Chapter: One

Geometric Design of Highways

1.1 Introduction

A geometric design is defined as the design of visible components of a highway. Therefore, the geometric designer can be considered as the architect of the roadway. 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 (including verges), horizontal and vertical alignments, intersections and the length of acceleration and deceleration lanes and so on. These components are highly influenced by characteristics of driver and vehicle performance. Depending on the level of the highway relative to the surrounding terrain, side-slopes may also be a design issue

In addition, radii of curves of an intersection are governed by the minimum radius of design vehicle being using the highway. Therefore, the purpose of a geometric design of the roadway is to provide a consistent design that satisfies the characteristics of driver, vehicle, pedestrians and safety.

1.2 Highway Design Control

Geometric design of highway is the determination of layout and features visible on highway. The emphasis is more on satisfying the need of the driver as well as to ensure the safety of the vehicle, the comfort while driving and efficiency. Other related factors are also considered based on the project.

Highway design depends on many factors, mostly include:

- Highway classification
- Traffic volume and traffic type
- Design Speed
- Design vehicle
- Cross-section of highway
- Presence of heavy vehicles on steep grades
- Topography and environmental
- Level of service
- Safety
- Funds
- Restrictions

1.2.1 Highway classification

Grouping streets and highways into systems or classes is called functional classification. The latter provides an identification of the role of any highway class in the highway network. Basically, roads can be classified (based on the area in which they locate) as Urban and Rural. Rural Roads are usually earth, dust and gravel surfaced. These roads are not demarcated or they do not have any carriage markings like that we see on urban roads. Usually rural roads do not have traffic engineering tools like give way signs, stop signs or traffic lights. The use of rural roads is designated to light vehicles or heavy vehicles alone, but will have users mixed at any time.

On the other hand, Urban roads are usually planned into an interconnected network owing to human and economic activities and exchange. These roads are usually associated with designated traffic engineering equipment like give way signs, stop signs and carriage markings. Moreover, Urban roads usually have demarcations of space of road, there are cases of separate cyclists ways, pedestrian ways and carriage ways for public buses.

In other words, in terms of population, Urban areas are those with a population of at least 5,000. They are further classified as urbanized area (with population of 50,000 or more) and small urban areas (with a population between 5,000 and 50,000).

Roads can be further classified into different types in accordance with their function which is generally related to the mobility and access they provide. Mobility and access are the two important objectives need to be achieved. Mobility means less interrupted follow of traffic, higher design speeds, less access points and sustain higher traffic volume. On the other hand, access indicates interrupted traffic, less design speed and higher accessibility.

In general, both urban and rural roads can be further classified into Freeway, arterials, collectors and locals as follows

- ***Freeway or Expressway:*** it is a type of road which is served only higher degree of mobility which means achieving higher design speeds and uninterrupted traffic flow. Therefore, freeways road have the highest design standards compared with other facilities. Figure 1.1 illustrates an example of freeway roads.

Figure 1.1: Freeway, Express or Motorway

- ***Arterial Road***: Theses Street are primarily for high traffic volume on a continuous road and it has a higher level of traffic mobility. In fact, this type of road has similar function of freeway with less degree of mobility. Figure 1.2 shows different types of arterial roads

Figure 1.2: a- Rural arterial road

Figure 1.2: b- urban arterial road

- ***Collector or distributer road***: collectors have good balancing between mobility and access. The main function of collectors is to facilitate the travel between the arterials and the local roads. They collect the traffic from local roads and convey it to the arterials roads. Furthermore, it has normally full access with a speed limit of 30-55Km/h. Figure 1.3 presents an example of collector road.

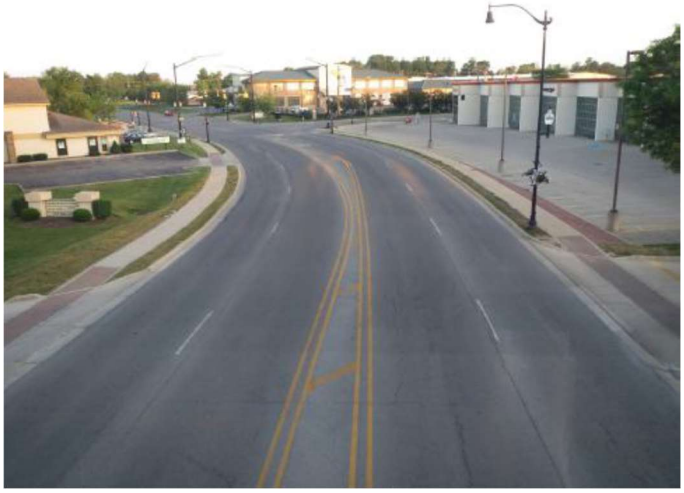

Figure 1.3: Collector road

- ***Local Street:*** this type is normally designed to provide access to different adjoining property (business, residential…. etc.) while minimizing speeds. Figure 1.4 illustrates an example of Local Street.

Figure 1.4: Local Street

1.2.2 Traffic volume and traffic type

It will be uneconomical to design the road for peak traffic flow. Therefore, a reasonable value of traffic volume is selected as the design hourly volume, which is determined from the various traffic data collected. The geometric design is thus based on this design volume, capacity etc. The following types of traffic numbers are frequently used in highway design:

- ***Annual Average Daily Traffic (AADT)***: it is the total volume of vehicle traffic of a highway or road for a year divided by 365 days.
- ***Average Daily Traffic (ADT)***: it is the average number of vehicles using a roadway in a 24-hour period. ADTs can be calculated from any sample of repeated daily counts of traffic volumes, with duration as short as one week.
- ***Design Hourly Volume (DHV)***: it is the estimated number of vehicles using the roadway in the 30th highest hour of the year. This number is generally 8 to 12 percent of the ADT and is used extensively in determining lane widths and shoulder characteristics of the roadway cross section.
- ***Directional Design Hourly Volume (DDHV)***: the estimated number of vehicles traveling in one direction of a two-way roadway in the 30th highest hour of the year. This number must be at least 50 percent of the DHV and is usually in the range of 50 to 60 percent.

  DHV = ADT x K
  DDHV = DHV x D or DDHV = ADT x K x D
  where
  DHV=design hourly volume.

DDHV=directional design hourly volume (vehicles per hour, veh/h).
ADT=average daily traffic (vehicles per day, veh/d).
K=design hourly volume factor (0.10 typically).
D=directional movement factor (0.60 typically).

Example 1: The following traffic counts were taken along an Arterial:

Day 1: 1900 vehicles

Day 2: 2150 vehicles, D=55%

Day 3: 2300 vehicles, K=12%

Day 4: 1950 vehicles

Day 5: 2000 vehicles

Find the ADT, DHV, and DDHV

ADT = (1900 + 2150 + 2300 + 1950 + 2000)/5 = 2060 veh /day

DHV = ADT x K = 2060 x 0.12 = 247 veh / hour

DDHV = DHV x D = 247 x 0.55 = 136 veh / hour in the peak direction

1.2.3 Design Speed

Design speed is the single most important factor that affects the geometric design. It directly affects the sight distance, horizontal curves, and the length of vertical curves. Since the speed of vehicles vary with driver, terrain etc, a design speed is adopted for all the geometric design. It is defined as the highest continuous speed at which individual vehicle can travel with safety on the highway when weather conductions are conductive. It should be noted that design speed is different from the legal speed limit which is the speed limit imposed to curb a common tendency of drivers to travel beyond an accepted safe speed.

Since there are wide variations in the speed adopted by different drivers, and by different types of vehicles, design speed should be selected such that it satisfies nearly all drivers. For example, low design speed should not be selected for a rural collector road solely because the road is located in an area of flat topography, since motorists will tend to drive at higher speeds. In fact, Design speed depends on the functional classification of the highway, the topography of

the area in which the highway is located, and the land use of the adjacent area. Table 1.1 shows suggested design speeds for different conditions.

Table 1.1: Design Speed

Type of Terrain	Metric: Design Speed (km/h) for Specified Design Volume (veh/day)					
	under 50	50 to 250	250 to 400	400 to 1500	1500 to 2000	2000 and over
Level	50	50	60	80	80	80
Rolling	30	50	50	60	60	60
Mountainous	30	30	30	50	50	50

1.2.4 Design vehicle

The diminutions, weight of the axle and operating characteristics of a vehicle influences the design aspects such as width of the pavement, radii of the curve, clearance, parking The vehicle type selected as the design vehicle is the largest that is likely to use the highway with considerable frequency. Figure 1.5 illustrates the design vehicle

Generally, vehicle which used roads are classified into category:

- Passenger cars: these include all passenger cars, including minivans, vans, pick-up trucks, and Sport vehicles.
- Trucks: these include all buses, single-unit trucks, combination trucks, and recreational vehicles

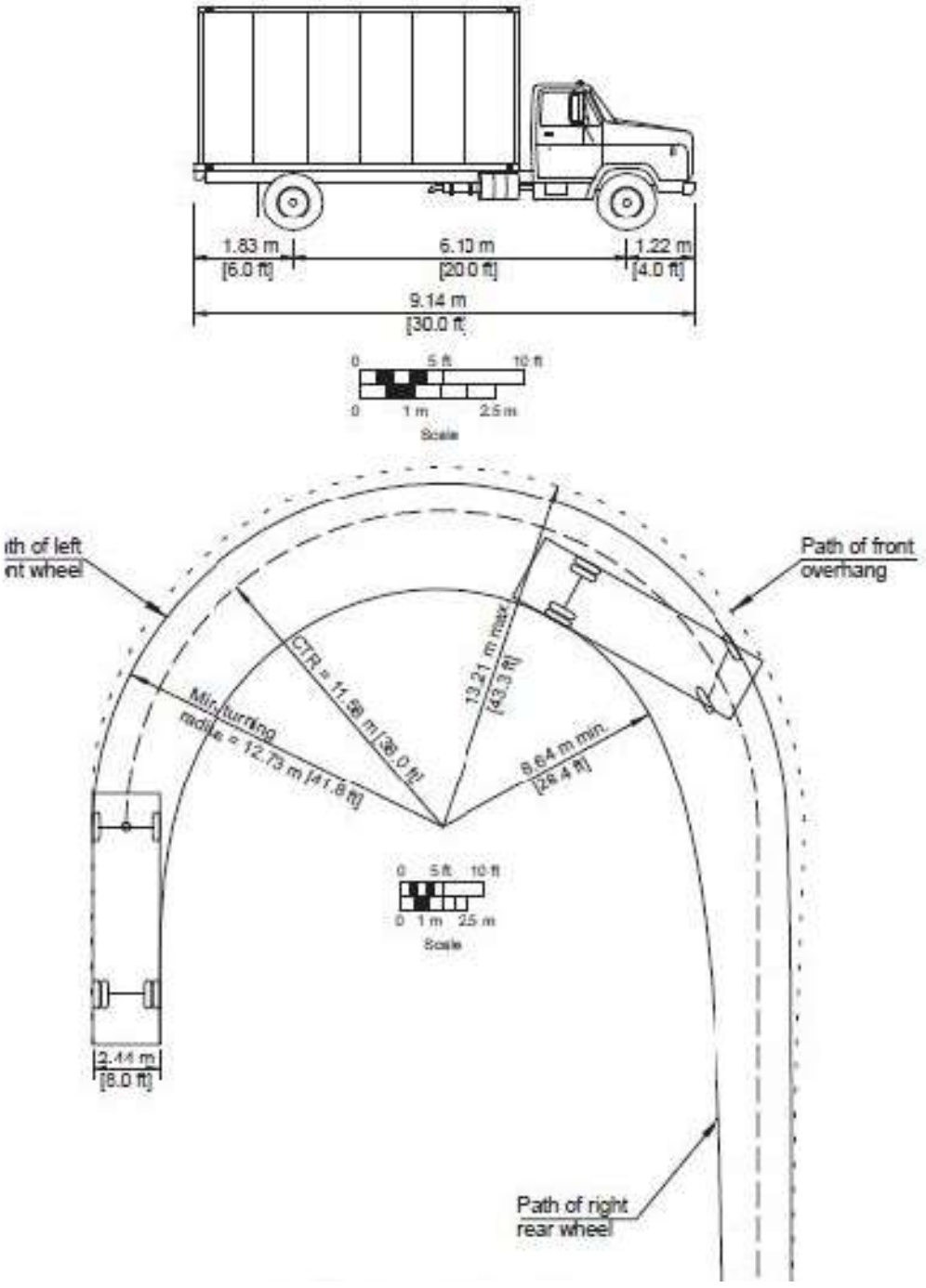

Figure 1.5: Design Vehicle

1.2.5 Cross-section of highway

Cross-section elements of a roadway include principal elements such as travel lanes, shoulders, and medians and marginal elements such as gutters, sidewalks, cross slopes, side slopes, back slopes, guard-rails. However, the availability of these elements depends of whether the road is in urban or rural areas. The element of cross-section will discussed later in detail. Figure 1.5 shows a typical cross-section of highway.

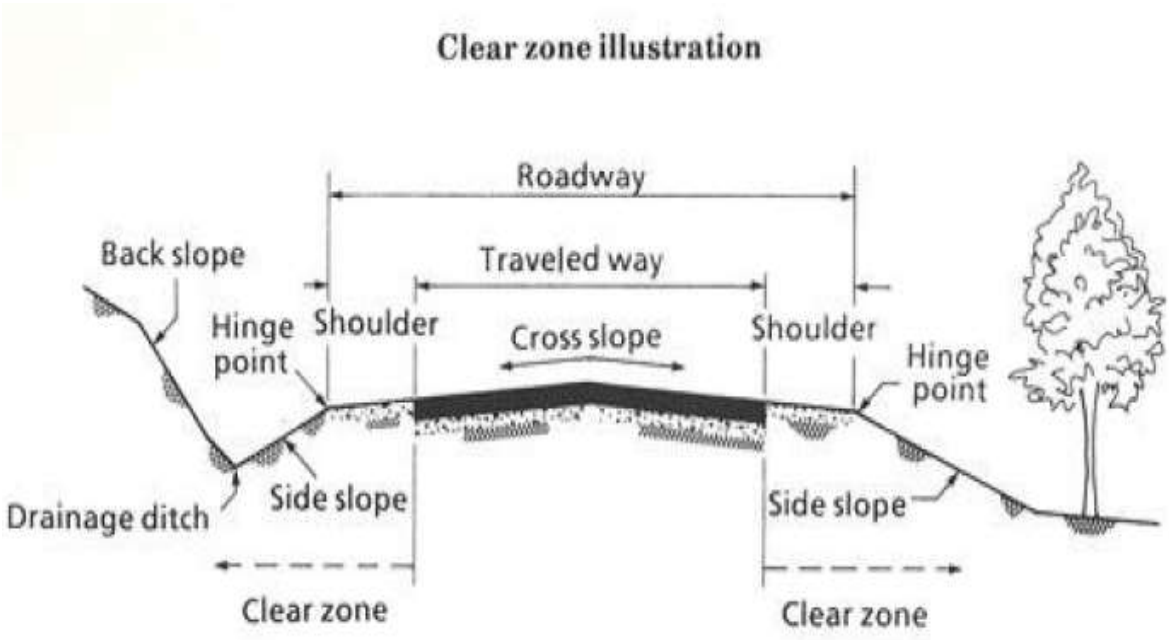

Figure 1.5: Typical cross-section of road

1.2.6 Presence of heavy vehicles on steep grades

The presence of heavy vehicles affects the required geometric design of road. This point is mostly related to next point.

1.2.7 Topography and environmental

For highway design, topography is generally classified into three groups:

1. Level terrain: this is relatively flat. Horizontal and vertical alignments are generally long or can be achieved without much construction difficulty or major expense. In addition, these horizontal and vertical alignments permitting heavy vehicles to maintain approximately the same speed as passenger cars. Grades are generally limited to 1 or 2 percent.

2. Rolling terrain: this type has natural slopes that often rise above and fall below the highway grade with occasional steep slopes that restrict the normal

vertical and horizontal alignments. This terrain causing heavy vehicles to reduce their speeds substantially below those of passenger cars, but not to operate at crawl speeds.

3. Mountainous (hilly) terrain: it has sudden changes in ground elevation in both the longitudinal and transverse directions, thereby requiring frequent hillside excavations to achieve acceptable horizontal and vertical alignments. Furthermore, this type of terrain causing heavy vehicles to operate at crawl speed. Heavy vehicles are defined as any vehicle having a weight (Pounds) to horsepower ratio of 200 or greater. Crawl speed is defined as the maximum sustained speed that heavy vehicles can maintain on an extended upgrade

1.2.8 Level of service
1.2.9 Safety
1.2.10 Funds
1.2.11 Restrictions