheet of instrument calibration = $\pm_{r} = 2.5''$
- Angle measured with directional method.

*** Directional Method:**

When horizontal angle is measured by directional method, the horizontal circle is read in both the backsight and foresight directions. The angle is the difference between the two readings. Multiple measurements of the angle are made, with the circle being advanced prior to each reading to compensate for the instruments systematic errors. The final angle is taken as the mean of all measured values.

3-3-2 Pointing Errors:

Accuracy in pointing to a target is dependent on several factors. These include the optical qualities of the telescope, target size, the observer's personal ability to place the crosswire on a target, and wither conditions at the time of observation. Pointing errors are random, and they will occur in every angle measurements no matter what instrument is used. Since each repetition of an angle consists of two pointings, the pointing error for an angle that is the main of (n) repetitions can be estimated .Using this equation:

õ we assumed the $\pm_p = 2''$

$$\pm_{\sim p} = \frac{\pm_o \sqrt{2}}{\sqrt{n}}$$

3-3-3 Target Centering Errors:

whenever a target is set over the station, their will be some error due to faulty centering .It can be attributed to environmental conditions, optical plummet errors, quality of optical plummet optics, plumb bob centering error, personal abilities.

When care is taken, the instrument is usually within (0.001 – 0.01) ft of the true station location. Although these sources produces a constant centering error for any particular angle, target centering error will appear as random in the adjustment of the network involving many stations. An estimate the effect of this in an angle measurment can be made by analyzing its contribution to a single direction. The angular error due to centering is dependent on the position of the target. If the target is online but off center, target decentering contributes no angular error. However, as the target moves to either side of the sight line, the error size increases. The largest error occurs when the target is offset perpendicular to the line of sight. Letting (σ d) represent the distance the target is from the true station location, the maximum error in an individual direction due to target decentering is:

$$e = \frac{\pm \pm_{d}}{D}$$

Where: - **e** is the uncertainty in the direction due to the target decentering

$\pm_{d}$ The amount of a centering error at the time of pointing.

- **D** the distance from the instrument center to the target.

Since two directions are required for each angle measurment, an estimate of the angular error is :

$$\pm_{\sim t} = \sqrt{\left(\frac{\pm_{d1}}{D_1}\right)^2 + \left(\frac{\pm_{d2}}{D_2}\right)^2}$$

The final equation can we use to estimate this error is:

$$\pm_{\sim\sim t} = \pm \frac{\sqrt{D_1^2 + D_2^2}}{D_1 D_2} \pm_{T} \circ$$

***** We assume $\pm_{t} = \pm 3mm$

3-3-4 Instrument-centering Error:

For any time the instrument is centered over a point, there is some error in its position with respect to the true station location. The error is dependent on the quality of the instrument and the adjustment of its optical plummet, the quality of tripod, and the skills of the observer. The error can be compensating, or it can be maximum when the instrument is on the angle bisector. For any individual setup this error is a constant, however, since the instruments location is a random with respect to the two station location, it will appear to the random to the adjustment of a network involving many stations .so the equation is written as:

$$\pm_{\sim\sim i} = \pm \frac{D_3}{D_1 D_2 \sqrt{2}} \pm_i {}^{\circ}$$

- We assumed $\pm_i = \pm 3mm$

So the combined error propagation in a single horizontal angle is :

$$\pm_{\sim} = \sqrt{\pm_{\sim r}^2 + \pm_{\sim p}^2 + \pm_{\sim t}^2 + \pm_{\sim i}^2}$$

3-4 Error in Electronic Distance Measurements:

All EDM instrument measurements are subject to instrumental errors that manufactures list as a constant and scalar error. A typical specified accuracy is $\pm$ (a + b ppm). In this expression, (a) is generally in the range (3-10 mm), and (b) is a scalar error which typical has the range (3-10 ppm) .Other errors involved in electronic distance measurements stems from target an instrument decentering. Since in any survey involving several stations these errors tend to be random. The estimated error in an EDM measured distance is:

$$\pm_d = \sqrt{\pm_i^2 + \pm_t^2 + a^2 + \left(D \times b \quad ppm\right)^2}$$

õ From paper sheet of instrument calibration = (3 + 2 ppm)

3-5 Error in Azimuth of Courses:

Travers Azimuth are normally computed from measured angles rather than observed directly. Thus another level of error propagation exists in calculating the Azimuth from angular values. In the following analysis, consider that interior angles are measured and that Azimuth are computed in a counter clockwise direction successfully around the traverse using the formula:

$$AZ_c = AZ_p + 180° + -_i$$

Where: AZ_c = Is the Azimuth for the current course

AZ_p = Is the previous course Azimuth.

$-_i$ = The appropriate interior angle to use in computing the current Azimuth.

The error in the current Azimuth $\pm_{AZ_c}$ can be estimated as:

$$\pm_{AZ_c} = \sqrt{\pm_{AZ_p}^2 + \pm_{-_i}^2}$$

3-6 Traverse fieldwork:

The traverse in this project is constructed with four control points, start from two control points and closed with two control points; the coordinates of these control points and its description as follow:

Table (3-1): Control Points

Point	E	N	Description
First Back Site	156215.78	108603.58	Alrahman Mosque(A)
Start Station	155486.24	109046.78	Trig (S.T.1)
End Station	157933.1	107161.35	Trig(S.T.5)
End Back Site	158637.53	106717.56	Alribat Mosque(B)

Five fundamentals occupied station are constructing the traverse, two of them are control points (trigs), and other stations are placed on:

- S.T.2: placed on Abed Alrahman Assafrah home, on north-east corner, in Beit kahel.
- S.T.3: placed on Khader Hammad Assafrah home, on south-east corner, in Beit kahel.
- S.T.4: placed on Aljoulani home, on north-east corner, in Beit kahel.

The observation angles and distances are tabulated as follow:

Table (3-2): Distance observations:

From	To	Distance (m)	S.D. (m)
S.T.1	S.T.2	882.277	.00549
S.T.2	S.T.3	783.420	.00543
S.T.3	S.T.4	975.350	.00555
S.T.4	S.T.5	981.905	.00555

Table (3-3): Angle observation:

Back sight	Occupied	Fore sight	Angle	S.D. (second)
A	S.T.1	S.T.2	347d 32’ 03”	2.480”
S.T.1	S.T.2	S.T.3	178d 53’ 02”	2.711”
S.T.2	S.T.3	S.T.4	185d 14’ 55”	2.676”
S.T.3	S.T.4	S.T.5	248d 55’ 09”	2.542”
S.T.4	S.T.5	B	120d 20’ 43”	2.604”

Table (3-4): Departure & Latitude Calculations

From	To	Distance	Azimuth			S.D. Az.	Departure	Latitude
A	S.T.1	853.613	121	16	44	0.00”	====	====
S.T.1	S.T.2	882.277	108	48	47	2.480”	835.142	-284.518
S.T.2	S.T.3	783.420	107	41	49	3.674”	746.347	-238.146
S.T.3	S.T.4	975.350	112	56	44	4.545”	898.176	-380.246
S.T.4	S.T.5	981.905	181	51	53	5.208”	-31.951	-981.385
S.T.5	B	832.569	122	12	36	5.823”	====	====
Sum		3622.952					2447.714	-1884.295

3-7 Angular misclosure:

Angular misclosure is the difference between fixed and computed azimuth of last course (S.T.5 - B):

Angular misclosure = Az (S.T.5 - B) (fixed) - Az (S.T.5 - B) (calculated)

=122d 12’ 39.15” – 122d 12’ 36” = 3.15”

Since the angular misclosure (3.15”) less than permissible angular misclosure (5.82”) there is no reason to assume that the angles contain blunders.

3-8 Linear misclosure:

ΔE=E (S.T.1) + $\sum(Dep)$ - E (S.T.5)

=155486.24 + 2447.714 – 157933.1 = 0.854

ΔN=N (S.T.1) + $\sum(Lat)$ - N (S.T.5)

=109046.78 – 1884.295 – 107161.35 = 1.135

Misclosure Error = $\sqrt{(\Delta N)^2 + (\Delta E)^2}$

$= \sqrt{(0.8548)^2 + (1.135)^2}$ = 1.42 m

3-9 Expected Misclosure for the Traverse

The expected misclosure in this link traverse is estimated. The Jacobian matrix of the partial derivative (J) for the latitude and departure with respect to the distance and Azimuth measurment is:

$$J = \begin{vmatrix} Cos(AzA1) & -D_{A1}Sin(AzA1) & 0 & 0 & 0 & 0 \\ Sin(AzA1) & D_{A1}Cos(AzA1) & 0 & 0 & 0 & 0 \\ 0 & 0 & Cos(Az12) & -D_{12}Sin(Az12) & 0 & 0 \\ 0 & 0 & Sin(Az12) & D_{12}Cos(Az12) & 0 & 0 \\ : & : & : & : & : & : \\ : & : & : & : & : & : \\ 0 & 0 & 0 & 0 & Cos(Az5B) & -D_{5b}Sin(Az5B) \\ 0 & 0 & 0 & 0 & Sin(Az5B) & D_{5b}Cos(Az5B) \end{vmatrix}$$

The corresponding covariance matrix $\sum$ has the form:

$$\sum = \begin{vmatrix} \pm DA1^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & \left(\frac{\pm AzA1}{\circ}\right)^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & \pm D12^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & \left(\frac{\pm Az12}{\circ}\right)^2 & 0 & 0 \\ : & : & : & : & : & : \\ : & : & : & : & : & : \\ 0 & 0 & 0 & 0 & \pm D5B^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & \left(\frac{\pm Az5B}{\circ}\right)^2 \end{vmatrix}$$

The corresponding covariance matrix $\sum Lat, Dep$ can be obtained by the follow equation:

$$\sum Lat, Dep = J \sum J^T$$

$$A = \begin{vmatrix} \frac{\Delta Lat}{LC} & \frac{\Delta Dep}{LC} & \frac{\Delta Lat}{LC} & \frac{\Delta Dep}{LC} & ..... & \frac{\Delta Lat}{LC} & \frac{\Delta Dep}{LC} \end{vmatrix}$$

The expected standard error in the misclosure of the traverse is obtained by following equation:

$$\sum LC = A \sum Lat, Dep\, A^T$$

$$\sum LC = A \sum Lat, Dep\, A^T = |0.2820|$$

From this result and using a ***t*** value for 3 degrees of freedom, the estimated linear misclosure error for a 95% confidence level is:

$$\pm_{95\%} = 3.183\sqrt{0.2820} = \pm 1.690$$

Because the actual misclosure of 1.42 m is less than the misclosure expected at the 95% level ($\pm$1.690), there is no reason to believe that the traverse measurement contain any blunders.

The assumed permissible misclosure value is:

$$(\frac{1}{2000} \times \text{Length of traverse}) = \frac{1}{2000} \times 3622.952 = 1.811$$

Since the expected misclosure of 1.690 m is less than the permissible misclosure of 1.811 m, so there is no reason to change the instrument.

3-10 Correction of the Coordinates:

The non fixed stations in the traverse (ST.2, S.T.3, ST.4) are corrected with least square techniques by using "Surveying Calculator I" programmed by Eng.Osama Al-Falah, Eng.Hamed Shoukha and Eng. Wisam Tamimi, its from previous graduation projects in Palestine Polytechnic University.

Table (3-5): Corrected Coordinates

# Of Station	X	Y
S.T.2	156321.382	108762.262
S.T.3	157067.729	108524.116
S.T.4	157965.904	108143.868

The observations of (S.T.6) are taken from (S.T.4):

Horizontal angle = 212d 09' 50" $\pm$ 2.6" …………. (Back site (S.T.3)).

Horizontal Distance = (1067.967 ± 0.0056) m.

The horizontal angle is measured by direction method, with 8 repetitions are made (4-faceleft & 4-faceright), then the average of 8 reading is considered.

The corrected coordinates of *(station 6)* is obtained:

X = 158576.79

Y = 107267.87

This station which is occupied for “Beer Al-Mahgar” land surveying.

3-11 Traverses of the Project:

3-11-1 Beer Al-mahgar traverse:

The usual procedures followed in traverse computations, all of which are discussed above**.**

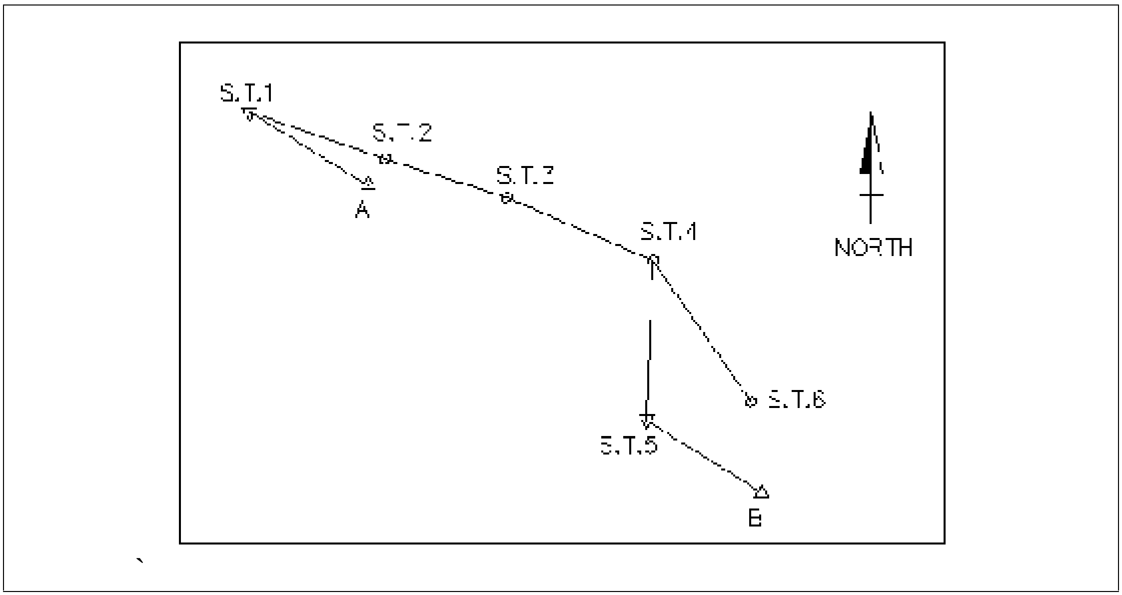


Fig. 3-1 The Traverse of the Project.

3-11-2 Abu-Rumman coordinates stations:

In the abu-rumman intersection the standard deviation for the stations coordinates as this table:

Table 3-6. The standard deviation for the stations coordinates of abu-rumman

Station	X	Y	$\pm x$	$\pm y$
Al-shreyia	158404.667	103763.214	0.5	0.6
Huda school	158526.358	103114.372	0.41	0.35
Alrahma	158779.853	103593.754	0.38	0.27

3-11-3 Al-saheb coordinates stations:

In the Al-saheb intersection the standard deviation for the stations coordinates as this table:

Table 3-7 The standard deviation for the stations coordinates of Al-saheb

Station	**X**	**Y**	$\pm x$	$\pm y$
S.T.6	102713.386	159593.894	0.53	0.46
S.T.7	102705.902	159569.709	0.21	0.28

CHAPTER FOUR

Geometric Design

4-1 Introduction:

Geometric design are primarily concerned with related the physical elements of the highway with relating the physical elements off the vehicle. The physical elements that have to be considered in geometric design are primarily:

1- Basic physical element of a highway.
2- Design speed.
3- Sight distances.
4- Highway cross-section design.
5- Island and channelizing design for intersection

The factors that affect the design of these elements are:

1- Driver behavior and ability.
2- Vehicle characteristics.
3- Traffic speeds and volumes.

These characteristics of vehicles, traffic, drivers, etc. That influence the design of Roads is referred as design controls.

The design engineer has to consider the following points when selecting the design standards for a highway:

1- Adequate geometric design in planning highway facilities ensures that the facility will not become obsolescent in the future. Hence, the volume and composition of traffic in the design year should be the basis of design.

2- Faulty geometric are costly to rectify later and so due consideration should be given to geometric design at the initial stage it self.

3- The design should be consistent with standards proposed for different elements and should be compatible with one another. Abrupt changes in the design should be avoided.

4- The design should embrace all aspects of geometric of road, including signs, markings, proper lighting, intersections, etc.

5- The cost should be minimized.

6- The design should be selected such as not only the initial cost of construction of the facility, but also the total transportation cost, including maintenance cost and road user

7- Safety should be built into the design elements.

8- The design should enable all the road users (motor vehicles, animals drawn vehicles, cyclist and pedestrians) to use the facilities. The performance of the vehicles using the facility should be given due consideration. Highway should be considered as an element of the total environment and its location and design should enhance rather than degrade the environment. The design elements should strive to control pollution.

4-2 Basic physical element of a highway:

The basic features of a highway are the carriageway itself, expressed in terms of the number of lanes used, the central reservation or median strip and the shoulders. Depending on the level of the highway relative to the surrounding terrain, side-slop may also is a designed issue.

4-2-1 Main carriageways:

The chosen carriageway depends on a number of factors, most notably the volume of traffic using the highway, the quality of service expected from the installation and the selected design speed. In most situations a lane width of 3.65m is used, making a standard divided or undivided 2-lane carriageway 7.3m wide in total.

Table 4.1 gives a summary of carriageway widths normally used in UK. Any reduction or increase in these widths is considered a departure from standard. The stated lane widths should only be departed from in exceptional circumstances such as where cyclists need to be accommodated or where the number of lanes needs to be maximized for the amount of land available. In Scotland and Northern Ireland a total carriageway width of 6.0m may be used on single carriageway all-purpose roads where daily flow in the design year is estimated not to exceed 5000 vehicles.[**1**]

Table (4-1) Standard carriageway width [2]

Road description	Carriageway width (m)
Urban/rural 4-lane dual	14.60
Urban/rural 3-lane dual	11.00
Urban/rural single/dual 2-lane (normal)	7.30
Rural single 2-lane (wide)	10.00

4-2-2 Central reservations:

A median strip or central reservation divides all motorways/dual carriageways. Its main function is to make driving safer for the motorist by limiting locations where vehicles can turn right (on dual carriageways), completely separating the traffic traveling in opposing directions and providing a space where vehicles can recover their position if for some reason they have unintentionally left the carriageway. In urban settings, width of 4.5m is recommended for 2/3-lane dual carriageways, width 4.0m recommended for rural highways of this type.

While these values should be the first option, a need to minimize land take might lead to reductions in their value. Use of central reservation widths greater than the

[1] From Reference No.8
[2] From Reference No.8

values stated is permitted .it s surfacing material should be different to that on the carriageway itself. Grass, concrete or bituminous material can be used.

4-2-3 Hard strips/verges:

On single carriageway roads (normal and wide), a 1m wide hard strip and a 2.5m wide grassed verge are employed on the section of roadway immediately adjacent to the main carriageway on each side. On rural 2 and 3-lane motorways, a hard shoulder of 3.3m and a verge of 1.5m are the recommended standard .on rural 2/3-lane dual carriageways, the 1m wide hard strip and 2.5m wide verge is detailed on the nearside with a 1m hard strip on the offside. For urban motorways the verge dimension varies while the hard shoulder is set at 2.75m wide. Diagrams of typical cross-sections for different road classifications are given figs 4.1 to 4.4. [**1**]

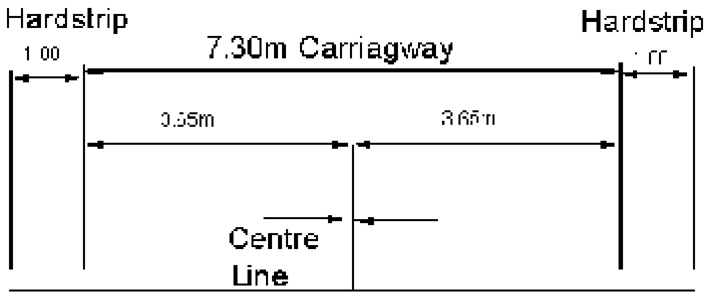


Fig. 4-1 Single 7.30 meter all-purpose roadway.

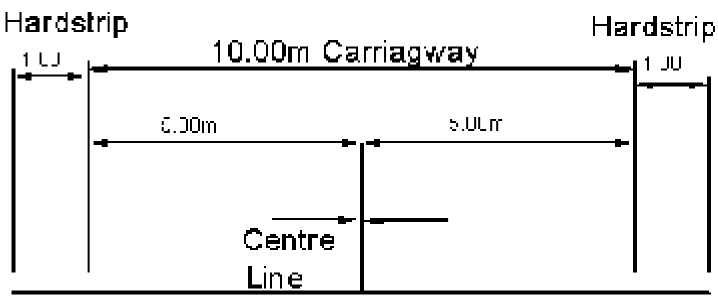


Fig. 4-2 Wide single all-purpose.

[1] From reference No.8

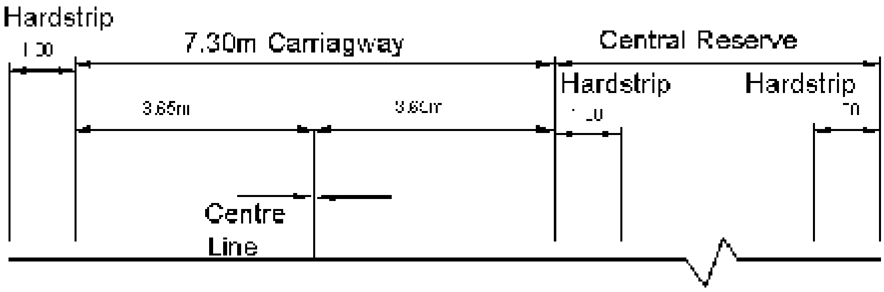


Fig. 4-3 Dual 2-lane all-purpose.

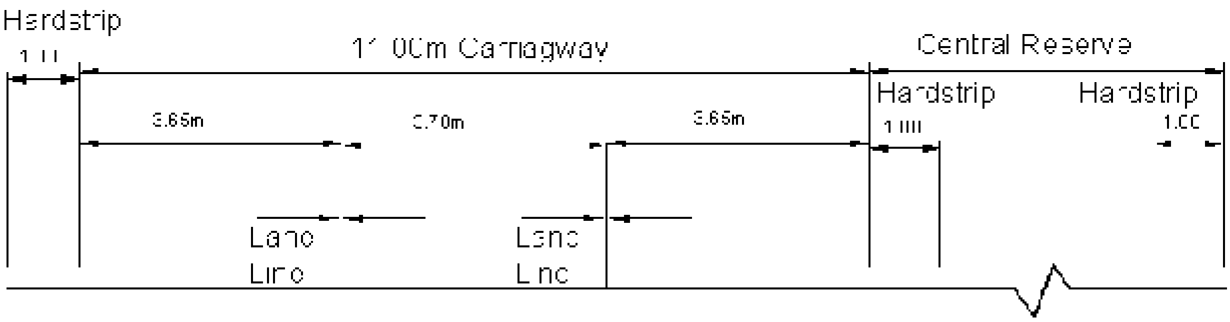


Fig. 4-4 Dual 3-lane all-purpose.

The proper geometric design of a highway ensures that drivers use the facility with safety and comfort. The process achieves this by selecting appropriate vertical and horizontal curvature along with physical features of the road such as sight distances and superelevation .The ultimate aim of the procedure is a highway that is both justifiable in economic terms and appropriate to the local environment.

4-3 Design Speed:

Design speed is a selected speed used to determine the various geometric design features of the roadway. The design speed of a project has a direct impact on the cost, safety, and quality of the finished project. With the exception of local streets, the chosen design speed in rural areas should be as high as practicable to attain a specified degree of safety, mobility, and efficiency while taking into consideration constraints of environmental quality, social and political impacts, economics, and aesthetics.

In urban situations, the design speed should generally be slightly higher that the posted speed of the particular section of roadway and consider land use, pedestrian needs, safety, and community livability. Care must be taken to not confuse design speed with operating speed, posted speed, 85^{th} percentile speed, and running speed.

The selection of a design speed for any given project is dependent on several factors; these factors include; traffic volume, the geographic characteristics of an area, the functional classification of the roadway, the number of travel lanes, the posted speed, roadway environment, adjacent land use, and the type of project being designed.

When selecting an appropriate design speed the designer should not only look at the roadway section in question but also adjacent sections to the proposed project. Within the project, the chosen design speed should be applied consistently throughout the section keeping in mind the speed a driver is likely to expect. This is very important when dealing with horizontal and vertical alignments, superelevation rates, and spiral lengths. For example, a project with a selected design speed of 90 km/h consists of multiple horizontal curves. All horizontal curves should be designed for 90 km/h along with the appropriate superelevation and spiral length for the 90-km/h-design speed.

Due to economical or environmental reasons all curves may not be able to achieve a 90-km/h-design speed. In these cases it is important that the driver be warned well in advance of the lower speed condition ahead with the use of curve-speed signs. By using design speeds in a consistent manner, the driver is able to operate a vehicle in the same consistent manner of expectation.

Finally, selecting the appropriate design speed for a particular section must consider transition areas from rural to urban environments. Providing a smooth and clear transition from high rural speed conditions to urban environments is critical in controlling driver’s perceptions of the areas they are entering. These transitions alert users of the changing environment, and control vehicular speeds as they enter various urban environments. The most common and effective transitions are those that establish a different roadway culture such as sidewalks, buffer strips, and raised medians. Another common technique for transition areas is visual narrowing of the roadway. This can be accomplished with raised islands, buffer strips, and landscaping.

**** 85th and 99th percentile speed: [1]**

The standard design speeds are 50, 60, 70, 90, 100 and 120 km/h. these bands are based on the premise that it is considered acceptable if 85% of drivers travel at or below the designated design speed for a given highway, generally enduring a situation where approximately 99% of the drivers travel at or below one speed category above the design speed (i.e. if the speed limit is set at 85 km/h, it can be assumed that 85% of drivers will travel at or below this value while 99% will travel at or below 120km/h).
The design bands can thus be structure as shown in this table:

Table (4-2) Framework for design speed. [2]

85th percentile speed	99th percentile speed
120	145
100	120
85	100
70	85
60	70

[1]From reference No.8
[2]From reference No.8

4-4 Sight distance:

Sight distance is unobstructed distance of roadway ahead visible to the driver. There are multiple types of sight distance that include stopping sight distance, passing sight distance, decision sight distance and intersection sight distance.
Intersections at grade shall be provided with at least minimum stopping sight distance and preferably intersection sight distance for the design speed. Sufficient sight distance should be provided so that the entering vehicle may cross or make a turn without significant slowing of the through traffic.

4-4-1 stopping sight distances:

Stopping sight distance is the minimum distance required for a vehicle traveling at a particular design speed to come to a complete stop after an obstacle on the road becomes visible. Stopping sight distance is normally sufficient to allow an alert and prudent driver to come to a hurried stop under normal circumstances. Stopping sight distance is measured from the driver’s eye (assumed to be 1080 mm above the roadway surface) to an object 150 mm above the roadway surface (ODOT has maintained the 150 mm height of object). Stopping sight distance is the summation of two distances: the distance traveled by a vehicle from the time the driver sees an object that requires a stop to the instant the brakes are applied, and the distance required to stop the vehicle from the time the brakes are applied. These two distances are called brake reaction distance and braking distance on Table (4-3) contains the safe stopping sight distance standards.

Table (4-3) Safe Stopping Sight Distance [1]

Design Speed	Safe Stopping Sight Distance
40 km/h	50 m
50 km/h	65 m
60 km/h	85 m
70 km/h	105 m
80 km/h	130 m
90 km/h	160 m
100 km/h	185 m
110 km/h	220 m
120 km/h	250 m

4-4-2 Decision sight distance:

Many times the elements of the roadway become complex and require additional distances for drivers to make the proper maneuver. Stopping sight distance may not be adequate when drivers must process complex roadway information at an instance or when the roadway information is difficult to decipher or unexpected. Decision sight distance should be provided at locations where multiple information processing, decision-making, and corrective actions are needed. Sample locations where decision sight distance is needed includes unusual intersection or interchange configuration and lane drops. Decision sight distance is calculated using the 1080 mm eye height and the 150 mm object height that is also used for stopping sight distance, (fig. 4-5).

[1] From reference No.14

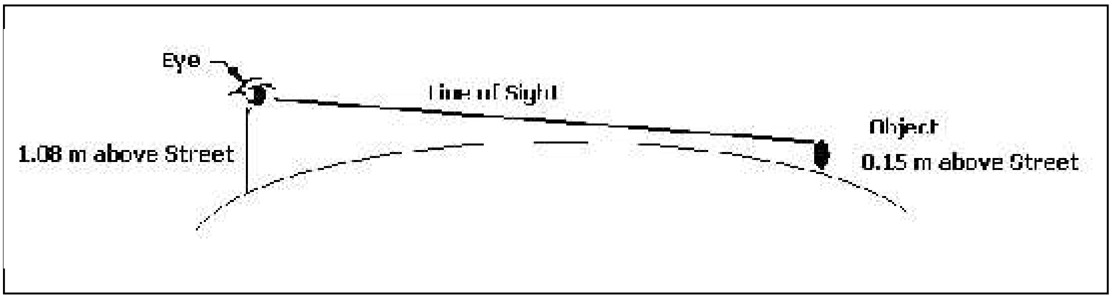


Fig. 4-5 Sight Distance.[1]

4-4-3 Intersection sight distance:

Road approaches should be placed so that intersection sight distance is provided. The vehicle entering the traffic stream should have a view along the highway equal to the intersection sight distance for the design speed of the highway. At a minimum, stopping sight distance for the design speed of the highway must be provided at all approaches.

Obtaining intersection sight distance is important in the design of intersections. Intersection sight distance is considered adequate when drivers at or approaching an intersection have an unobstructed view of the entire intersection and of sufficient lengths of the intersecting highways to permit the drivers to anticipate and avoid potential collisions. Sight distance must be unobstructed along both approaches at an intersection and across the corners to allow the vehicles simultaneously approaching, to see each other and react in time to prevent a collision. Intersection sight distance is determined by using a 1080 mm eye height and a 1080 mm height of object.

Intersection sight distance should be obtained at every road approach, whether it is a signalized intersection or private driveway. In no case should the sight distance be lower than safe stopping sight distance.

[1] From Reference No.16

When reviewing intersection sight distance, items such as building clearances, street appurtenances, potential sound walls, landscaping, and other roadway elements must be taken into consideration in determining and obtaining the appropriate sight distance at intersections. Railroad and rail crossing should be treated in the same manner as roadway intersections in determining intersection sight distance.

The following figures (4-5) [1], which shows the intersections sight distance at-grad intersections.

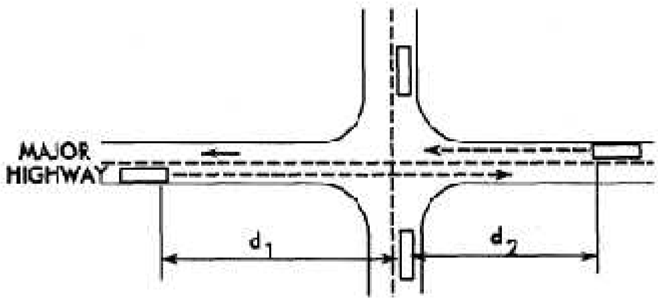


Fig.(4-5a) stopped vehicles crossing a major highway

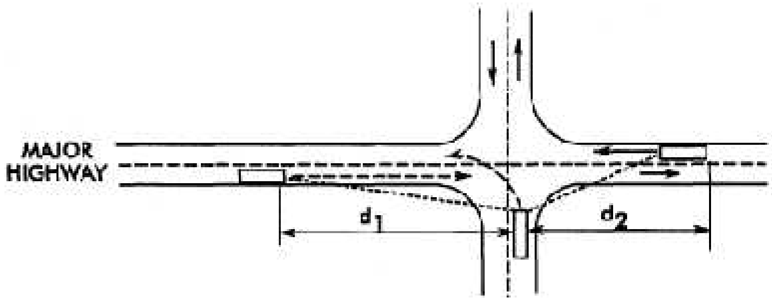


Fig.(4-5b) stopped vehicles turning left into two-lane major highway

[1] From Reference No.16

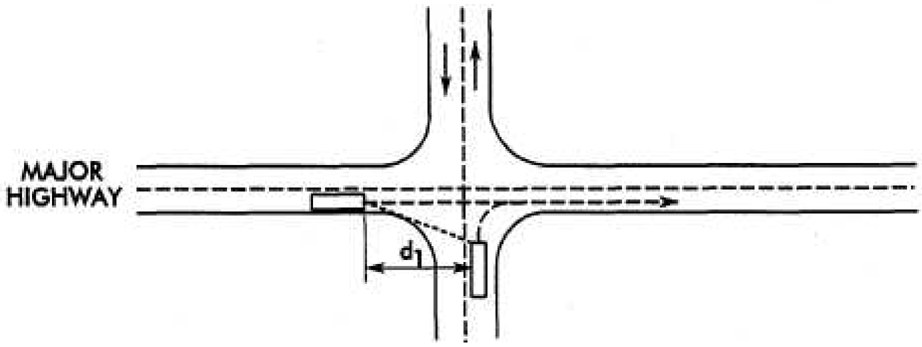
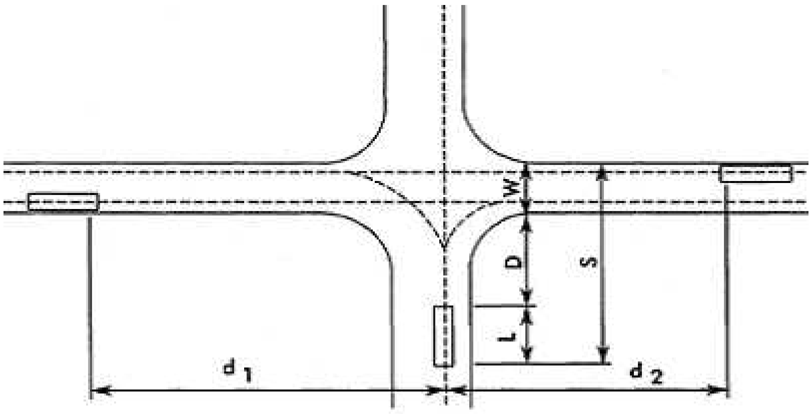


Fig. (4-5c) stopped vehicles turning right into two-lane major highway



Case a

Stop control on minor road

In the above figure, the distance "s" that the crossing vehicle must travel to clear the major highway is the sum of the following three distances (in feet):

$$S = D + W + L.$$

Where: D = Distance from near edge of pavement to front of a stopped vehicle, ft.

W = Pavement width along path of crossing vehicle, ft.

L = Overall length of vehicle, ft.

The sight distance for a crossing maneuver is based on the time it takes for the stopped vehicle to clear the intersection and the distance that a vehicle will travel along the major road at it's design speed in that amount of time. this distance may be calculated from the equation :

$$d = 1.47\ v\ (j = ta).$$

Where: d = Sight distance along the major highway from the intersection, ft.

v = Design speed on the major highway, mph.

j = Sum of the perception time and the time required to actuate the clutch or actuate automatic shift, seconds.

ta = Time required to accelerate and traverse the distances to clear the major highway pavement, seconds.

4-5 Intersection Design:

The Preliminary Design Unit can provide design assistance in the areas of interchange design, intersection design, channelizations, road approaches, roundabouts, large vehicle accommodation, and alternative mode accommodation. The Preliminary Design Unit is responsible for the preparation of all interchanges layout sheets for all new and modified interchanges.

The design of private road approaches is affected by many factors. The type of access, volume of vehicles, type of vehicles, grades, alignment, and adjacent land use all influence the design. The spacing of approach roads should be consistent with the spacing guidelines specified in the Oregon Highway Plan.

Approaches on opposite sides of the highway should be located across from each other, whenever possible. However, under high speed and high traffic volume conditions, approaches may need to be separated to reduce the complexity and number of conflicts (see Figure 4-6). The approaches need to be separated far enough that they operate independently outside their functional areas (See Figure 4-7). Although this situation is possible at some high volume private approaches, this treatment is generally only appropriate for public road approaches. Preliminary Design and the Region Access Management Engineer should be contacted when considering separation of private approach roads. Major public roads with large volumes of through traffic should generally not be separated.

No approach road should be constructed within the functional area of an adjacent intersection (see Figure 4-7). [1]

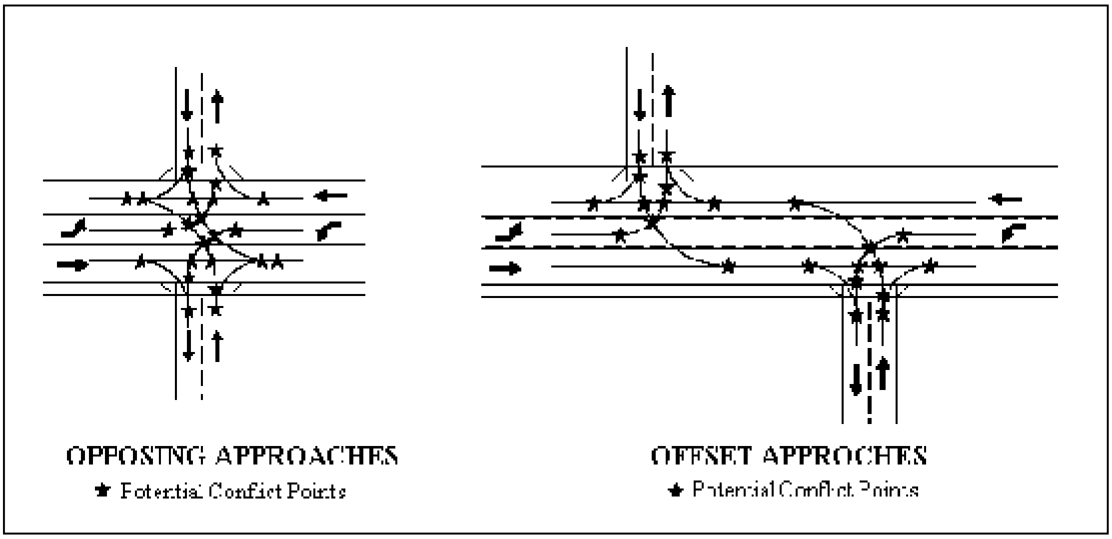


Fig. 4-6 offset approaches

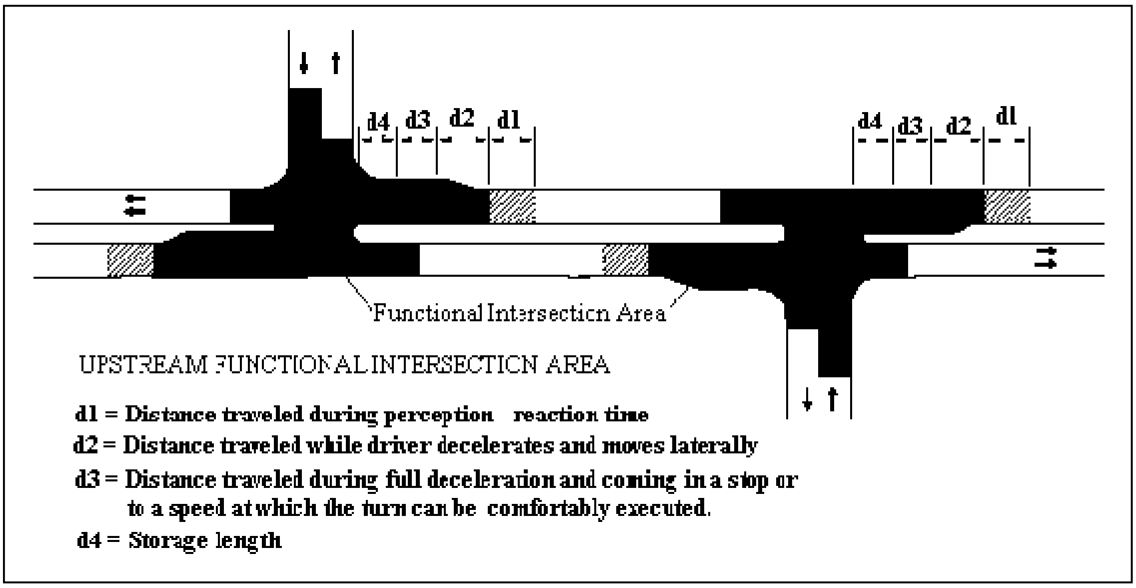


Fig. 4-7 Functional intersection area

[1] From Reference No 15

Where a private approach serves a high volume of traffic, additional design and/or traffic controls may need to be incorporated into the design. High volume approaches often will require channelization along the highway. In some instances, the approach may require a traffic signal in order to operate safely and efficiently. The designer should work with the Region Access Management Engineer to determine solutions for high volume private approaches and potential private approaches opposite signalized intersections. Private approaches are not allowed directly opposite interchange ramp terminals. NOTE: *the Traffic Engineer prior to installation must approve all traffic signals. Generally only public road approaches should be considered for signalization. Signalizing private approaches should be avoided*. [1]

4-6 Design considerations of intersections:

In this section we will describes the standards and guidelines for the geometric design of traditional at-grade intersections including lane widths, shoulders, superelevation, skew angles, turning radii, left turn lanes, right turn lanes, channelization islands, curb extensions, and bicycle and pedestrian needs.

4-6-1 Approach Grade:

The approach grades of intersecting roadways with a state highway should be kept to a minimum. It is preferable to have a relatively flat or slightly elevated roadway connecting with a state highway. This helps improve the visibility of the intersecting roadway.

Generally the intersecting roadways vertical alignment should match with the cross slope of the highway as long as the cross slope is less than 3%. Where the cross slopes is equal to or greater than 3% a small break in the grade or vertical curve may necessary. The goal is to provide a connection that does not require vehicles to stop

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[1]From reference No.14

and enter the highway from a steep grade. The flatter the approach, the better, particularly for large vehicles.

The maximum grade break between the highway shoulder and intersecting road should be held to 6% or less. Where the algebraic grade difference is greater than 6%, a short vertical curve should be used. In addition, a 6 m landing should be provided (See Appendix B, Standard Design). [**1**]

4-6-2 Travel lane widths:

Through travel lane widths should remain constant through an intersection. The lane lines should line up throughout the entire intersection and not be offset. This helps to discourage lane changes through the intersection area. The appropriate travel lane width is determined by the location (rural or urban), design speed, volume of trucks, and alignment. The rural or urban highway design chapters of this manual should be used to determine the appropriate through lane width.

Through travel lanes may need to be widened when a two-lane highway flares to provide a left turn lane channelization. In these situations the through travel lanes should be widened to 4.2 m when the design speed is greater than 70 km/h. All other situations should retain the existing through travel lane width. When an intersection is a part of or connecting to a turning roadway, the lane widths may need to be increased to allow for large vehicle off tracking.

4-6-3 Shoulder Widths:

As with travel lanes, the width of shoulders should generally remain constant through an intersection. However, two-lane highways that are flared to provide left turn channelization may require shoulder width modifications. When the through travel lanes are widened, the shoulder should be reduced 0.6 m from standards but shall be

[1]From reference No.14

no less than 1.2 m. Where the travel lanes are not widened, the shoulder width should remain at standard width.

Shoulder widths will also require modifications where the intersection includes a right turn lane. In these situations, the shoulder should be reduced to match the dimensions of Figure (See Appendix B, Standard Design). [**1**]

4-6-4 Superelevations:

It is undesirable to have an intersection located within a horizontal curve. However, in many existing situations, intersections are present within a highway curve. In many situations, these connections cannot be relocated. When an intersection occurs within a highway curve, the highway superelevation should be kept to a minimum. The highway still needs to provide for safe movement of traffic through the intersection at highway speeds. However, stopping traffic on steep cross slopes is undesirable due to the potential for slippage under ice conditions. In most situations, the superelevation should be held to 4% or less. In some cases, trying to hold the superelevation to 4% or less will result in design speeds less than desirable for a specific highway. At a minimum, the superelevation at an intersection should provide safe speeds equal to the desirable design speed. This means that if the design speed for the highway segment is 70 km/h, then the safe speed for the curve at the desired Superelevation must be at least 70 km/h.

It is critical to ensure that connections on the high side of a superelevated highway curve provide an approach with adequate sight distance. Ideally, intersection sight distance should be provided. Where this is not feasible or practical, stopping sight distance must be provided.

[1] From reference No.14

4-6-5 Skew Angles:

Roadway connections should intersect at a 90-degree angle. 90-degree intersections maximize sight distance, improve safety, increase efficiency, and improve operations and safety of bike and pedestrian movements. In some situations however, obtaining a 90-degree intersection is impractical or excessive in cost. Where this is the case, skewed intersections may be unavoidable. Skew angles of up to 30 degrees from perpendicular may be justified. The amount of skew should be held to a minimum.

Several factors can help determine the amount of skew that is acceptable for any particular intersection. Intersections with all or most of the following characteristics might justify allowing a skew angle of up to 30 degrees.

(a) Highway speeds are low,
(b) Volume on both the highway and intersecting roadway are low (not much above left or right turn channelization warrant limits),
(c) Large vehicle turning movements are minimal,
(d) Intersecting roadway has a functional classification of minor collector or below.
(e) Intersection sight distance is available.

For all other intersections, the maximum skew should be held to 15 degrees from perpendicular.

4-6-6 Turning Radii:

Turning Radii are one of the most important design elements of intersections. The turning movements control the operations, safety, and efficiency of an intersection. If the turning vehicles are geometrically limited from completing the maneuver properly, the intersection will break down, capacity is limited, and accident potential will increase.

The appropriate design vehicle must be identified prior to designing the intersection turning movements. Selection of the appropriate design vehicle can sometimes be difficult. Issues to take into consideration in choosing design vehicles include number and type of trucks, functional classification of the intersecting roadways, surrounding land use, consideration of future changes in land use and traffic, freight route designation, etc... After determining the appropriate design vehicle, a decision needs to be made as to the level of design accommodation to be made. In other words, is the intersection radius to be designed for the design vehicle or merely accommodate the design vehicle? The concept of designing for the design vehicle is to provide a path for the vehicle that is free of encroachments upon other lanes. Providing a design that only accommodates the design vehicle means that some level of encroachment upon other lanes is necessary for the vehicle to make a particular movement. (See Figure 4-8). An example of an intersection that would need to be design for trucks with no encroachment into adjacent lanes would be: A stopped controlled intersection with a state highway, the highway being two lane or multi-lane with higher speeds and/or high traffic volumes. Finding a gap in multiple traffic flows may not be possible, therefore, requiring the truck driver to turn from their lane into a single lane. Other factors to consider in turning radii are the affect on pedestrians and bicycles. Large crossing distances and long exposure time impacts safety for bicycles and pedestrians.

Another item that must be decided is the turning radius of the design vehicle. The turning radius of the design vehicle determines the ease and comfort of making the turning maneuver. The smaller the turning radius, the larger the off tracking of the vehicle and slower the speed. Forcing large vehicles to use very small turning radius will force the driver to perform a very slow maneuver that may not be in the best interests of the operation of the intersection. Generally the radius chosen is in line with the surrounding culture as tighter radii are chosen for low and/or urban speeds, while a larger turning radii is selected for higher speed and rural intersections.

Once the design vehicle is selected and the level of design accommodation determined, then the intersection radii can be designed. Intersection radii should be kept as small as possible to minimize the size of the intersection and the pedestrian crossing distance. Any time the design vehicle is larger than a Single Unit (SU) truck or a bus, the radii may need to consider using a two-centered curve. Off-tracking templates or automated off-tracking programs should be used to determine the vehicle path. Once this path is identified a two-centered curve can be developed which closely emulates this path. The designer may need to look at a range of vehicle turning radii and the subsequent intersection designs. This allows the designer to select the best design for the design vehicle while minimizing the size of the intersection. (See Appendix-B).

Designers are encouraged to keep the size of intersections to a minimum. Often when accommodating large trucks, the intersection radii become very large. This can substantially increase the size of the intersection. Larger intersections generally have greater accident potential, are difficult to delineate, can be confusing, require more rights of way, and significantly increase pedestrian and bicycle crossing times and distances.

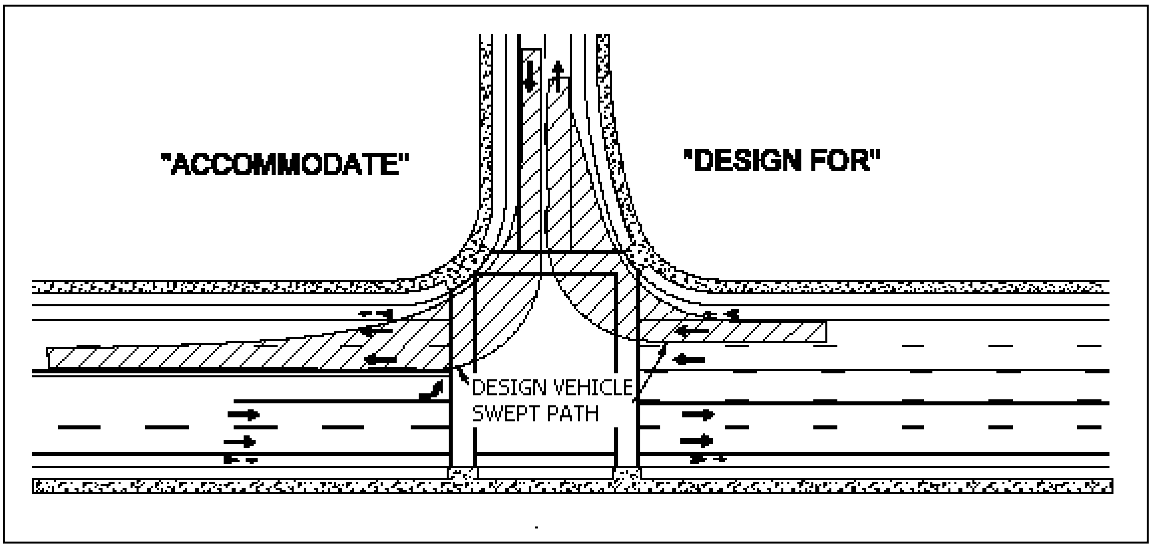

Fig. 4-8 Accommodating and designing for. [1]

[1] From reference No.2

4-6-7 left turn lanes:

Providing a left turn lane at an intersection will significantly improve the safety of the intersection. Eliminating conflicts between left turning vehicles decelerating and stopping and through traffic is an important safety consideration. A left turn lane must be provided at all non-traversable median openings. Left turn lanes may be installed at intersections meeting the installation criteria. The left turn lane installation criteria are different for signalized and unsignalized intersections.

Left turn lanes shall be 3.6 m wide plus the appropriate traffic separator width. The width of the traffic separator is determined by several factors. If the median includes a raised curb design, the traffic separator width shall be a minimum of 1.2 m. When pedestrians are to be accommodated on the raised portion of the median with separate phases for the crossing maneuver, the raised traffic separator width shall be 1.8 m minimum. Medians that use raised curb also need to provide the appropriate shy distance from the curb and adjacent through travel lanes. The width of striped traffic separators is determined by the design speed of the highway and the type of land use area. For design speeds of 60 km/h or less the striped separator shall be 0.6 m and 1.2 m for design speeds of 70 km/h or greater. (See Appendix B, Standard Design).

4-6-8 Right turn lanes:

Speed differential between right turning traffic with through traffic can create significant safety problems at intersections. To reduce this conflict, installation of right turn lanes may be appropriate at some intersections. Right turn lanes also help improve traffic operations and mobility standards at some intersections. Installation of right turn lanes should be considered at intersections that meet the siting criteria.

Not all intersections that meet the siting criteria should have right turn lanes installed. In urban situations, only significant public roads and large private approaches should be considered for installation of a right turn lane. A proliferation of right turn lanes along an urban arterial is undesirable for bicycles and pedestrians, creates an aesthetically unpleasing typical section, and may not improve safety throughout the section.

4-6-9 Channelization Islands:

Channelization islands help to direct turning traffic through an intersection. Channelization islands are a tool to help decrease the exposed crossing area of very large intersections. These islands can provide a refuge area for crossing pedestrians and offer a location for signal poles and signposts. Where channelization islands are to accommodate poles or sign posts, the island should ideally have an area of 9 m^2.

Channelization islands are also useful for decreasing the crossing distance of pedestrians. When intersections are very wide, pedestrians must cross a very long distance that increases their exposure time to traffic, reduces safety, and reduces efficiency of the signal due to the time necessary to cover the crossing maneuver. The designer should consider using channelization islands where crossing distances are greater than 27 m and where right turn lanes are used Channelization islands should be designed in conformance with Standard Drawing RD220. Figure 4-9 provides additional information regarding pedestrian crossings and channelization islands.

In rural areas it may be advantageous to provide a moderate to high-speed right turn movement at major intersections. Channelization islands could also be used in these instances.

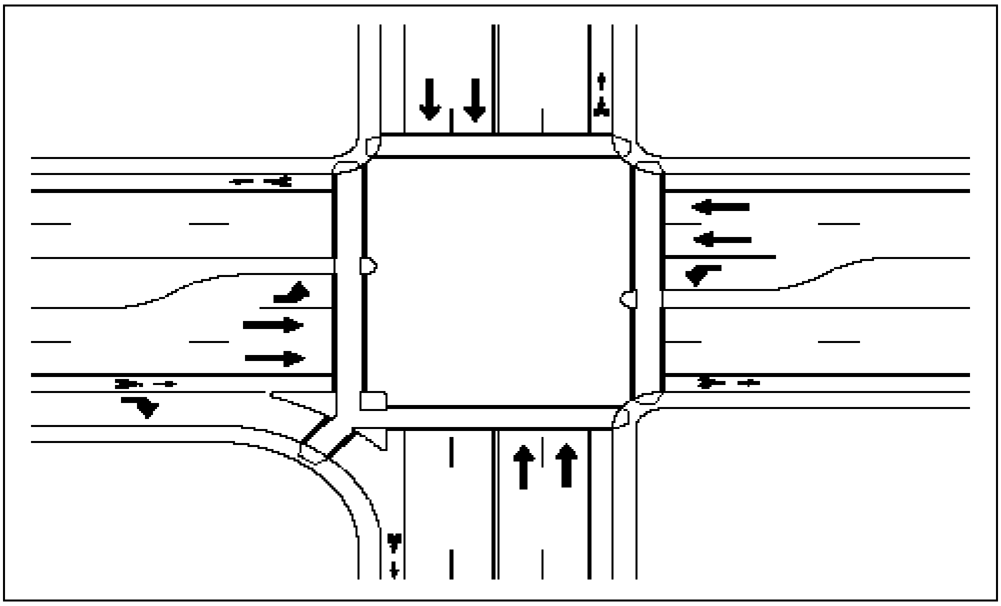

Fig. 4-9 Channelized Intersection. [1]

4-7 Roundabouts:

A modern roundabout is a form of intersection control. The distinctive characteristics of a modern roundabout include a central island with a circulatory roadway, raised splitter islands at the entry to introduce deflection to the vehicle path and a yield control for approaching vehicles. Figure 4-10 details several major roundabout elements.

[1] From reference No.2

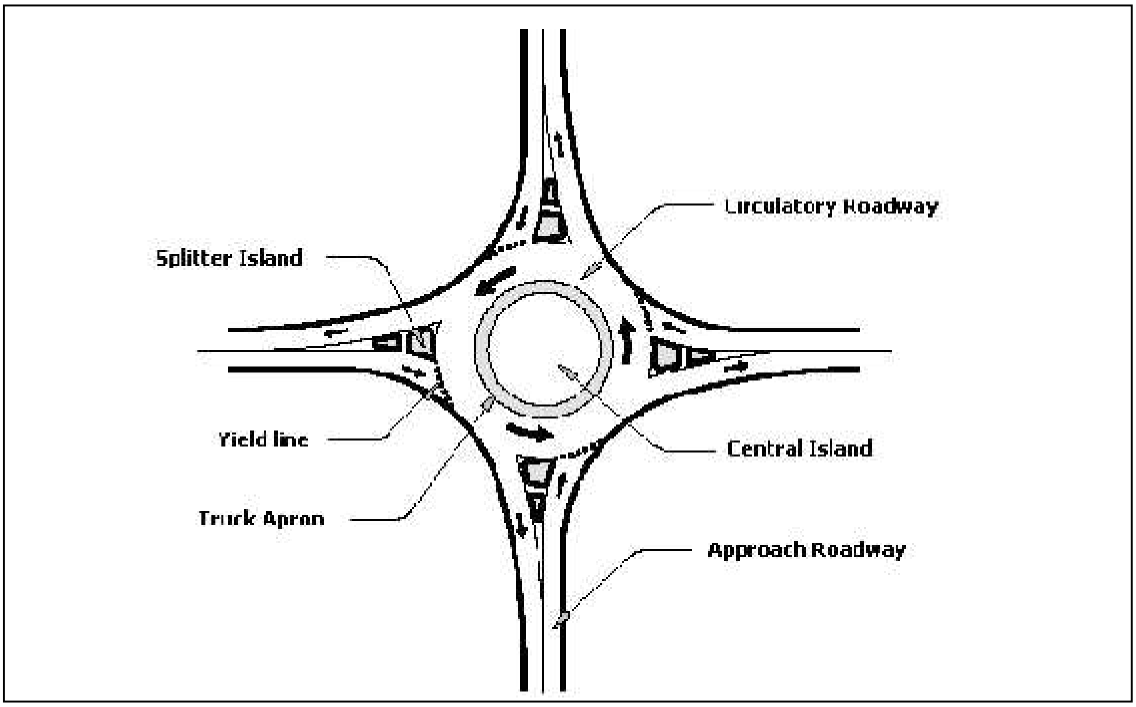

Fig. 4-10Elementes of Roundabout. [1]

4-7-1 Roundabout elements:

Modern roundabouts show promise of reducing crashes and delay. They can be particularly efficient where traffic volumes are roughly equal on all approaches. But they can also have limitations:

1. Generally, higher capacities can be achieved with traffic signals
2. Roundabouts are more expensive than stop control at low volume locations
3. Provide a less positive form of intersection control Cannot provide a smooth progression for arterial flows

[1] From reference No.2

4-7-2 Types of roundabout:

1. Mini-roundabout:

Mini-roundabouts can be extremely successful in improving existing urban junction where side road delay and safety are a concern. Drivers must be made aware in good time that they are approaching roundabout. Mini-roundabouts consist of a l-way circulatory carriageway around a refectories, flush /slightly raised circular island less than 4m in diameter which can be overrun with ease by the wheels of heavy vehicles. It should be domed to a maximum height of 125mm at the center for a 4m diameter island, with the height reduced pro rata for smaller islands. The approach arms may or may not be flared mini –roundabouts are used predominantly in urban areas with speed limits not.

Exceeding 48km/h (50mph). They are never used on highway with high speed limits. In situations where physical deflection of vehicle paths to the left may be difficult to achieve, road markings should be employed in order to Indus some vehicle deflection /speed reduction. If sufficient vehicle deflection cannot be achieved, the speed of the traffic on the approach roads can be reduced using traffic calming techniques.

Because of the short distance between the entry points to the roundabout, drivers arriving at the intersection must monitor very closely movements of other vehicles both within the junction and on the approaches in order to be in a position to react very quickly when a gap occurs.

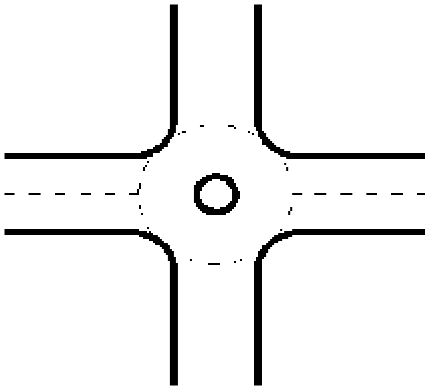

Fig. 4-11 Mini – roundabout [1]

2. Normal roundabout:

A normal roundabout is defined as a roundabout having a l-way circulatory carriageway around a kerbed central island at last 4m in diameter , with an

Inscribed circle (ICD) of at least 28m and with flared approaches to allow for multiple vehicle entry. The number of recommended entry arms is either three or four. If the number is above four, the roundabout became larger with the higher circulatory speeds will be generated. In such situation double roundabouts may provide a solution (Dot, 1993).

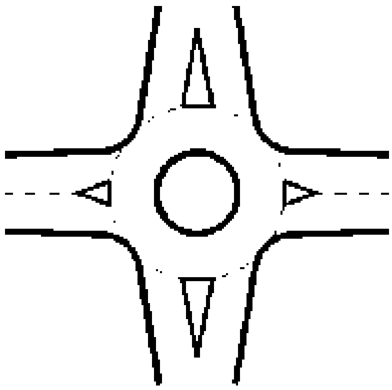

Fig. 4-12 Normal Roundabout [2]

[1] From Reference No 8
[2] From Reference No 8

3. Double roundabout:

A double round about can be defined as an individual junction with two normal /mini-roundabout either contiguous or connected by a central link road or kerbed island. It may be appropriate in the following circumstances:

1. For improving an existing staggered junction where it avoids the need to realign one the approach roads.
2. In order to join two parallel routes separated by a watercourse, railway or motorway.
3. At existing crossroads intersection where opposing right –tuning movements can be separated
4. Catering for junction with more than four entries and overloaded single roundabouts where overall capacity can be increased by reducing the circulating flow traveling past critically important entry points.

In situations where the double is composed of two mini-roundabouts, the speed limit on the approaches must not exceed 48km/h (30mph).

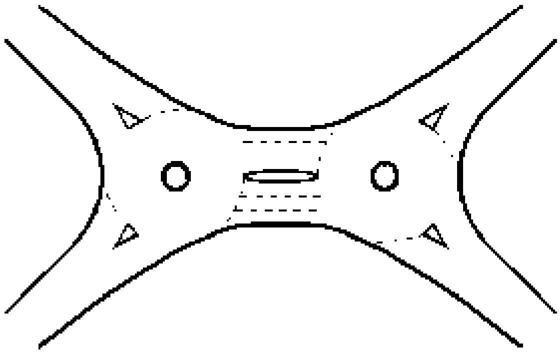

Fig. 4-13 Double Roundabout [1]

[1] From Reference No 8

4-7-3 Roundabout selection criteria:

The following recommendations will be used in evaluating proposed roundabout locations:

1. Should not have more than 4 approach legs.
2. Should have posted speeds 60 km/h or less.
3. Should have normal circular geometry.
4. Should have similar or balanced volumes on all approach legs.
5. Should be at an intersection of two highways with roughly the same functional classification or no more than one level of difference.
6. Should be mostly commuter and local traffic.
7. Should not have high pedestrian volumes.
8. Should not have high volumes of large trucks.
9. Should not be located within an interconnected signal system.
10. Should not be in locations where exiting vehicles would be interrupted by queues from signals, railroads, drawbridges, ramp meters, or by operational problems created by left turns, accesses, etc.
11. Should not be located where grades or topography limit visibility or greatly complicate construction.

4-7-4 Design considerations:

The geometric design of roundabouts adheres to principals that encourage lower speeds and increased safety for all users. These principals will also have traffic-calming benefits on the road system. It must be recognized that the design of a roundabout is an iterative process. Geometric layout may need to be refined several times before capacity and safety requirements can be achieved. Engineering judgment will be required to refine the layout.

The following discussion points present some basic design considerations for modern roundabouts. Additional design details and layout considerations can be obtained through consultation with the Preliminary Design Unit.

4-7-4-1 Design Speed:

Design speed plays an important part for safety at roundabouts. Roundabouts are purposely designed so that traveling speeds are restricted to a low and consistent speed through the roundabout. The design speed of the roundabout intersection should not be confused with the design speed of the highway. A safely designed roundabout should have geometry that accommodates all traffic movements at the chosen intersection design speed, thereby maximizing safety benefits and minimizing the area needed. The recommended maximum design speed of all vehicles entering and raveling through a roundabout is 40 km/h.

4-7-4-2 Inscribed Circle and Central Island:

The inscribed circle is the outside edge of travel of the circulatory roadway. The central island is the raised area surrounded by the circulatory roadway. There are two areas of a central island, the mountable truck apron and the non-traversable raised area. Figure (4-11) shows a typical cross-section of the truck apron and Central Island.

On low-truck-volume roads, encroachment on the truck apron is permitted; however, all vehicles smaller than the Interstate Design Vehicle should be accommodated without encroachment. Where high proportion of heavy vehicles is expected, the design of adequate circulatory roadway width with minimal use of the truck apron is preferred.

The minimum inscribed circle diameter for a single lane roundabout (accommodating the Interstate Design Vehicle) shall be 50 m. The recommended circulatory roadway width for a single lane roundabout is 6.5 m, excluding the truck apron width. A truck apron should be designed in such a way that mounting over by a passenger car would feel uncomfortable but not safe.

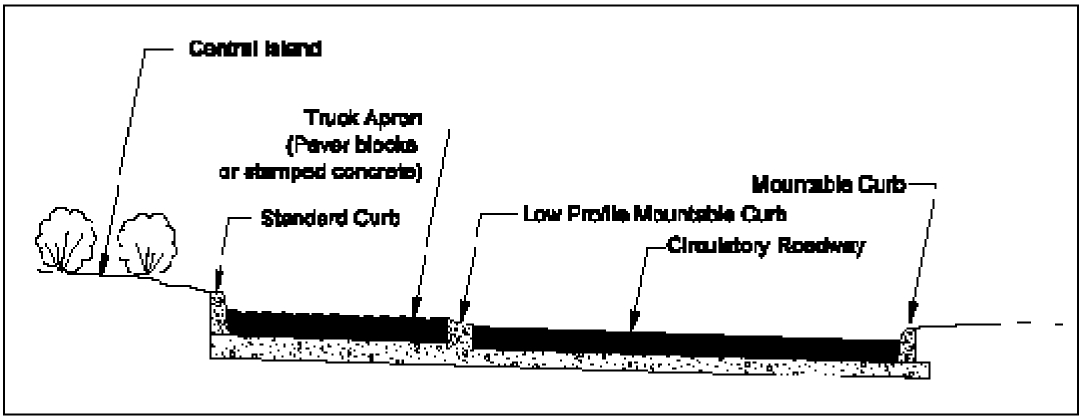

Fig. 4-14 Central Island Cross-section. [1]

4-7-4-3 Splitter Island:

The purposes of splitter islands are to:

1. Help alert drivers of the upcoming roundabout, regulate entry and exit speed;
2. Physically separate entering and exiting traffic, minimize potential for wrong-way movement;
3. Introduce deflection into vehicle paths;
4. Provide a refuge for pedestrians, and a place to mount traffic signs.

The length of the island measured along the approach should be at least 15 m long to provide sufficient protection for pedestrians. Longer islands or extended raised medians should be used in areas with high approach speeds. A separation between

[1] From reference No.2

the yield line on the circulatory roadway and the pedestrian crossing is crucial to safety and operation. This separation distance helps split up the decision points of yielding to a pedestrian and picking a gap in the vehicular.

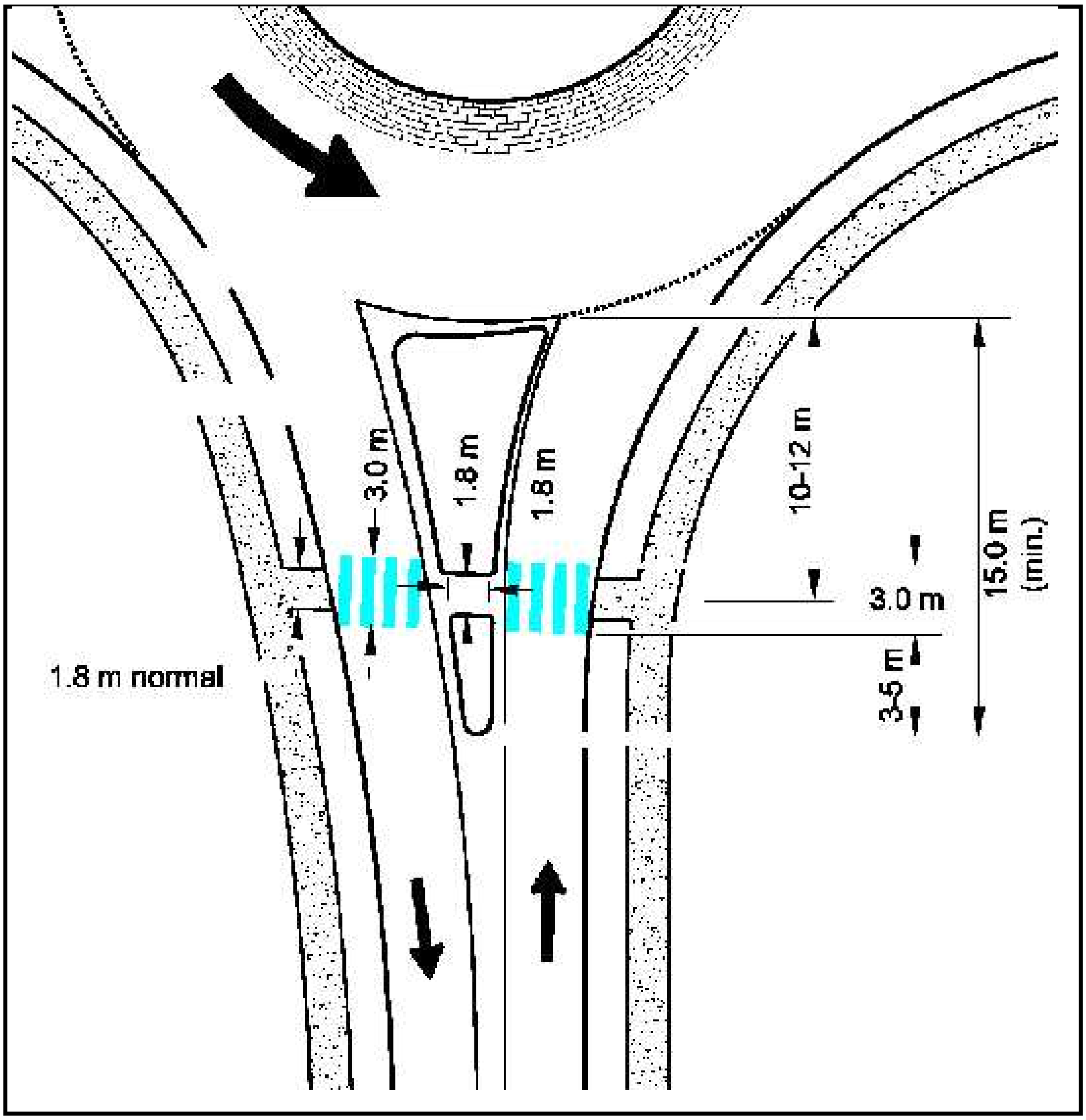

Fig. 4-15 Minimum "SPLITTER ISLAND" Dimensions [1]

[1] From reference No.15

4-8 Pedestrian Designs:

The designs of intersections take into account the needs of bicyclists and pedestrians. The level and amount of design effort required to ensure adequate design for these modes will vary among different areas.

Intersection designs should try to keep the crossing distances and pedestrian exposure to a minimum. Pedestrians and motorists must be able to see each other clearly and understand how the other will proceed through the intersection. This can sometimes be difficult at major intersections that accommodate multiple turn lanes. When intersections become excessively large and complex, pedestrian safety is often at a higher risk. The designer should try to find mitigation measures to reduce the crossing distance.

When pedestrians must cross more than 6 lanes of traffic or 6 lanes with an intersection skew angle of 20 degrees or greater, a pedestrian median refuge should be provided to enable the pedestrian to cross the street in two phases. A right turn channelization island should also be considered to reduce the pedestrians' exposure to both through and right turning vehicles.

4-8-1 Intersection Design Affecting Pedestrians:

There are several aspects of intersection design that impact the safety, comfort or access needs of pedestrians. For each identified issue, measures that can be used to mitigate these effects will be proposed.

4-8-1-1 Excessive Skews:

Skewed approaches have several negative effects for pedestrians:

1. They make the crossing longer.
2. They enable motorists to make a turn at high speeds.

3. They force entering motorists to look backwards for conflicts, so that a pedestrian approaching from the other direction is out of sight.
4. They place crossing pedestrians with their back to approaching traffic.

The best way to mitigate for a skew is to reconfigure the intersection at or close to a right angle. If sufficient right of way is not available for total reconfiguration, the negative effects can be mitigated with a curb extension in the flat-angle corner(s). Figure 4-13 shows an example of an intersection with excessive skew and the intersection reconfigured with improve skew angle. If a curb extension isn't feasible, then use the tightest possible radius in the flat-angle corner(s).

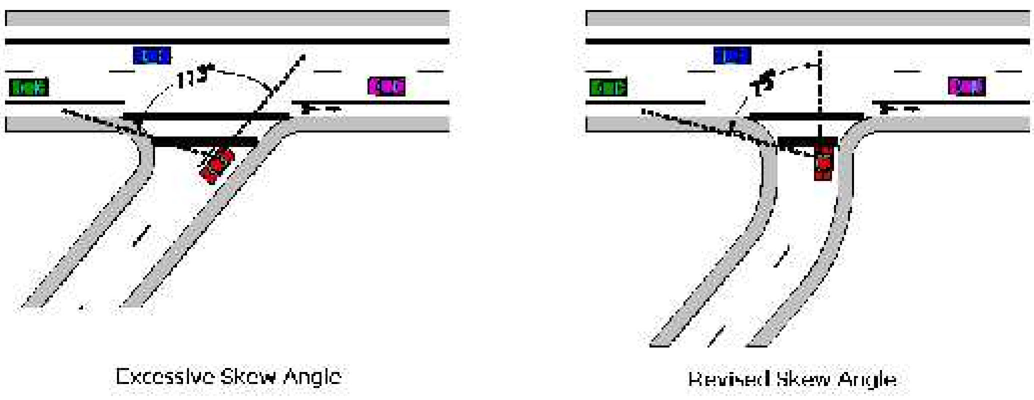

FIG. 4-16 Skew angle (EXCESSIVE SKEW). [1]

4-8-1-2 Island Geometry:

An island placed between a slip lane and through traffic can offer pedestrians a refuge, but if it is poorly designed, the geometry can encourage drivers to make turns at high speeds without looking for pedestrians. This can be mitigated by a design that brings the motorist to the intersecting street at close to a right angle, rather than a

[1]From reference No.15

skew. This forces the driver to slow down, and enables the driver to see the crossing pedestrian. Figure 4-14 shows an example of a skewed flat angle designed and a reconfigured right angle design. The type of design chosen varies depending upon the right turn vehicle accommodation. In many cases the presence of large trucks prohibits the use of this treatment.

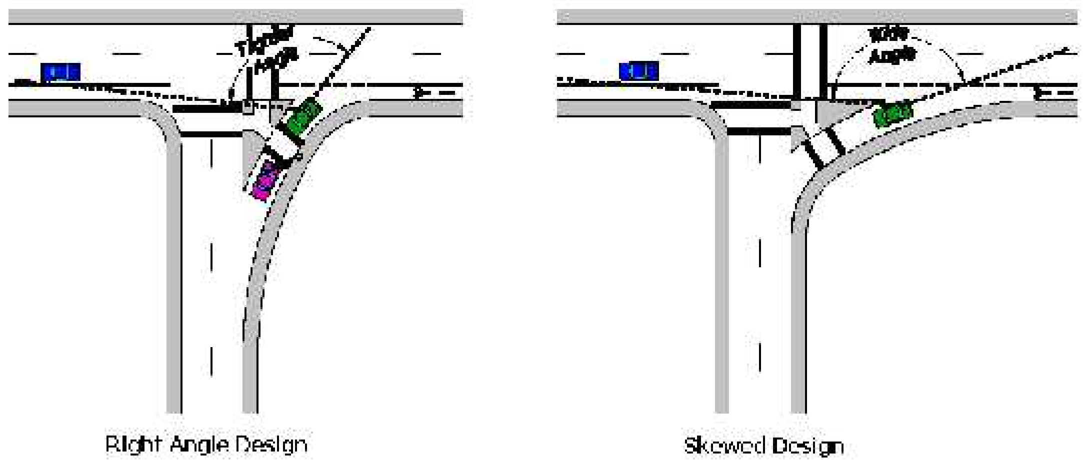

FIG. 4-17Island Geometry. [1]

4-8-1-3 Corner Radii:

Large corner radii present several problems for pedestrians:

1. They make the crossing longer;
2. They enable motorists to make a turn at high speeds;
3. They make it very difficult to line up the sidewalks, crosswalks and curb cuts.

Designers should try every possible technique to minimize the corner radii at intersections in urban areas.

Choosing the appropriate radius is often dependent on factors other than strict interpretation of design parameters. For example, it may be acceptable to design to a

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[1]From reference No.15

tight radius on approach streets with very little truck traffic; even if that means that the occasional truck may have to encroach into traffic to make a turn.

4-8-2 Pedestrians on roundabout:

The accommodation and safety of pedestrians at roundabouts is dependent on the following design features:

1. Slow speeds, achieved through sufficient deflection.
2. Separation of conflicts, achieved by placing the crosswalk 8-12m (approx. one car length) away from the yield line of circulatory roadway.
3. Breaking up the pedestrian crossing movements, achieved by placing a splitter island at each leg.

CHAPTER FIVE

Traffic Signs, Marking, and Lighting

5-1 Introduction:

All movement on the road and intersections must be regulated so the use of traffic control devices might be needed to provide the road user limited, but essential, information regarding regulation, guidance, and warning.

Traffic control signs include intersection control (Stop and Yield), lane usage control (Right Lane Must Turn Right, etc.), movement prohibition (No U-Turn, etc.), speed limit, and parking signs among others.

In addition to separating opposing traffic and designating lanes for traffic moving in the same direction, pavement markings are used in many other ways. This includes designating where pedestrians are to cross the street (crosswalks), indicate where drivers should stop their vehicles (stop bars), and complement lane usage control signs (turn and through arrows).

5-2 Traffic Signs:

The most common and oldest method of traffic control is by means of the traffic sign. Signs functions are to control the movement of vehicles, to reduce the hazard of traffic operation, and to improve the quality of flow.

Signs should be placed as necessary for safety and proper regulation of traffic. However, the use of too many signs in a given location may reduce the effectiveness of all the signs at that location.

5-2-1 Purposes of Traffic Signs:

Traffic signs are devices placed along, beside, or above a highway, roadway, pathway, or other route to guide, warn, and regulate the flow of traffic, including motor vehicles, bicycles, pedestrians, equestrians, and other travelers.

It is possible, in many cases, to provide essential information to road users on low-volume roads with a limited number of traffic control devices. The focus might be on devices that:

A. Warn of conditions not normally encountered;

B. Prohibit unsafe movements; or

C. Provide minimal destination guidance.

As with other roads, the application of traffic control devices on low-volume roads is based on engineering judgment or studies.

Signs, like any other traffic control devices, must meet five fundamental requirements:

- Fulfill a need
- Command attention
- Convey a clear, simple meaning
- Command respect from travelers
- Give adequate time for proper response

Signs should be placed only where warranted by facts and engineering studies. Signs that are unwarranted or ineffective may distract road users from more important traffic control devices, may breed disrespect for all signs in the area, and are often a waste of valuable public agency and taxpayers' resources.

5-2-2 Traffic sign Function:

These three functions are carried out by three different classifications of road sign, which are visually different to enable drivers to determine rapidly the category of any particular sign. Signs shall be defined by their function as follows:

1. Regulatory signs give notice of traffic laws or regulations.
2. Warning signs give notice of a situation that might not be readily apparent.
3. Guide signs show route designations, destinations, directions, distances, services, points of interest, and other geographical, recreational, or cultural information.

5-2-2-1 Regulatory signs:

Regulatory signs shall be used to inform road users of selected traffic laws or regulations and indicate the applicability of the legal requirements.

Regulatory signs shall be installed at or near where the regulations apply. The signs shall clearly indicate the requirements imposed by the regulations and shall be designed and installed to provide adequate visibility and legibility in order to obtain compliance.

Regulatory signs shall be retro reflective or illuminated to show the same shape and similar color by both day and night, unless specifically stated otherwise in the text discussion of a particular sign or group of signs.

The requirements for sign illumination shall not be considered to be satisfied by street, highway, or strobe lighting.

Regulatory signs inform the driver of the applicability of specific laws and regulations along indicated sections of road. Regulatory signs are posted where they can be seen clearly, and the section of road over which the regulation applies should be delineated clearly. Regulatory signs themselves can subclassify into:

1- Right of way signs
2- Speed signs

3- Movement sign
4- Parking signs
5- Pedestrian signs

Some of regulatory signs as “AASHTO”

Fig. 5-1 Some of regulatory signs [1]

5-2-2-2 Warning Signs:

Warning signs call attention to unexpected conditions on or adjacent to a highway or street and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations.

[1] From Reference No. 15

The purpose of a warning sign is to provide advance warning to the road user of unexpected conditions on or adjacent to the roadway that might not be readily apparent.
The use of warning signs should be kept to a minimum as the unnecessary use of warning signs tends to breed disrespect for all signs. In situations where the condition or activity is seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist.

Where caution is required, including in some cases the reduction of speed or a special alertness to conditions on or close to the road, warning signs alerts the driver. Warning signs may be erected under the following conditions:

1- To indicate changes in horizontal alignment.
2- To indicate an intersection.
3- To give warning that the driver should expected traffic control devices.
4- To warn converging traffic lanes.
5- To indicate narrow roadways
6- To indicate changes in highway geometry such as the end of a divided highway.
7- To advise of unexpected or unusual grades.
8- To indicate sudden changes in surface condition or poor pavement condition.

All warning signs shall be diamond-shaped (square with one diagonal vertical) with a black legend and border on a yellow background unless specifically designated otherwise. Such as "regarding conditions associated with pedestrians, bicyclist school buses, and schools".
The total time needed to perceive and complete a reaction to a sign is the sum of the times necessary for Perception, Identification (understanding), Emotion (decision making), and Volition (execution of decision), and is called the PIEV time. The PIEV time can vary from several seconds for general warning signs to 6 seconds or more for warning signs requiring high road user judgment.

Warning signs should be placed so that they provide adequate PIEV time Warning signs should not be placed too far in advance of the condition, such that drivers might tend to forget the warning because of other driving distractions, especially in urban areas.

Minimum spacing between warning signs with different messages should be based on the estimated PIEV time for driver comprehension of and reaction to the second sign. The effectiveness of the placement of warning signs should be periodically evaluated under both day and night conditions.

Some of warning signs:

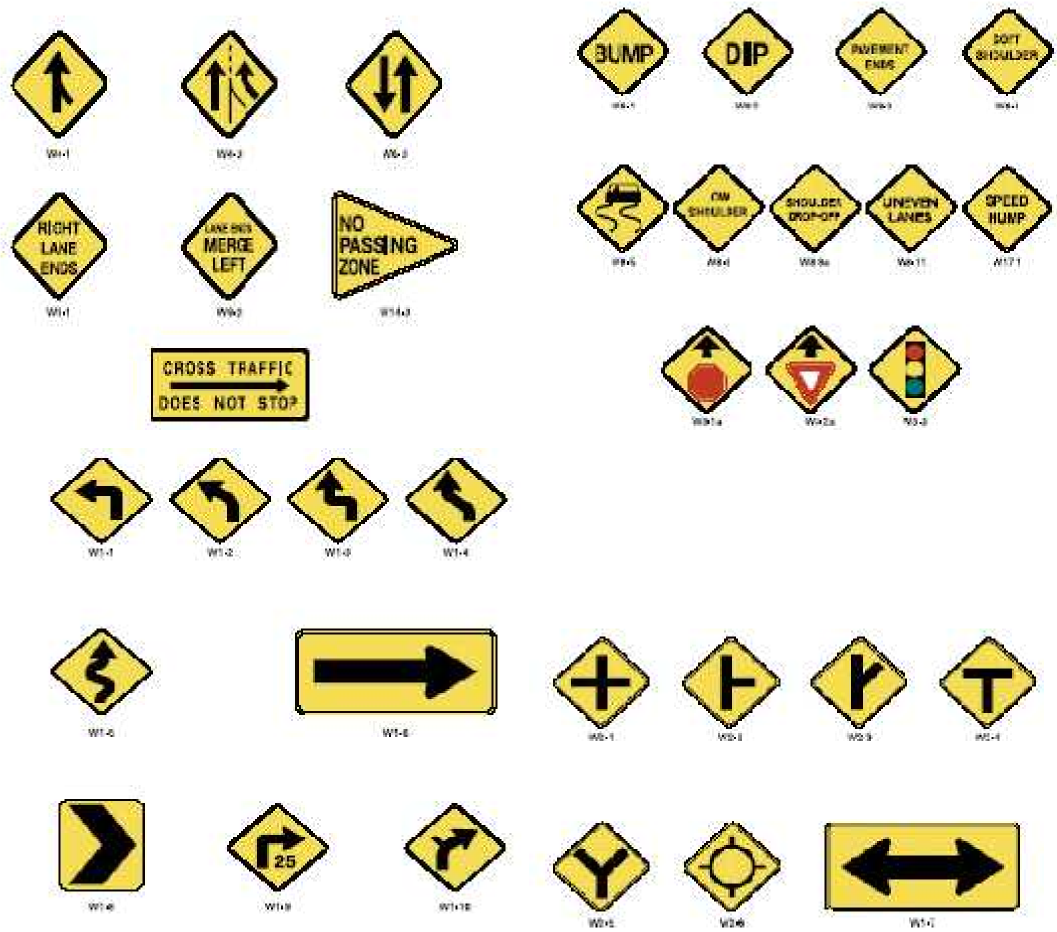


Fig 5-2 Some of warning signs [1]

[1] From Reference No. 15

5-2-2-3 Guide Signs:

The purpose of a guide sign is to inform road users regarding positions, directions, destinations, and routes.
The familiarity of the road users with the road should be considered in determining the need for guide signs on low-volume roads. Low-volume roads generally do not require guide signs to the extent that they are needed on higher classes of roads.

Because guide signs are typically only beneficial as a navigational aid for road users who are unfamiliar with a low-volume road, guide signs might not be needed on low-volume roads that serve only local traffic.

If used, destination names should be as specific and descriptive as possible, destinations such as campgrounds, ranger stations, recreational areas, and the like should be clearly indicated so that they are not interpreted to be communities or locations with road user services.
Guide signs may be used at intersections to provide information for road users returning to a higher class of roads.
Guide signs erected along highway to enable the traveler to find and follow routes in rural and urban areas and to identify and locate items of need and interest. The class of sign normally is considered composed of three categories:

1- Route markers and auxiliary markers.
2- Destination and distance signs.
3- Information signs.

5-2-3 Shape of the sign:

Particular shapes, as shown in Table (5-1), shall be used exclusively for specific signs or series of signs.

The shape of a road sign can tell you as much about the sign's message as its color.

Table 5-1 Uses of sign shape as “AASHTO” [1]

Shape	Signs
Octagon	Stop
Equilateral triangle	Yield
Circle	Highway- rail grad Crossing (advanced warning) Emergency evaluating rout marker
Pennant shape/isosceles triangle	No Passing
Pentagogon	ShcoolCrossing Series County Rout Sign
Crossbuck (Two rectangles in an”x” configuration	Highway-Rail Grad Crossing
Diamond	Warning Series
Rectangle	Regulatory Series Guide Series Warning Series
Trapezoid	Recreational Series

5-2-4 Colors of the Sign:

There are eight shapes and eight colors of traffic signs. Each shape and each color has an exact meaning, so you must acquaint yourself with all of them. A common uses of sign colors are shown in Table (5-2) as ASSHTO.

[1] From Reference No. 15

Table 5-2 Use of color sign as "AASHTO" [1]

Type of Sign	Legend					Background								
	Black	Green	Red	White	Yellow	Black	Blue	Brown	Green	Orange	Red	White	Yellow	FYG*
Regulatory	X		X	X		X					X	X		
Prohibitive			X	X							X	X		
Permissive		X										X		
Warning	X												X	
Pedestrian	X												X	X
Bicycle	X												X	X
Guide				X					X					
Interstate Route				X			X				X			
State Route	X											X		
US Route	X											X		
County Route					X		X							
Forest Route				X				X						
Evacuation Route				X			X							
Information				X			X		X					
Milepost Signs				X					X					
Road User Service				X			X							
Recreational				X				X	X					
Street Name				X					X					
Destination				X					X					
Temporary Traffic Control	X									X				
School	X												X	X

*FYG is fluorescent yellow-green

5-2-5 Sign Borders:

A dark border on a light background should be set in from the edge, while a light border on a dark background should extend to the edge of the panel. A border for 750 mm (30 in) signs with a light background should be from 13 to 19 mm (0.5 to 0.75in) in width, 13 mm (0.5 in) from the edge. For similar signs with a light border, a width

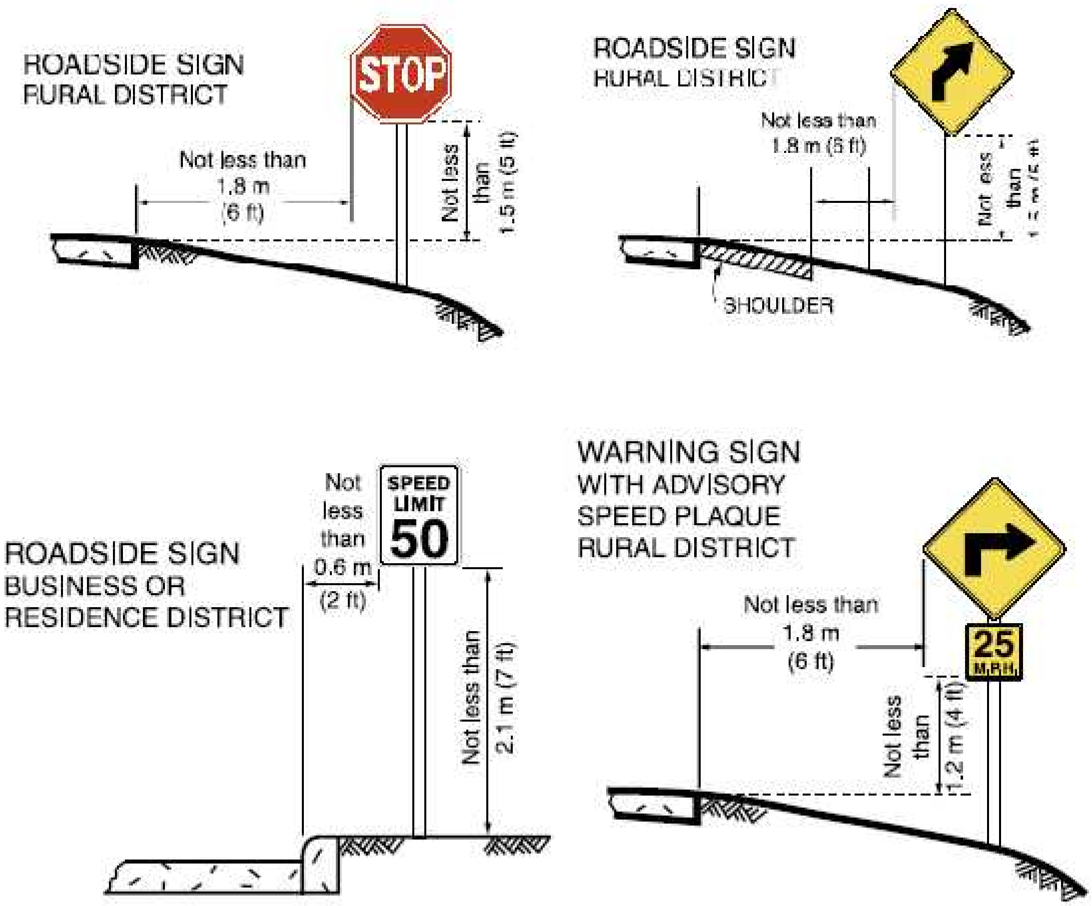
[1] From Reference No. 15

of 25 mm (1 in) should be used. For other sizes, the border width should be of similar proportions, but should not exceed the stroke-width of the major lettering of the sign. On signs exceeding 1800 x 3000 mm (72 x 120 in) in size, the border should be 50 mm (2 in) wide, or on larger signs, 75 mm (3 in) wide. Where practicable, the corners of the sign should be rounded to fit the border, except for STOP signs.

5-2-6 Standardization of Location:

Standardization of position cannot always be attained in practice. Locations for a number of typical signs are illustrated in Figures as “AASHTO”:

1. **Heights and lateral location of signs for typical installation**.



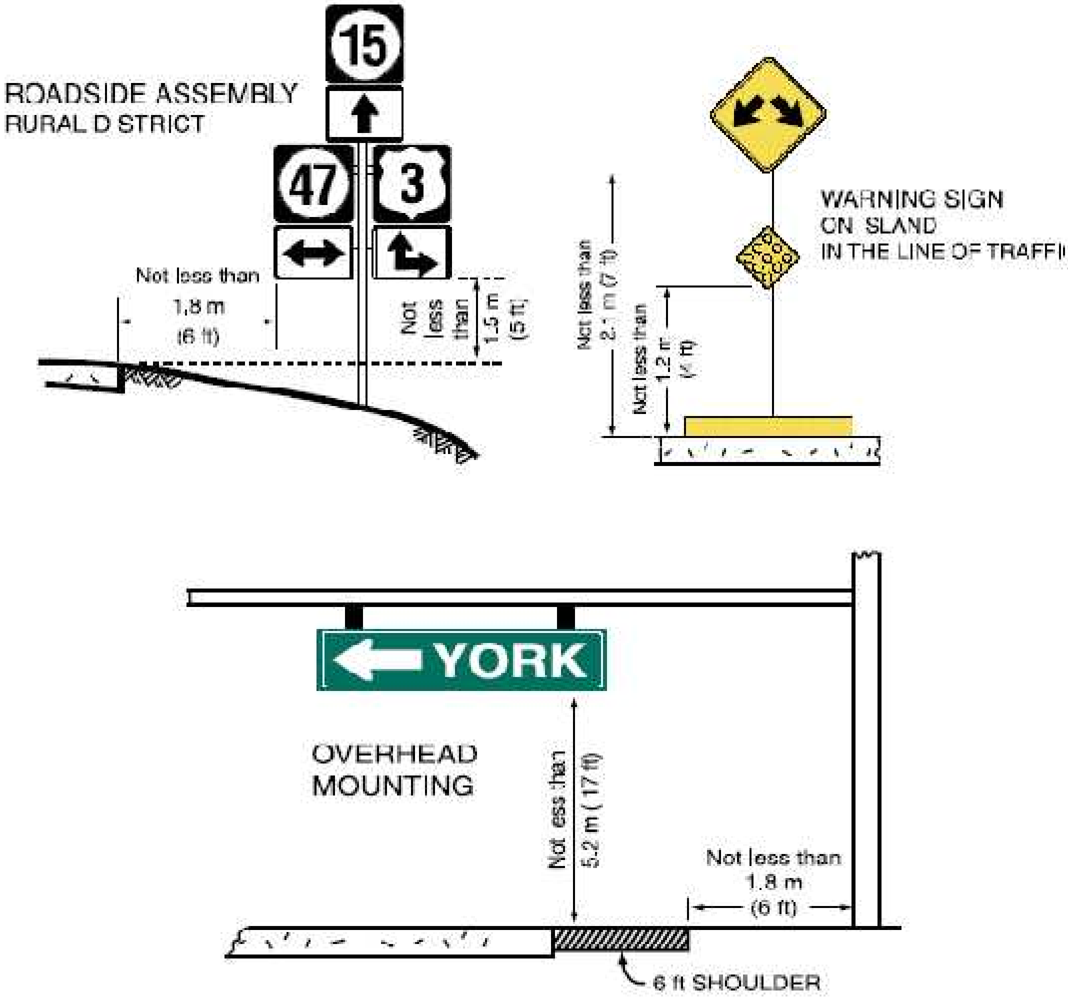


Fig 5-3 Heights and lateral location of signs for typical installation. [1]

[1] From Reference No. 15

2. Typical location for signs at intersections

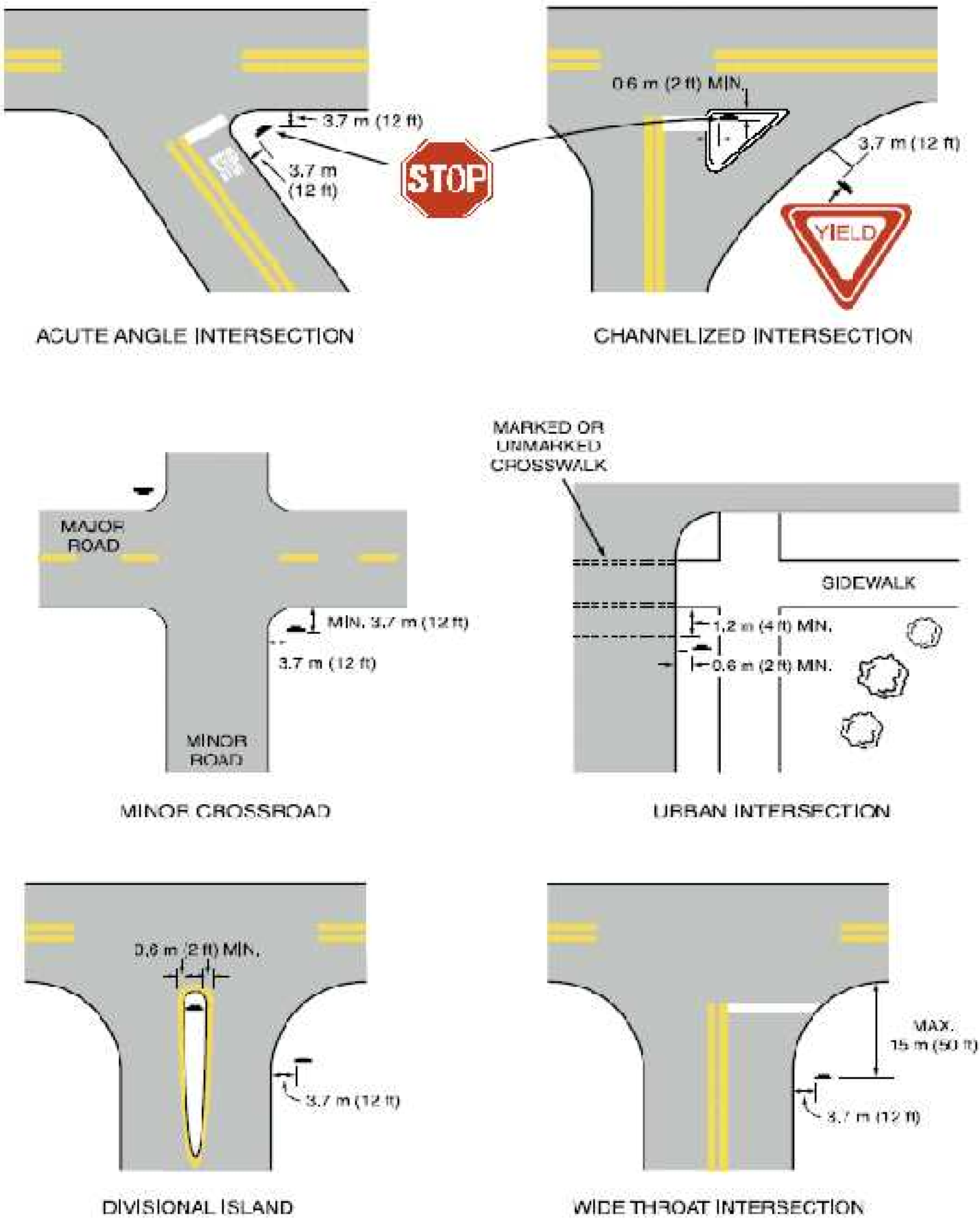


Fig 5-4 Typical location for signs at intersections [1]

[1] From Reference No. 15

3. Typical one way signing for dividing highways with medians lees than 9m (30ft)

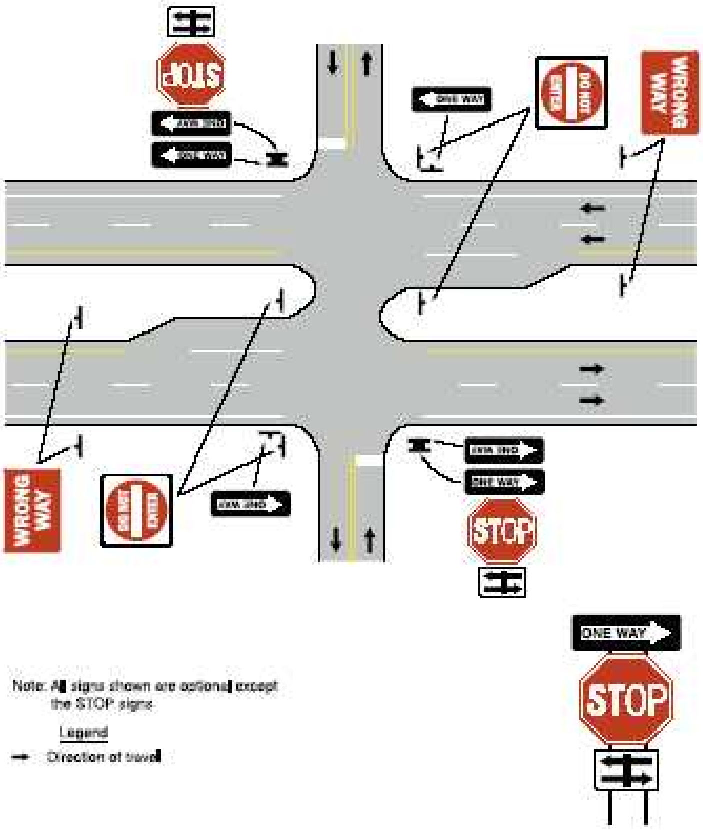


Fig 5-5 Typical one way signing for dividing highways with medians lees than 9m (30ft) [1]

[1] From Reference No. 15

4. Typical one way signing for dividing highways with medians greater than 9m (30ft)

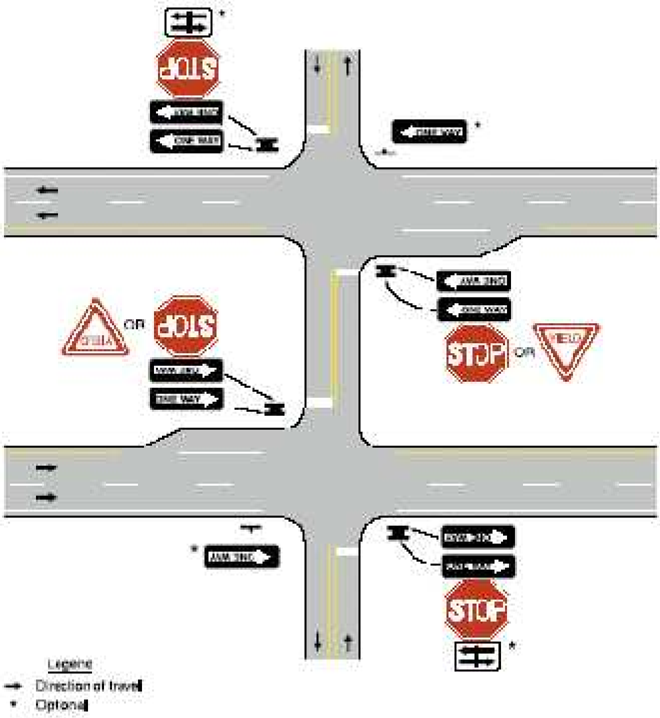


Fig 5-6 Typical one way signing for dividing highways with medians greater than 9m (30ft) [1]

[1] From Reference No. 15

5. Typical locations of one-way signs

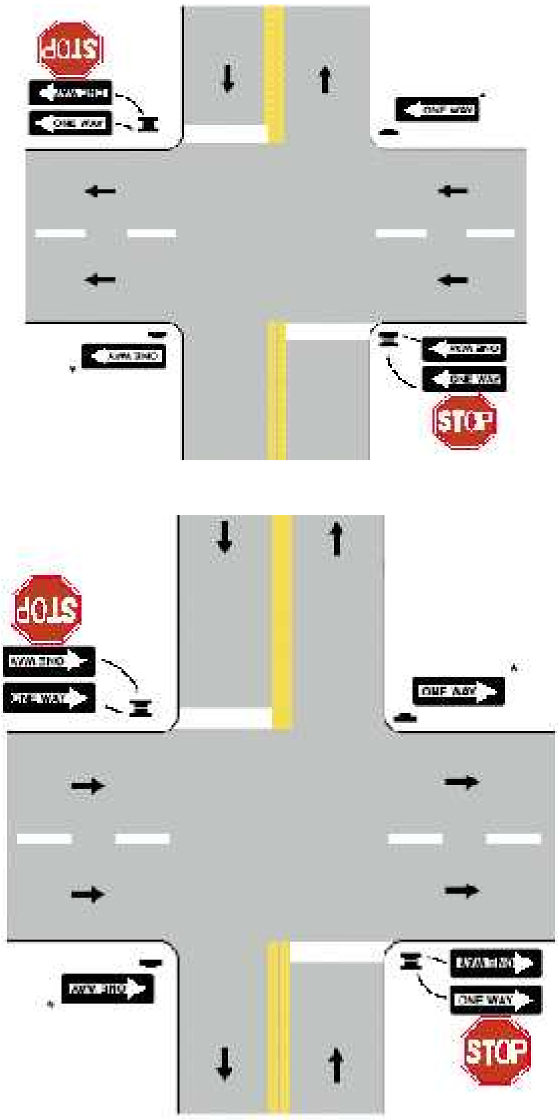


Fig 5-7 Typical locations of one-way signs [1]

[1] From Reference No. 15

6. **Typical locations of one-way signs**

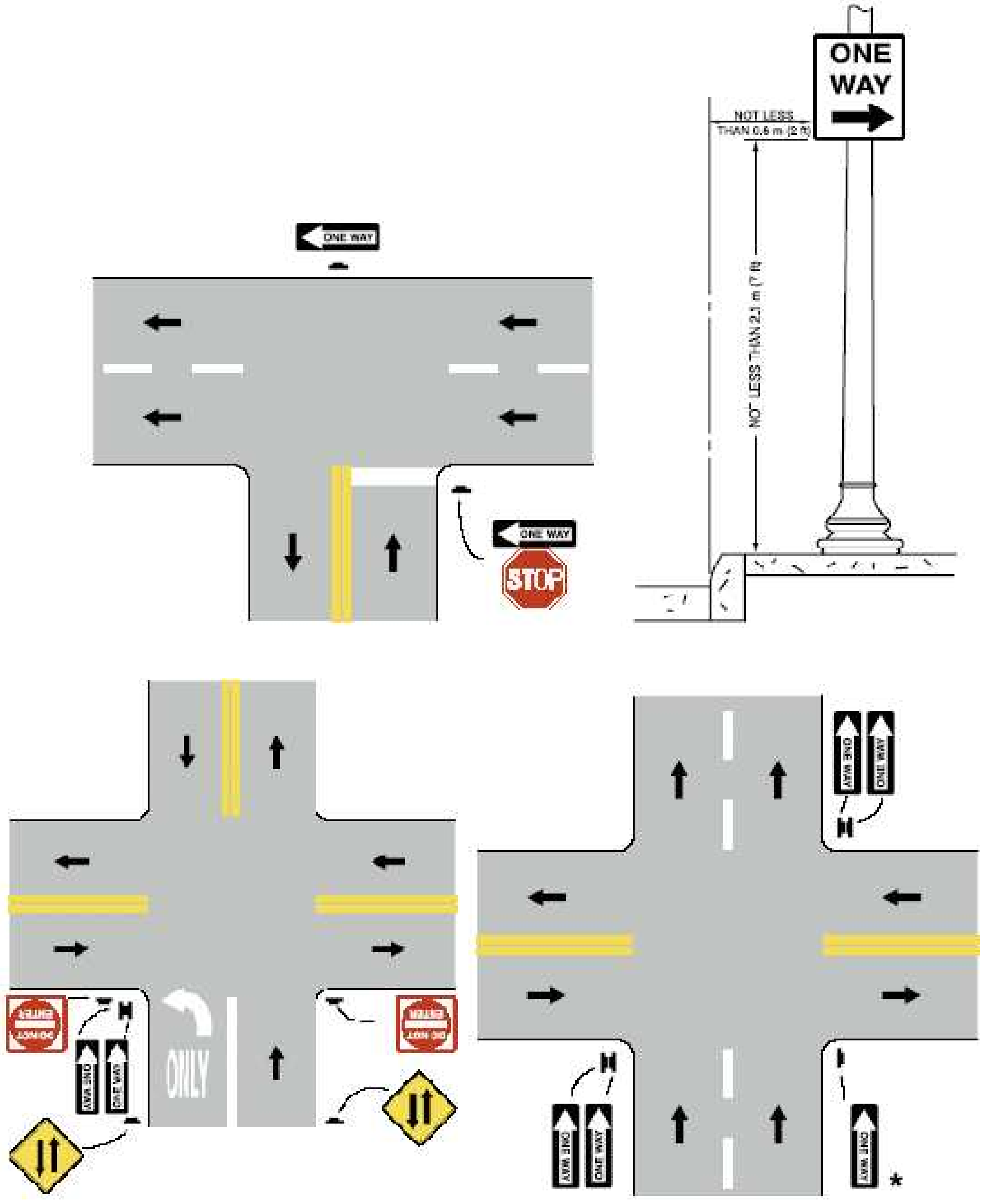


Fig 5-8 Typical locations of one-way signs [1]

[1] From Reference No. 15

7. **Typical application of warning signs**

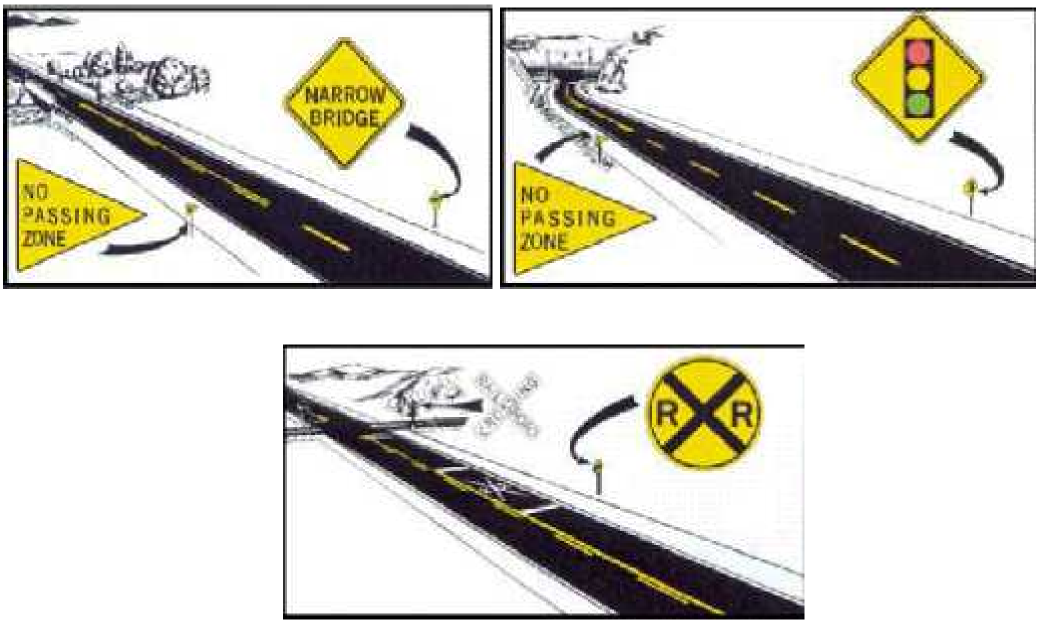


Fig 5-9 Typical application of warning signs as AASHTO [1]

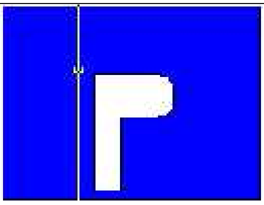
The next table shows the main signs, which we use it in our project:

Table 5-3 Main signs

Warning Signs	**A meaning of the sign**
	Crossroads in intersection
	Crossroads in intersection to left
	Crossroads in intersection to right

[1] From Reference No. 15

	To indicate high turn to left
	To indicate high turn to right
	In front of you a crossing for the pedestrian
	Children are near the place
	Maximum speed limited
	Stop
	No left turn
	No Right turn
	T- junction

	Roundabout road
	Left-Right passing
	Parking

5-3 Traffic Marking:

Markings on highways have important functions in providing guidance and information for the road user. Major marking types include pavement and curb markings, object markers, delineators, colored pavements, barricades, channelizing devices and islands. In some cases, markings are used to supplement other traffic control devices such as signs, signals and other markings. In other instances, markings are used alone to effectively convey regulations, guidance, or warnings in ways not obtainable by the use of other devices.

5-3-1 Purposes of traffic marking

1- To define and separate the lanes.
2- To indicate no passing zone.
3- To separate the traffic flow.
4- To define the parking of vehicle.

5- Define the sides of road

6- To indicate no standing or stopping.

7- To definition a crossing places for pedestrian.

5-3-2 Classification of traffic marking:

1- Lines:

Lines, symbols and words are often painted on a roadway to help direct drivers and control traffic flow. You must know what the different lines and colors mean and obey them as you would traffic signs or signals.

Yellow lines separate travel lanes moving in opposite directions. White lines separate travel lanes moving in the same direction. A yellow skipped or broken line is used as the centerline on a two–lane, two–way road where passing with care is permitted in both directions. When continuous, double, solid, yellow lines are the centerlines you cannot cross them to pass in either direction. On a two–lane road, passing with care is permitted if the skipped yellow line is in your lane.

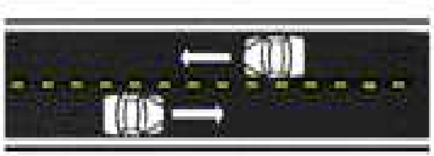
White and yellow lines are used along pavement edges and between lanes to keep vehicles in line. These lines may be solid or broken (long dashes), single or double.

Unless you are turning, exiting a highway, or changing lanes, always stay between the lines marking your lane.

Yellow Lane Lines

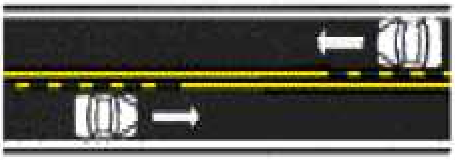
Yellow lane lines separate lanes of traffic moving in opposite directions. Single yellow lines may also mark the left edge of the pavement on divided highways and one-way streets.

A Broken Yellow Line



A broken yellow line separates lanes of traffic moving in opposite directions. Stay to the right of the line unless you are passing a vehicle in front of you. When passing, you may cross this line temporarily when it is safe to do so.

Double Yellow Lines: One Solid, One Broken.



A solid yellow line to the right of a broken yellow center line means passing or crossing is prohibited in that lane, except when turning left. If the broken line is closer to you, then you can the broken line only to pass another vehicle and only when it is safe to do so.

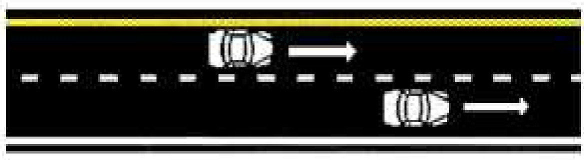
Double Solid Yellow Lines

Double, solid yellow lines prohibit vehicles moving in either direction from crossing the lines. You may not cross these lines unless turning left when it is safe to do so.

White Lane Lines

White lane lines separate lanes of traffic moving in the **same** direction. Single white lines may also mark the right edge of the pavement.

Broken White Line



Broken white lines separate lines of traffic going in the same direction. They may be crossed with care.

Solid White Line

A solid white line marks the edge of the roadway or separates lanes of traffic moving in the same direction. You may travel in the same direction on both sides of this line, but you should not cross the line unless you must do so to avoid a hazard.

Double Solid White Line

Double solid white lines indicate that changing lanes is not allowed.

Solid with Turn Lane Arrow

Solid white lines are used for turn lanes and to discourage lane changes near intersections. Arrows are often used with the white lines to show which turn may be made from the lane.

If you are in a lane marked with a curved arrow and the word ONLY, you must turn in the direction of the arrow. If your lane is marked with both a curved and straight arrow, you may either turn or go straight.

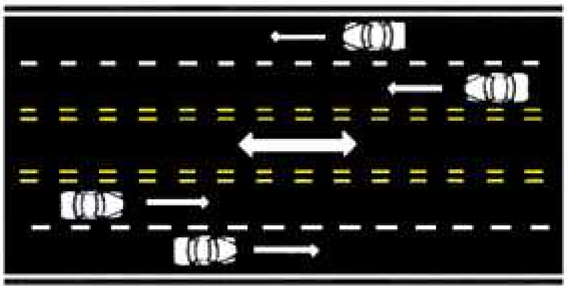
Reversible Lanes

Some highways have reversible traffic lanes to help handle rush-hour traffic. The direction of traffic is normally reversed at set times each day. These pavement markings are used along with special lane signals and other signs and symbols.

A solid white line marks the edge of the pavement on most roads. White lines also mark stop lines, crosswalks and parking spaces. Symbols such as arrows are in white also. A single yellow line marks the left edge of all divided or one-way roadways. Curbs are often marked yellow in no-parking zones near fire hydrants or intersections.

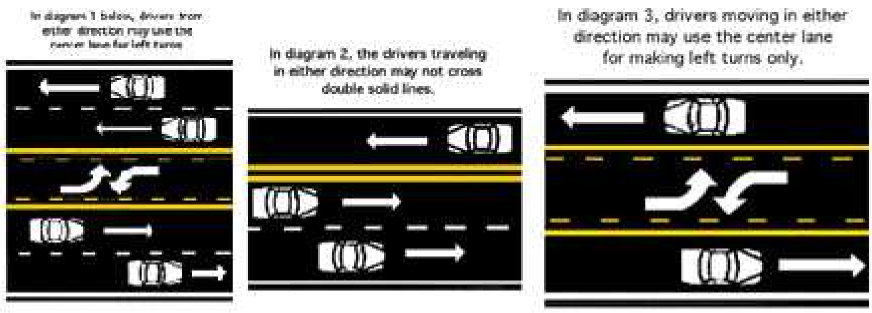
It is unlawful to park in or drive through areas that have pavement markings indicating fire lanes or safety zones.

The lane marking arrow, in the center lane in the diagram below, indicates that traffic in this lane can be reversed in accordance with local traffic controls due to "rush hour" traffic or other special traffic conditions.



Two-Way Roadway with Center Lane

Two-way roadway with a center lane for left turns in either direction of travel. The specially marked center turn lane is intended for slowing down and for sheltering of turning vehicles and may not be used for passing.



Marking consist of paint or some other material placed on the pavement, curb, or object to convey traffic regulation and warning to drivers. Marking may be used alone or in combination with traffic signs or signals. Although marking are an effective and essential means of traffic control, they tend to be difficult to see in rainy weather and may be obliterated altogether by snow and ice.

The traffic marking must be clear seeing in night as in day, and clear for all times and conditions. Her instructions must easy to understand and seen from enough distance.

2. Words:

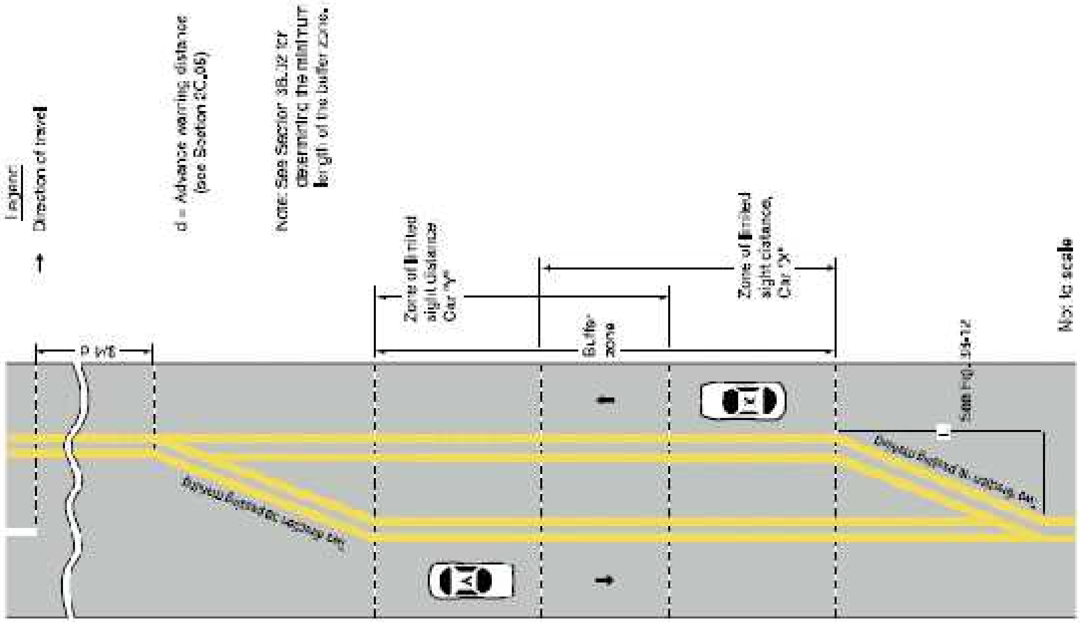
We write some words in the road surface, for special in the intersection as stop, or turn right. The words must be big and suitable to become clear for reading. it must not be increase about one or two words. The position of the letter of words it must be suitable of the position of the drivers.

3. Arrow:

It may be used without words to determine the traffic direction or with the words as arrow to turn right, with the word right.

4. Colors:

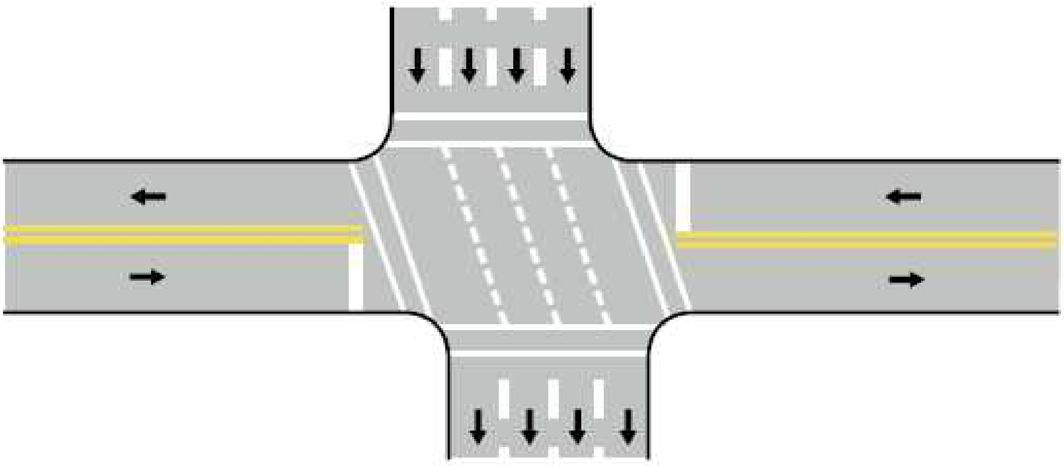
The white color used for separate lanes, yellow color definition islands and parking for vehicle.



a - Typical pavement markings with offset lane lines continued through the intersection and optional crosswalk lines and stop lines

Legend

→ Direction of travel
★ Optional
★★ Arrows required where through lane becomes mandatory turn lane



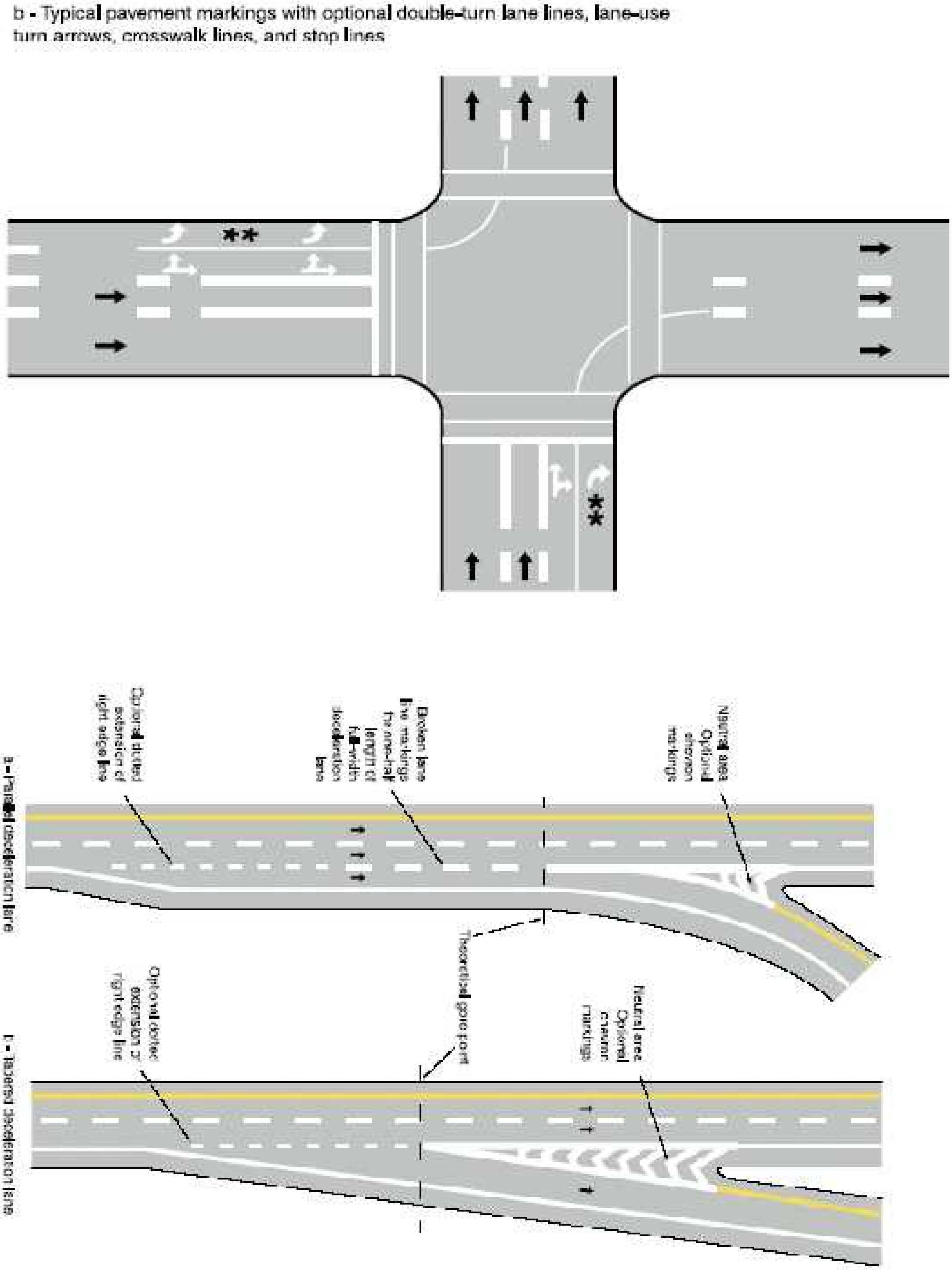


Fig. 5-10 Typical Pavement Marking [1]

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[1] From Reference No. 15

Typical Lane Reduction Transition Markings

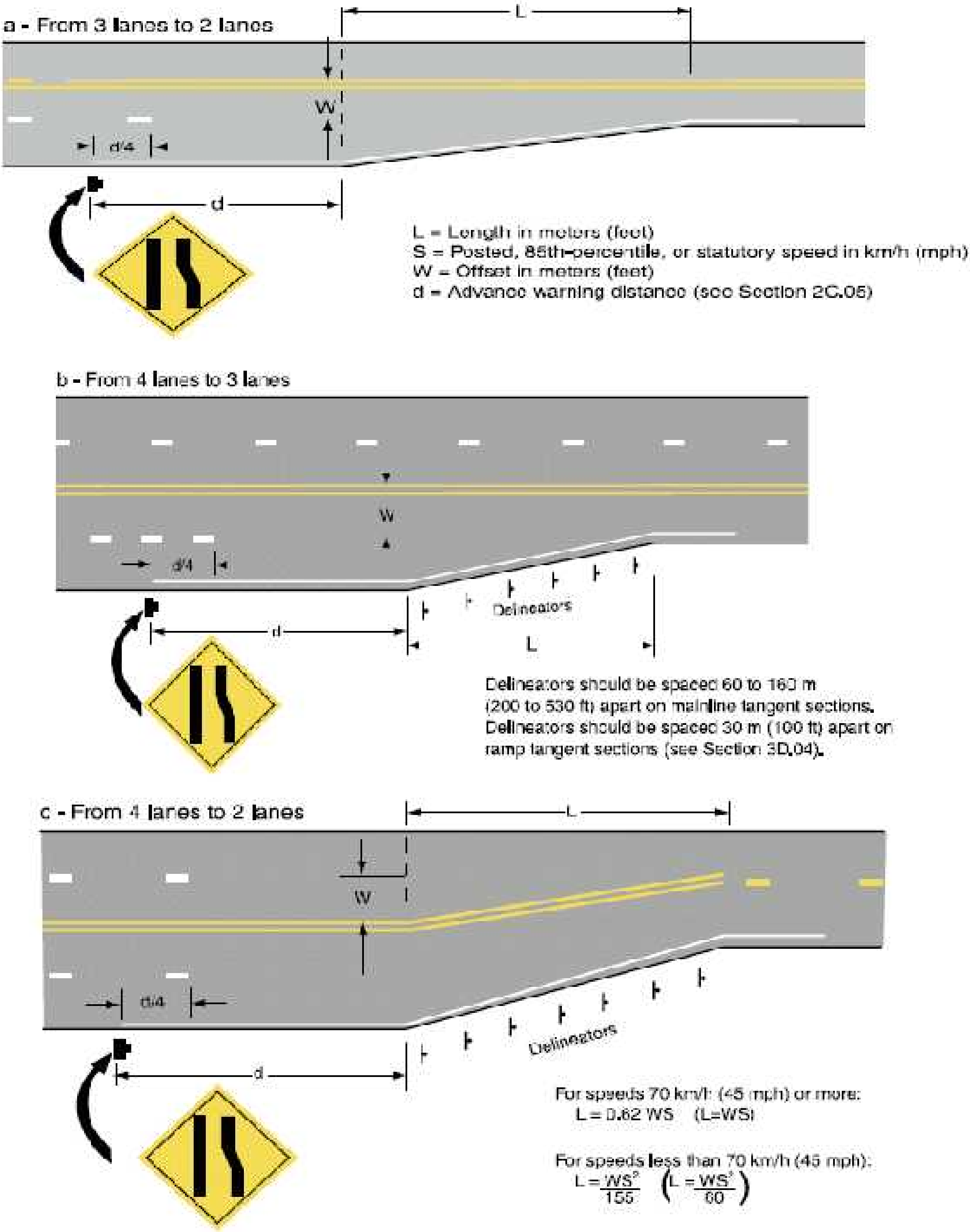


Fig 5-11 Typical Lane Reduction Transition Markings [1]

[1] From Reference No. 15

5-4 Highway Lighting:

A primary purpose of lighting a roadway at night is to increase the visibility of the roadway and its immediate environment, thereby permitting the driver to maneuver more efficiently and safely. The visibility of an object is that property which makes it discernible from its surroundings. This property of an object depends on a combination of the following factors:

(1) The differences in luminance, hue, and saturation between the object and its immediate background (contrast).

(2) The angular size of the object at the eye of the observer.

(3) The luminance of the background against which it is seen.

(4) The duration of the observation.

5-4-1 Types of Lamp:

Lamp is the bulb or light source. The lamps considered suitable for road lighting are of five main types. These are tungsten filament, sodium vapor, tubular fluorescent, high-pressure mercury fluorescent, and the uncorrected high-pressure mercury lamps.

In our project, we use the tungsten filament, because its use is now generally confined to residential streets and pedestrian areas such as sidewalk and shapping areas. The use of tungsten lamps in residential streets is due to their low initial cost, and the comfortable warm light.

In highway lighting we must define the following terms;

1- **Lantern:**

It consists of the lamp together with its hosing, reflectors to distribute the light and diffusers to decrease the glare effect.

2- **Outreach:**

This is the horizontal distance measured between the center of a lantern mounted on a bracket and the center of the supporting column or wall face.

3- Overhang:

The overhang is the horizontal distance between the center of a lantern and the adjacent edge of the carriageway.

5-4-2 Lighting On Intersection:

Intersection Lighting: Normally there are four properties at an intersection that are directly affected by the installation of a street light. 75% of those property owners must agree with the installation and location of the light. If traffic safety issues can be documented, the light may be installed without 75% agreement. Installation is dependent on the availability of funding. County and State Road intersection lighting is controlled by the State Highway Administration, please contact the SHA. County and Private Road intersection lighting is the responsibility of the owners of the private road.

Long Line Lighting: This lighting provides roadway lighting between intersections in a subdivision or urbanized area. If the distance between intersections is between 800 and 1,000 feet, a light could be warranted. Funding for long line lighting is not generally available and would require an outside funding source such as a Home Owners Association or any other individual or group who is requesting the street light installation. This type of installation can only be accomplished in an area where underground electric cable is available.

Development Lighting: The developer provides public street lighting as a requirement of the development process. Streetlights are installed at County road intersections, at the end of a cul-de-sac that is a minimum of 500' in length, and between intersections at 400 to 500 foot spacing. Developments with lot sizes that are 2 acres or larger are not required to provide lighting between intersections unless there is a traffic safety issue. If street lighting is an issue with you, ask the builder or the Harford County Street Light Representative to advise you of the location, type and size of any street lighting proposed near your home site.

End of Roadway: If the street is 500' or longer to its terminus and 75% of the adjacent property owners agree with the street light installation, a light would be considered, dependent on the availability of funding.

Some of lights on intersection:

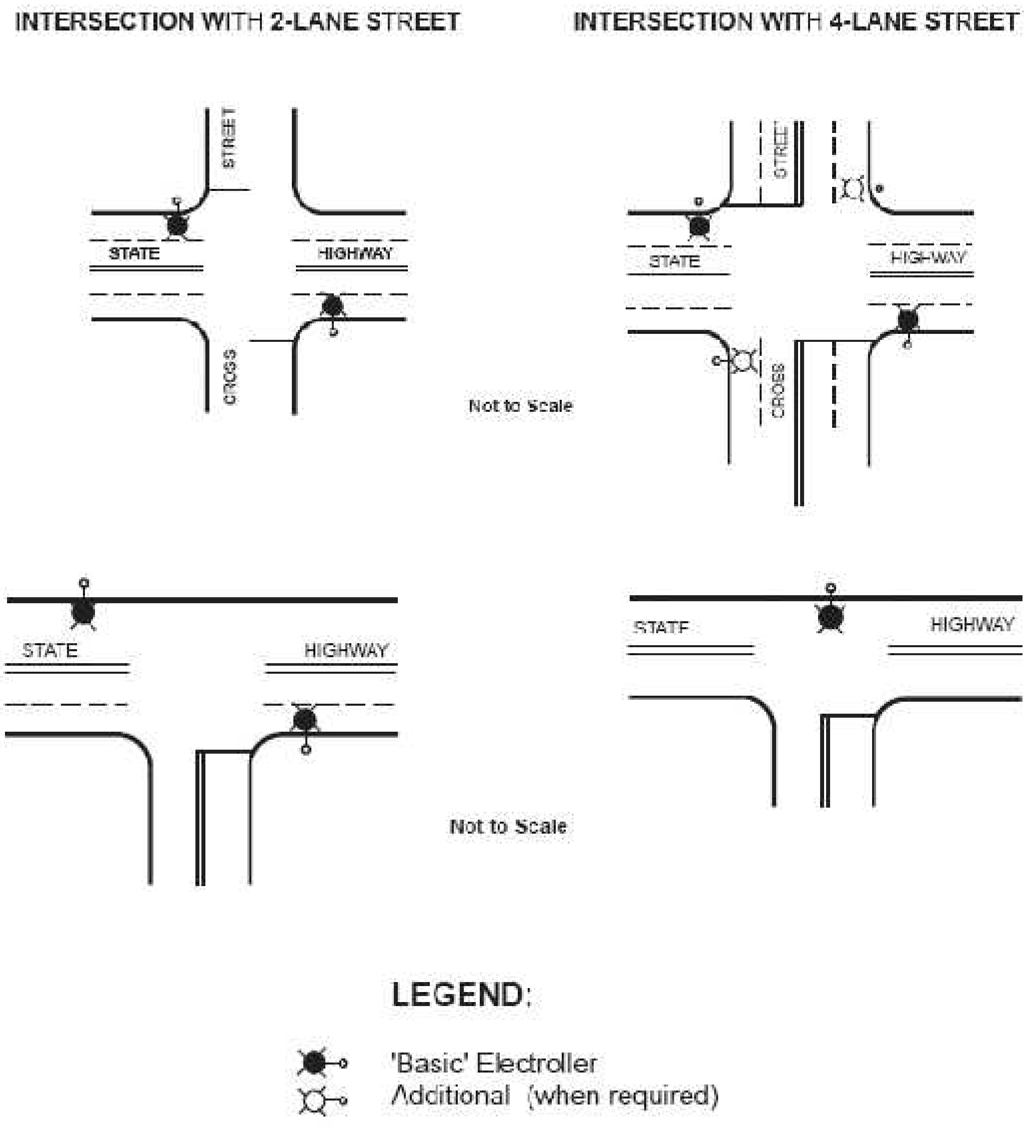


Fig. 5-12 Intersections lighting [1]

[1] From Reference No. 13

5-4-3 Solar lighting systems:

5-4-3-1 Functions:

Unique Solar Powered Highway/Street lighting system utilizing the latest Xenon Gas Discharge Lighting Technology to provide a brilliant white light(more has twice the brightness of halogens) and many times brighter than compact fluorescents.

Illuminates an area over 100 feet in diameter (at only 15 feet high,) totally independent of any external power supply.
The self contained system consists of a light weight 9 foot structural aluminum lamp extension arm, with electronics & power supply housed in a single integrated assembly, mounted high on a customer supplied pole. There are no wires to run to the ground or provide easy access to vandals.

The system is preset at the factory to illuminate automatically at sunset & turn itself off after 12 hours (or at sunrise, whichever occurs first.) The lamp will not illuminate during the day (since a photocell is not used.) Consequently, false activations are completely eliminated.

5-4-3-2 Applications:

Highways, intersections, residential streets, loading areas, driveways, parking lots, villages etc. or any situation where the cost of installing conventional power supply is prohibitive or inconvenient in remote locations.

5-4-3-3 System includes:

1- Die cast aluminum Roadway lamp fixture with optics& glass lens mounted on a 9 foot extension arm.

2- High Tech. Eagle-1 electronics/gas discharge (no filament to burn out) lighting system with a lamp life of over 5,000 hours with a light out put of 3,600 lumens!

3- Twin "over 30 year life" high efficiency crystalline solar panels: considered the highest quality panels in the industry.

4- Powder painted aluminum solar panel exclusive top mount brackets rotate able 360 degrees and swivels 270 degrees for optimum alignment.

5- Electronics/timer housed in durable weatherproof die cast aluminum enclosure.

6- High Capacity Heavy Duty deep cycle Zero Maintenance (for life) battery.

7- Exclusive "posi-loc" connectors for easy field hook-up.

8- Rugged scratch resistant aluminum & steel battery case powder painted in "medical" white, vandal proof (pad lockable.)

9- Quality Marine Grade (USCG, UL, Lloyds, BV approved) tin coated copper heavy gage electrical cables: 6 feet to solar panel, 10 feet to lamp fixture, 3 feet to battery case.

10- Quality Stainless Steel hardware (corrosion resistant) included for mounting to customer's pole.

5-4-3-4 Solar Requirements:

At least 4 hours of bright direct sunshine (solar irradiance of 1 kW/m2) a day to obtain 12 hours of brilliant white light (color temperature: 4,100 degrees Kelvin) for night after night of reliable lighting that is insulated from any "man made" power outages.

Fig. 5-13 Some of solar Lighting [1]

5-4-4 Steps of Design:

The lighting requirements depend upon the type of road and the volume and composition of traffic. The roads can then be classified in the following groups:

1. The common heights of column used are 7.5, 10,12m, and the distance between the center of column and sidewalk is 1.5, 2, 2.5m respectively.

Group A1:

Lighting for principal traffic routes and important roads with heavy traffic for example through roads.

Group A2:

Lighting for normal traffic routes such as main roads having considerable vehicular and pedestrian traffic.

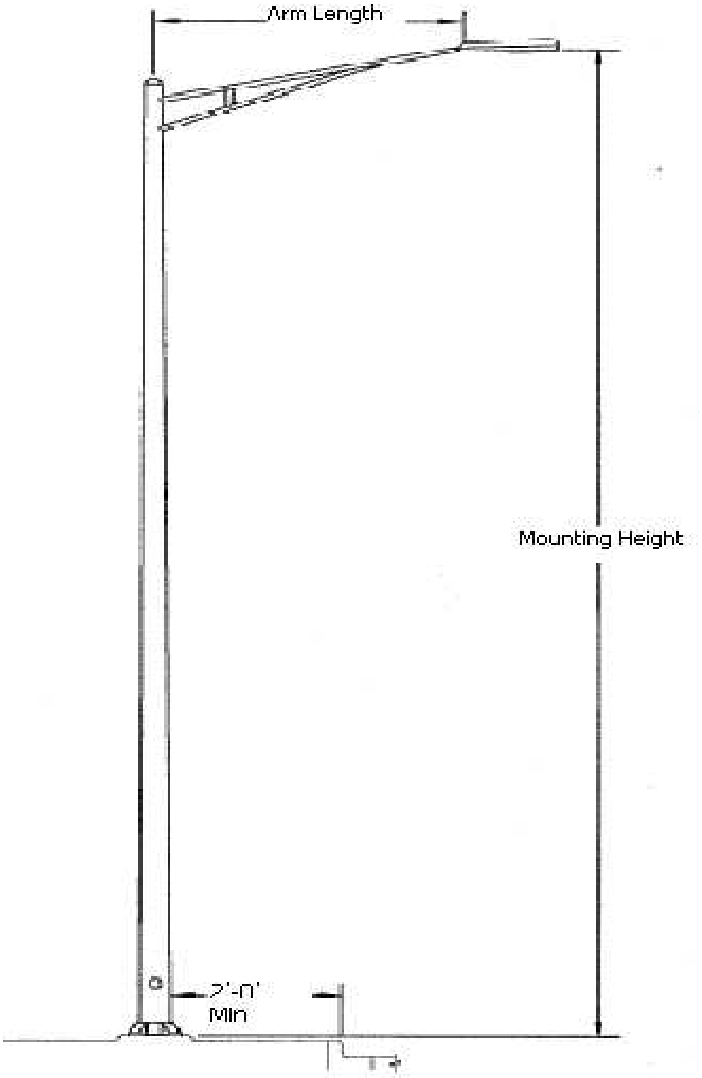
Group A3:

Lighting for normal traffic routes such as main rural roads or minor urban roads.

[1] From Reference No. 13

Table 5-4 Recommendation for lighting columns

Group	Mounting Height H m	Effective width, W m										
		7.62	9.14	10.69	12.19	13.72	15.24	16.76	18.29	19.81	21.34	Maximum overhang Am
		Maximum spacing, S m										
A1	7.62	30.5	25.9	21.3	18.3	16.8	-	-	-	-	-	1.82
	9.14	36.6	36.6	30.5	27.4	24.4	21.3	19.8	-	-	-	2.29
	10.69	42.7	42.7	42.7	38.1	33.5	30.5	27.4	24.4	22.9	-	2.59
	12.19	48.8	48.8	48.8	48.8	42.7	39.6	35.1	32.0	30.5	27.4	2.90
A2	7.62	33.5	30.5	25.9	22.9	19.8	-	-	-	-	-	1.82
	9.14	39.6	39.6	38.1	33.5	29.0	25.9	24.4	-	-	-	2.29
	10.69	47.2	47.2	47.2	45.7	39.6	36.6	33.5	30.5	27.4	-	2.59
	12.19	53.3	53.3	53.3	53.3	51.8	47.2	42.7	39.6	36.6	33.5	2.90
A3	7.62	36.6	36.6	32.0	27.4	24.4	-	-	-	-	-	1.82
	9.14	44.2	44.2	44.2	39.6	35.1	32.0	29.0	-	-	-	2.29
	10.69	51.8	51.8	51.8	51.8	47.2	42.7	39.6	36.6	33.5	-	2.59
	12.19	57.9	57.9	57.9	57.9	57.9	56.4	51.8	47.2	42.7	39.6	2.90



Tall Pole Standards		
Features	Residential local and collector streets	Non-Residential and arterial streets
Mounting height	22'-6'	40'
Arm length	6'	8'
Color	Dark forest green	Black

Fig. 5-14 Tall Pole Right-of-Way Light [1].

[1] From Reference No. 15

CHAPTER SIX

Traffic light signals

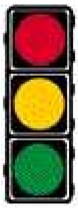
6-1 Introduction:

Traffic signals are placed at intersections to keep traffic moving and avoid accidents. Drivers, pedestrians, and bicycle riders must obey these signals except when an officer is directing traffic.

Standards for traffic control signals are important because traffic control signals need to attract the attention of virtually every road user, including those who are older, those with impaired vision who meet legal requirements, as well as those who are fatigued or distracted, or who are not expecting to encounter a signal at a particular location. Standards for traffic control signals are also important because signals need to function reliably under a wide range of conditions including day and night, adverse weather, and visually complex surroundings

Traffic lights for normal vehicles or pedestrians always have two main lights, a red one which means stop, and a green one which means go. Usually, the red light contains some orange in its hue, and the green light contains some blue, to provide some support for people with red-green color blindness. In most countries there is also a yellow (or amber) light, which when switched on and unflashing indicates to a person that he or she should stop if he or she is safely able to do so. In some systems, flashing amber means that a motorist may go ahead with care if the road is clear, giving way to pedestrians, and to other road vehicles that may have priority. A flashing red essentially means the same as a regular

The traffic signals are defined as advice, which manually, electrically or mechanically operated So that traffic is alternately directed to stop and permitted to proceed. A finite state machine positioned at road intersection or pedestrian crossings to indicate when it is safe to drive, ride, or walking universal color code but traffic lights will sometimes differ where there are several lanes of traffic.
A road signal for directing vehicular traffic by means of colored lights, typically red for stop, green for go, and yellow for proceed with caution. Also called stoplight, traffic signal



Lane signals:

Lane signals are used:

1. When the direction of the flow of traffic changes during the day.
2. To show that a tollbooth is open or closed.
3. To show which lanes are opened or closed.

You must never drive in a lane under a red X. A yellow X means that your lane signal is going to change to red. Prepare to leave the lane safely. You may drive in lanes beneath the green arrow, but you must also obey all other signs and signals

6-2 Traffic signals types:

The following types and uses of highway traffic signals are: -

1. Pedestrian signals.
2. Emergency-vehicle traffic control signals.
3. Traffic control signals for one-lane.
4. Traffic control signals for two-way facilities.
5. Traffic control signals for freeway entrance ramps.
6. Traffic control signals for movable bridges.
7. Lane-use control signals.
8. Flashing beacons.
9. And in-roadway lights.

6-3 Location and Orientation of Traffic Light signals:

1. Traffic lights are usually suspended on cables, gantries or horizontal poles high above junctions, rather than being mounted on relatively short vertical poles at the side of the road as in Britain.

2. Traffic lights are sometimes suspended from wires over the middle of an intersection rather than on poles at the entrance to it.

3. Occasionally the three lights can be arranged horizontally instead of vertically. If the lights are arranged horizontally then red will be on the left, yellow in the middle and green on the right.

6-4 Traffic controller signals:

This is the complete electrical mechanism, usually installed in a cabinet at the side of the road, which controls the operation of the traffic signals .it includes the timing equipment operating the mechanism .

6-4-1Types of Traffic controller signals:

Some of the different types of controllers are as follows:

1. Automatic controller:

A self-operating mechanism which operates the traffic signals automatically automatic controller are usually fitted with facility switch which enables the signals to be changed manually by depressing and releasing a push button.

2. Pretimed controller

An automatic controller for supervising the operation of traffic signals in accordance with predetermined fixed-time cycle.

3. Traffic –actuated controller

An automatic mechanism for supervising the operation of traffic signals in accordance with the varying demands of traffic.

4. Master controller:

An automatic controller for supervising system of secondary controllers, maintaining definite interrelationships, or accomplishing other supervisory functions .The secondary controllers are the automatic controllers at the individual intersections.

5. Local controller

A mechanism for operating traffic signals at an intersection, or two or three adjacent intersections, which may be isolated or included in a signal system.

6. Traffic detector

A device by which vehicles or pedestrians are enabled to inform a traffic-actuated controller of their presence.

7. Time cycle

The time period required for one complete sequence of signal indications.

8. Traffic phase

A part of time cycle allocated to any traffic movement or any combination of traffic movements receiving the right-of-way.

9. Inter green period

The time between the end of the green period of the phase losing the light-of-way and the beginning of the green period of the phase gaining the right-of-way, thus it includes amber time plus any all-red time between the two green periods.

6-4-2 Advantages and Disadvantages of Traffic Control Signals:

a. Advantages of traffic control signals

Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

1. They provide for the orderly movement of traffic.

2. They increase the traffic-handling capacity of the intersection if proper physical layouts and control measures are used, and if the signal timing is reviewed and

updated on a regular basis (every 2 years) to ensure that it satisfies current traffic demands.

3. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions.

4. They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.

5. They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

b. Disadvantages of Traffic Control Signals:

Traffic control signals, even when justified by traffic and roadway conditions, can be ill designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages:

1. Excessive delay.

2. Excessive disobedience of the signal indications.

3. Increased use of less adequate routes as road users attempt to avoid the traffic control signals.

4. Significant increases in the frequency of collisions (especially rear-end collisions).

5. Engineering studies of operating traffic control signals should be made to determine whether the type of installation and the timing program meet the current requirements of traffic.

6-5 Time intervals:

There are three definitions of time intervals

1. Traffic time

The individual traffic user that time needs it.

2. Signals times

These are the time intervals offered by each light.

1. Green time (t_{gr})

Absolute min: 7 sec (2 cars) it is composed of

Reaction time t_r 1-2 sec.

Effective time t_{gr}' 5 sec.

Clearing time t_d 6-8 sec.

Tgr min. = tgr' +tr + td = 12-15 sec.

If the green phase is combined with a pedestrian green, the min. time should be based on the pedestrians.

2. Amber or Yellow time (t ya)

The normal crossing speed of 60 km/h needs a yellow time of 3 sec. The could be reduced to 2 sec if a phase "all red" of min. 1 sec is introduced. In winter periods, an increase of 1 sec is recommended.

In normal conditions ty = 3 sec.

In winter ty = 4 sec.

3. Red time (tred)

Normally it is the summation of green and yellow time and all red of the conflicting traffic. Min = 7 sec + 3 sec = 10 sec.

4. All red time

To prevent conflicting cars to reach the conflict point at the same time, an all red time for all traffic of min. 1 sec can be introduced min (1-2 sec).

5. Red-yellow time

Red and yellow lighten at the same time of about 1-2 sec. this helps to reduce the starting time , but it is not recommended to avoid early starting which may yield to collision.

6. Flashing green

At the end of the green phase, flashing light could be used to warn the slow cars to accelerate.

3. Combination time:

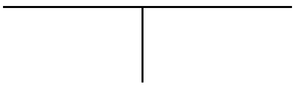
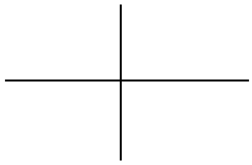
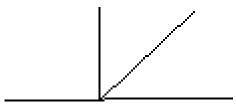
It is the combination of the lost times and the signal time.

1. The cycle time: (tc)

   Is the summation of the signal time depends on the traffic volume, the max is fined so that the traffic users would not loose patience and violate the signal.

The next table gives general information:

Table 6-1 General information

Intersection	No. of arms	Phase	Min.	Cycle time	
				Normal	Max.
	3	3	45	50-70	90
	4	2 3/4	35 45	45-60 50-70	120
	4	Depending Upon no. Of arms		70-90	120

An average value can be taken from the empirical rule:

$$Tc = 3n\sum^{n}\frac{M^{15}}{45}.$$

Tc = cycle time, n: no. Of phase, m15: volume of traffic in 15 min.

2. Waiting time:

The efficiency of light signal is measured by the waiting time of the car within the cycle time. This depends on the volume of the different types of traffic as well as the cycle time, for example at a crossing with 2 phase cycle observations gave the following results:

Cycle time at min.	40sec	60	100	120sec.
Waiting time (sec.	15	22	35	45 sec.
Volume	1600	2400	2800	3000 vl/h.

3. Safety time:

The last car of the give –way phase should leave the conflict point early enough before the cars of the opposite direction would reach the conflict point. This time interval is called the safety time and should be 2 sec.

6-6 Pedestrian Signal Heads:

Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DONT WALK).

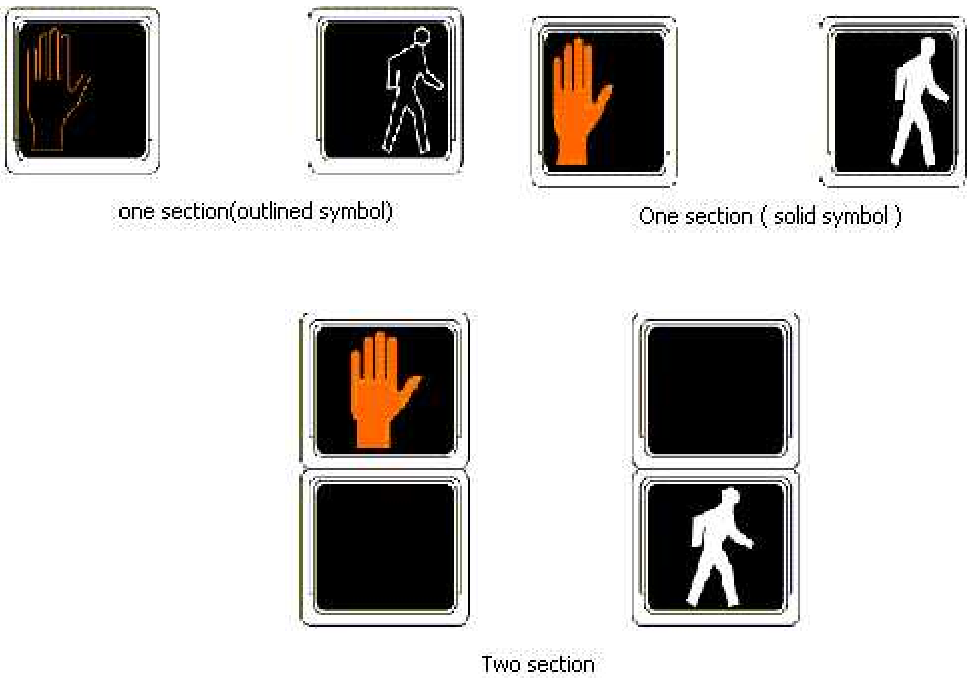


Fig. 6-1 some of pedestrian signal [1]

[1] From reference No.14

6-6-1 Meaning of Pedestrian Signal Indications:

The pedestrian signal indications shall have the following meanings:

1. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication may start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles.

2. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed out of the traveled way.
3. A steady UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.
4. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

6-6-2 Applications of Pedestrian Signal Heads:

Pedestrian signal heads should be used under any of the following conditions:

1. If it is necessary to assist pedestrians in making a safe crossing or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;

2. If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval.

3. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting or continuing a crossing provide insufficient guidance for them to decide when it is safe to cross, such as on one-way streets, at T-intersections, or at multiphase signal operations.

6-6-3 Locations of Pedestrian Signals:

Pedestrian signal indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 3 m (10 ft) from the end of the controlled crosswalk during both day and night.
For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the pedestrian signal indications, the symbols should be at least 225 mm (9 in) high.

6-7 Flashing Lights:

A flashing red light means the same thing as a stop sign. It is used at dangerous intersections; a flashing yellow light means you may move forward with caution. It is used at or just before dangerous intersections, or to alert you to a warning sign such as a school crossing or sharp curve.

A flashing red traffic light means that you must come to a complete stop and check that the road is clear before proceeding.

A flashing red light is not the same as a Four Way Stop, because cross traffic may be presented with a flashing yellow light.

A flashing red light at a railroad crossing indicates that a train is approaching and you must not proceed.

A flashing red light on a school bus means that traffic IN BOTH DIRECTIONS must stop, to allow children to safely cross the road.

A flashing yellow traffic light is just a caution - you don't need to stop but you most certainly do need to slow down and exercise care.

A flashing green light at a road junction indicates a filter (priority) for traffic turning left - traffic in the opposite direction is stopped.

A steady green indicates that traffic in the opposite direction is NOT stopped.

A flashing green light indicates a pedestrian crossing with no pedestrians on it. It acts as a warning, since a pedestrian may push the button and cause the light to change to red.

6-8 Traffic signals problems and its wrongs:

When reporting a fault please try to have the following information available:

- The location of the traffic signals, include road names where possible and district.
- The type of traffic signals involved, e.g. junction, pedestrian.
- The time and date the fault occurred.
- A description of the fault, please include as much detail as possible.
- Your name and contact details, if you require a response

6-9 Application of Steady Signal Indications:

Steady signal indications shall be applied as follows:

1. A steady CIRCULAR RED signal indication:

- Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area.
- Shall be displayed with the appropriate GREEN ARROW signal indications when it is intended to permit traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the intersection or other controlled area, except in protected only mode turn signal faces.

2. A steady CIRCULAR YELLOW signal indication:

1. Shall be displayed following a CIRCULAR GREEN or straight-through GREEN ARROW signal indication in the same signal face.

2. Shall not be displayed in conjunction with the change from the CIRCULAR RED signal indication to the CIRCULAR GREEN signal indication.

3. Shall be followed by a CIRCULAR RED signal indication except that, when entering preemption operation, the return to the previous CIRCULAR GREEN signal indication shall be permitted following a CIRCULAR YELLOW signal indication

3. A steady CIRCULAR GREEN signal indication

Shall be displayed only when it is intended to permit traffic to proceed in any direction that is lawful and practical.

4. A steady RED ARROW signal indication: -

Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area to make the indicated turn. Turning on a steady RED ARROW signal indication shall not be permitted.

5. A steady YELLOW ARROW signal indication:

1. Shall be displayed in the same direction as a GREEN ARROW signal indication following a GREEN ARROW signal indication in the same signal face, unless:

   a. The GREEN ARROW signal indication and a CIRCULAR GREEN (or straight-through GREEN ARROW) signal indication terminate simultaneously in the same signal face, or

   b. The green arrow is a straight-through GREEN ARROW.

2. Shall not be displayed in conjunction with the change from a RED ARROW signal indication to a GREEN ARROW signal indication.

3. Shall not be displayed when any conflicting vehicular movement has a green or yellow signal indication or any conflicting pedestrian movement has a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication .

4. Shall be terminated by a RED ARROW signal indication for the same direction or a CIRCULAR RED signal indication except:

a. When entering preemption operation, the return to the previous GREEN ARROW signal indication shall be permitted following a YELLOW ARROW signal indication.

b. When the movement controlled by the arrow is to continue on a permissive mode basis during an immediately following CIRCULAR GREEN signal indication.

6. A steady GREEN ARROW signal indication:

a. Shall be displayed only to allow vehicular movements, in the direction indicated, that are not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication.

b. Shall be displayed on a signal face that controls a left-turn movement when said movement is not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication

c. Shall not be required on the stem of T-intersections or for turns from one-way streets.

Steady RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications, if not otherwise prohibited, may be used instead of the corresponding circular signal indications at the following locations:

- On an approach intersecting a one-way street;
- Where certain movements are prohibited.
- And where certain movements are physically impossible

The installation of accessible pedestrian signals at signalized intersections should be based on an engineering study, which should consider the following factors:

1. Potential demand for accessible pedestrian signals.
2. A request for accessible pedestrian signals.
3. Traffic volumes during times when pedestrians might be present; including periods of low traffic volumes or high turn-on-red volumes.
4. The complexity of traffic signal phasing.
5. The complexity of intersection geometry.

CHAPTER SEVEN

Recommendation and conclusion

Conclusion:

1- Intersections need to be redesigned nearly all over the city.

2- Counting period for the vehicle is not enough.

3- Almost Hebron streets are not established within standard design.

4-There are many intersections which are not Channelized and not within development plans.

Recommendation:

1- Special specification for Palestine state must be available.

2- Municipality must give more attention to the illegal buildings all over the city and especially near intersections.

3-Civil engineering department at PPU must have special courses which emphasize on the problems of us transportations and intersections in local community.

4-The rehabilitation of selected intersection should be accomplished as soon as possible to mitigate the hazardous on it.

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APPENDIX – A

Computation of traverse and field surveying

A.1 Control Points:

The four control points, start from two control points and closed with two control points:

Table (A-1): Control Points

Point	E	N	Description
First Back Site	156215.78	108603.58	Alrahman Mosque(A)
Start Station	155486.24	109046.78	Trig (S.T.1)
End Station	157933.1	107161.35	Trig(S.T.5)
End Back Site	158637.53	106717.56	Alribat Mosque(B)

A.2 Distance / Angle observations:

The distances between the stations from fieldwork with there estimated errors are:

Table (A-2): Distance observations:

From	To	Distance (m)	S.D. (m)
S.T.1	S.T.2	882.277	.00549

S.T.2	S.T.3	783.420	.00543
S.T.3	S.T.4	975.350	.00555
S.T.4	S.T.5	981.905	.00555

The angles between the sides from fieldwork with there estimated errors are:

Table (A-3): Angle observation:

Back sight	Occupied	Fore sight	Angle	S.D. (second)
A	S.T.1	S.T.2	347d 32’ 03”	2.480”
S.T.1	S.T.2	S.T.3	178d 53’ 02”	2.711”
S.T.2	S.T.3	S.T.4	185d 14’ 55”	2.676”
S.T.3	S.T.4	S.T.5	248d 55’ 09”	2.542”
S.T.4	S.T.5	B	120d 20’ 43”	2.604”

A.3 Departure / Latitude Calculations:

Latitude = Distance * cos (Azimuth).

Departure = Distance * sin (Azimuth).

Table (A-4): Departure & Latitude Calculations

From	To	Distance	Azimuth	S.D. Az.	Departure	Latitude

A	S.T.1	853.613	121	16	44	0.00”	====	====
S.T.1	S.T.2	882.277	108	48	47	2.480”	835.142	-284.518
S.T.2	S.T.3	783.420	107	41	49	3.674”	746.347	-238.146
S.T.3	S.T.4	975.350	112	56	44	4.545”	898.176	-380.246
S.T.4	S.T.5	981.905	181	51	53	5.208”	-31.951	-981.385
S.T.5	B	832.569	122	12	36	5.823”	====	====
Sum		3622.952					2447.714	-1884.295

A.4 Angular misclosure:

Angular misclosure is the difference between fixed and computed azimuth of last course (S.T.5 - B):

Angular misclosure = Az (S.T.5 - B) (fixed) - Az (S.T.5 - B) (calculated)
=122d 12’ 39.15” – 122d 12’ 36” = 3.15”

Since the angular misclosure (3.15”) less than permissible angular misclosure (5.82”) there is no reason to assume that the angles contain blunders.

A.5 Linear misclosure:

ΔE=E (S.T.1) + $\sum(Dep)$ - E (S.T.5)

=155486.24 + 2447.714 – 157933.1 = 0.854

ΔN=N (S.T.1) + $\sum(Lat)$ - N(S.T.5)

=109046.78 – 1884.295 – 107161.35 = 1.135

Misclosure Error = $\sqrt{(\Delta N)^2 + (\Delta E)^2}$

$= \sqrt{(0.8548)^2 + (1.135)^2}$ = 1.42 m

A.6 Calculations:

The Jacobian matrix of the partial derivative (J) for the latitude and departure with respect to the distance and Azimuth measurment is:

$$J = \begin{vmatrix} Cos(AzA1) & -D_{A1}Sin(AzA1) & 0 & 0 & 0 & 0 \\ Sin(AzA1) & D_{A1}Cos(AzA1) & 0 & 0 & 0 & 0 \\ 0 & 0 & Cos(Az12) & -D_{12}Sin(Az12) & 0 & 0 \\ 0 & 0 & Sin(Az12) & D_{12}Cos(Az12) & 0 & 0 \\ : & : & : & : & : & : \\ : & : & : & : & : & : \\ 0 & 0 & 0 & 0 & Cos(Az5B) & -D_{5b}Sin(Az5B) \\ 0 & 0 & 0 & 0 & Sin(Az5B) & D_{5b}Cos(Az5B) \end{vmatrix}$$

The corresponding covariance matrix $\sum$ has the form:

$$\sum = \begin{vmatrix} \pm DA1^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & \left(\frac{\pm AzA1}{\circ}\right)^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & \pm D12^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & \left(\frac{\pm Az12}{\circ}\right)^2 & 0 & 0 \\ : & : & : & : & : & : \\ : & : & : & : & : & : \\ 0 & 0 & 0 & 0 & \pm D5B^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & \left(\frac{\pm Az5B}{\circ}\right)^2 \end{vmatrix}$$

The corresponding covariance matrix $\sum Lat, Dep$ can be obtained by the follow equation:

$$\sum Lat, Dep = J \sum J^T$$

$$A = \begin{vmatrix} \frac{\Delta Lat}{LC} & \frac{\Delta Dep}{LC} & \frac{\Delta Lat}{LC} & \frac{\Delta Dep}{LC} & ..... & \frac{\Delta Lat}{LC} & \frac{\Delta Dep}{LC} \end{vmatrix}$$

The expected standard error in the misclosure of the traverse is obtained by following equation:

$$\sum LC = A \sum Lat, Dep\, A^T$$

Mathematical model depending on equations above:

$$J = \left|\begin{array}{cccccccccccc}
-0.5192 & -729.5404 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.8547 & -443.1994 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & -0.3225 & -835.1421 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.9466 & -284.5179 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & -0.3040 & -746.3468 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.9527 & -238.1458 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & -0.3899 & -898.1761 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.9209 & -380.2463 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & -0.9995 & 31.9510 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & -0.0325 & -981.3850 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & -0.5330 & -704.4368 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.8461 & -443.7792
\end{array}\right|$$

$$\sum = \left|\begin{array}{cccccccccccc}
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 30.1137 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 29.4550 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 30.8052 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 30.8565 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000
\end{array}\right|$$

$$\sum Lat, Dep = \left| \begin{array}{cccccccccccc}
0.00 & 0.00 & & & & & & & & & & \\
0.00 & 0.00 & & & & & & & & & & \\
 & & 3.1317 & -9.1923 & & & & & & & & \\
 & & -9.1923 & 26.9820 & & & & \text{(Zeros)} & & & & \\
 & & & & 2.7220 & -8.5300 & & & & & & \\
 & & & & -8.5300 & 26.7332 & & & & & & \\
 & & & & & & 4.6824 & -11.0592 & & & & \\
 & & & & & & -11.0592 & 26.1233 & & & & \\
 & & & & & & & & 30.8239 & 1.0035 & & \\
 & & & \text{(Zeros)} & & & & & 1.0035 & 0.0333 & & \\
 & & & & & & & & & & 0.0004 & 0.0002 \\
 & & & & & & & & & & 0.0002 & 0.0002
\end{array} \right|$$

$$\sum LC = A \sum Lat, Dep \, A^T = |0.2820|$$

From this result and using a ***t*** value for 3 degrees of freedom, the estimated linear misclosure error for a 95% confidence level is:

$$\pm_{95\%} = 3.183\sqrt{0.2820} = \pm 1.690$$

Because the actual misclosure of 1.42 m is less than the misclosure expected at the 95% level ($\pm$1.690), there is no reason to believe that the traverse measurement contain any blunders.

The assumed permissible misclosure value is:

$$\left(\frac{1}{2000} \times \text{Length of traverse}\right) = \frac{1}{2000} \times 3622.952 = 1.811$$

Since the expected misclosure of 1.690 m is less than the permissible misclosure of 1.811 m, so there is no reason to change the instrument.

A.7 Correction of the Coordinates:

The non fixed stations in the traverse (ST.2, S.T.3, ST.4) are corrected with least square techniques by using "Surveying Calculator I" programmed by Eng.Osama Al-Falah, Eng.Hamed Shoukha and Eng. Wisam Tamimi, its from previous graduation projects in Palestine Polytechnic University.

Table (A-5): Corrected Coordinates

# Of Station	X	Y
S.T.2	156321.382	108762.262
S.T.3	157067.729	108524.116
S.T.4	157965.904	108143.868

The observations of (S.T.6) are taken from (S.T.4):

Horizontal angle = 212d 09' 50" ± 2.6" …………. (Back site (S.T.3)).

Horizontal Distance = (1067.967 ± 0.0056) m.

The horizontal angle is measured by direction method, with 8 repetitions are made (4-faceleft & 4-faceright), then the average of 8 reading is considered.

The corrected coordinates of *(station 6)* is obtained:

X = 158576.79

Y = 107267.87

This station which is occupied for "Beer Al-Mahgar" land surveying.

APPENDIX - B

Standard Design

B.1 Geometric details of roundabout:

The geometric guidelines for roundabout junction are set out in TD 16/93 (Dot, 1993). While it is not proposed to go into detail on the geometric considerations that must be addressed when designing a roundabout, the following are brief notes form TD 16/93 regarding design of the following main parameters:

* Entry width.
* Entry angle.
* Entry radius.
* Entry deflection.
* Inscribed circle diameter (ICD).
* Circulatory carriageway.
* Main central island.

Entry width

TD 17/93 stats that it is good practice to add at least an extra lane to the lanes on the entry approach. (This has been done at all entry arms in the above example. In all cases one lane has been widened to two at the entry points.)

Entry angle

It is recommended that the entry angle should be between 10 and 60. (In the above example, an entry angle of 30 was used at all entry points.)

Entry radius

The absolute minimum radius should be 6m and, in order to cater for heavy goods vehicles, it should preferably not be less than 10m.

Entry deflection

This is one of the mine determinants of safety on a roundabout, indicating the deflection to the left imposed on all entering vehicles. For each entry arm, the tightest radius of the entry path curvature, measured over a distance of at least 20 -25 m, should not exceed 100m.

Inscribed circle diameter (ICD)

In order to accommodate the turning movement of a standard 15.5m long articulated vehicle, the inscribed circle diameter must be at least 28m. the ICD in the above example is exactly 28m .

Circulatory carriageway

The width of the circulatory should not exceed 15m and should lie between 1.0 and 1.2 times the maximum entry width. The chosen design sets the circulatory carriageway at 9m, approximately 1.2 times the maximum entry width value (7.6m).

Main Central Island

The main central island will have a radius of 2m, the maximum allowable for an ICD of 28m, again to allow the safe movement through the junction of large articulated vehicles. In order to limit the circulatory carriageway, therefore, a low profile subsidiary central island should be provided, extending the radius of the central island out to a total of 5m. The subsidiary island provides deflection for standard vehicles while allowing overrun by the rear wheels of articulated vehicles.

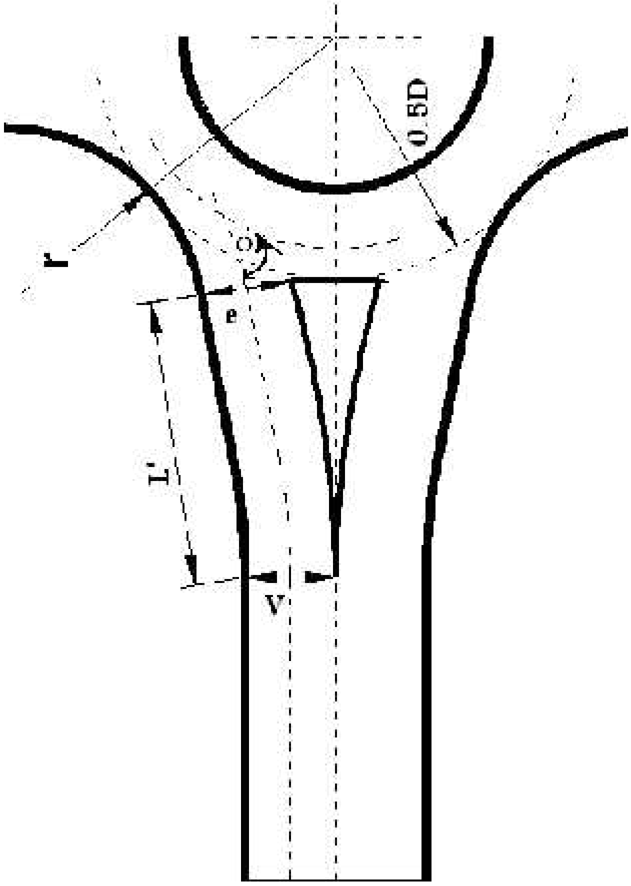


Fig.B-1 Geometric parameters of aroundabout [1**]**

Where:

e = entry width (metres) – measured from apoint normal to the near kerrbside.

V = Approach half width – measured along anormal from apoint in the approach stream from any entry flare.

L' = Averege effective flare length – measured along aline drawn at right angles from the widest point of the entry flare.

S = sharpness pf flare – indicates the rate at which extra width is developed within the entry flare .

D = insecribed circle diameter – the bigest circle that can be inscribed within the junction.

[1] Reference 8

Φ = entry angle – measures the conflict angle between intering and cerculating traffic.

r = entry radius – indicates the radius of curvature of the near side kerbline on entry.

The maximum ranges together with those recommended for design are as shown in this table.

Table B-1 Geometric parameters for roundabouts[1]

Symbol	**Discription**	**Allowable range**	**Recommended range**
e	Entry width	3.6-16.5m	4.0-15.0m
V	Approach half-width	1.9-12.5m	2.0-7.3m
L'	Average flare length	1m to infinity	1-100m
S	Flare sharpness	0-2.9m	----------
D	Inscribed circle diameter	13.5-171.6m	15-100m
Φ	Entry angle	0-77°	10-60°
r	Entry radius	3.4m to infinity	6-100m

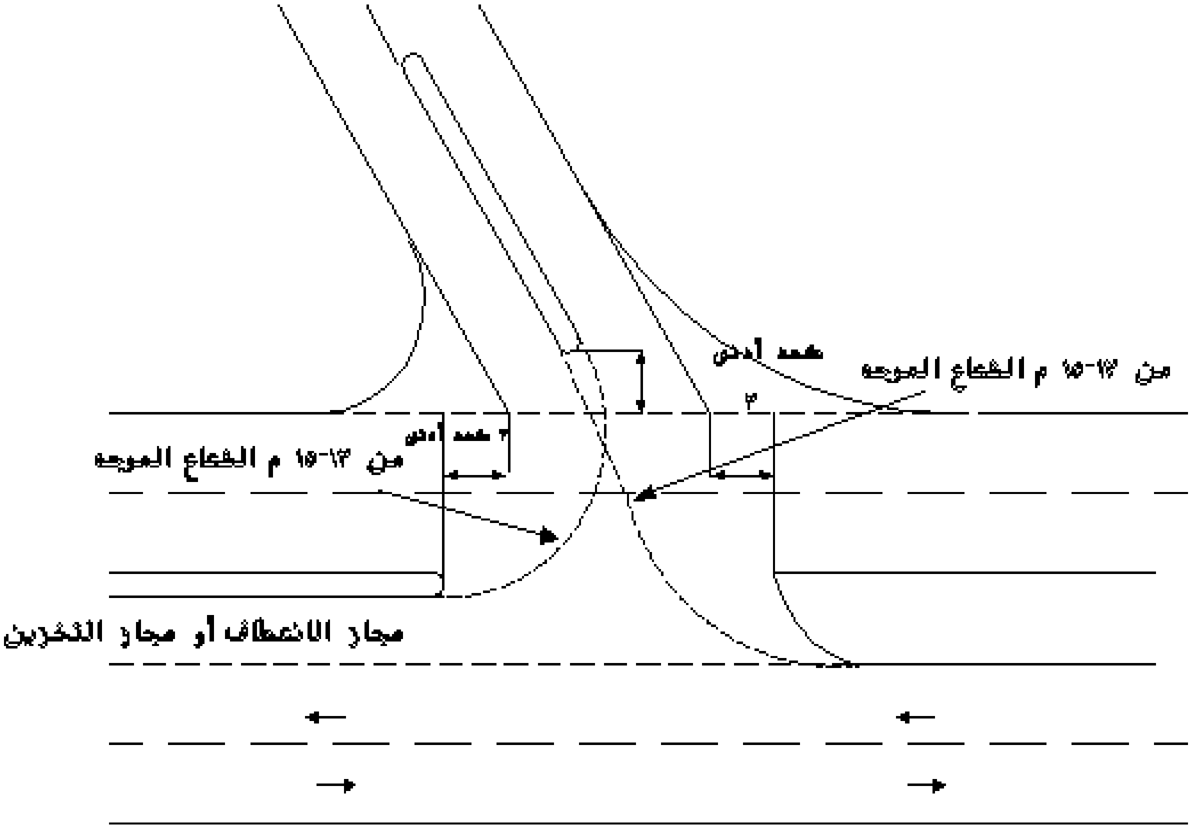
[1] Reference 8

B-2 Intersection Radii

Table B-2 Minimum Right-Turn radii At Edge of Traveled Way

Turn Angle (grad) (Φ)	Design Vehicle	Simple Curve – R (m)	Combination Taper and Simple Curve		
			Radius R(m)	Offset K(m)	Taper Ratio
35	SU	30	-	-	
	WB-12	45			
	WB-15	60			
65	SU	18			
	WB-12	27			
	WB-15	-	30	1	15:1
100	SU	15	12	0.6	10:1
	WB-12	-	13.5	1.2	10:1
	WB-15	-	18	1.2	15:1
135	SU	-	9	1	10:1
	WB-12	-	10.5	1.5	8:1
	WB-15	-	13.5	1.2	15:1
165	SU	-	9	1.2	8:1
	WB-12	-	9	1.8	8:
	WB-15	-	10.5	2.1	6:1
200	SU	-	9	0.5	10:1
	WB-12	-	6	3	5:1
	WB-15	-	8	3	5:1

B-3 Opening of Intersections (Turn Right &Turn Left):



Site	Approach	car	bus	truck	pedestrian	car	bus	truck	pedestrian	car	bus	truck	pedestrian	car	bus	truck	pedestrian	car	bus	truck	pedestrian	car	bus	truck	pedestrian	car	bus	truck	pedestrian
Bear Almahjar	A	273	36	10	30	180	20	5	25	250	32	9	12	261	39	11	14	400	34	14	10	290	31	4	12	30	2	1	1
	B	290	42	8	18	230	37	3	31	320	26	8	60	388	39	8	63	390	29	10	45	333	15	7	4	9	3	0	7
	C	83	13	7	7	70	8	5	5	120	22	8	15	143	27	3	16	166	37	10	31	74	22	3	0	11	0	0	2
	D	141	12	20	11	100	9	12	15	211	23	29	12	199	22	33	14	180	24	31	63	156	20	11	6	43	2	4	2
Abu Rumman	A	278	46	16	0	370	45	9	0	206	39	14	12	280	25	20	11	299	14	5	10	346	25	14	16	26	5	1	8
	B	130	23	13	0	133	23	16	10 1	106	31	10	4	173	35	15	10	168	36	4	3	146	12	13	91	12	0	1	0
	C	269	29	8	57	340	34	9	13	254	41	9	12	320	37	18	9	312	26	2	7	330	36	17	83	31	7	0	3
Alsaheb	A	212	19	6	0	204	28	1	27	201	34	3	20	290	18	10	7	437	31	4	34	171	28	2	20	17	5	5	3
	B	7	3	4	0	19	7	0	1	15	4	2	2	10	5	12	3	34	7	3	12	30	7	7	4	2	0	0	4
	C	35	6	8	0	39	19	7	13	45	11	15	4	50	25	23	1	40	5	10	31	49	11	9	0	20	3	2	1
	D	82	10	0	15	87	13	1	9	98	16	0	7	74	18	15	7	98	16	1	40	67	13	1	8	16	2	1	2
	E	87	12	0	85	86	8	0	21	78	5	2	8	84	11	12	30	149	14	0	99	54	6	0	0	19	0	0	13

WEEK / ACTIVITY	1,2	3,4	5,6	7	8,9	10	11 12	13 14	15 16
Field Surveying	■		■	■					
Counting Vehicles		■	■	■					
Design Intersections					■	■	■		
Preparing Maps						■	■	■	
Writing & Finishing							■	■	■