Design Controls and Criteria (II)

Key Ref: AASHTO's Green Book

DESIGN CONTROL AND CRITERIA

1. DESIGN VEHICLES
2. DRIVER PERFORMANCE AND HUMAN FACTORS
3. TRAFFIC CHARACTERISTICS
4. HIGHWAY CAPACITY
5. ACCESS CONTROL AND ACCESS MANAGEMENT
6. PEDESTRIAN FACILITIES
7. BICYCLE FACILITIES

2. DRIVER PERFORMANCE AND HUMAN FACTORS

- Consideration of **driver performance** is **essential** to **proper highway design and operation**. The suitability of a design rests as much on how effectively drivers are able to use the highway as on any other criterion.
- **Compatible highway design** with the capabilities of drivers > Drivers performance is aided.
- **Incompatible highway design** with the capabilities of drivers > The chance for driver errors increase, and crashes or inefficient operation may result.

Driver Performance and Human Factors

- It describes drivers in terms of their performance:
  - ***how they interact with the highway and its information system***
  - ***why they make errors***

Older Drivers and Older Pedestrians

<u>% of Drivers population (in USA) of age 65 and older:</u>

- At the start of the 20th century: ~ 4%
- 2010: ~ 15%
- 2030: ~ 22%

Special Need for Older Drivers

- Older drivers have special needs that should be considered in highway design and traffic control.

<u>Example:</u>

- For every decade after age 25, drivers need twice the brightness at night to receive visual information.
- => by age 75, some drivers may need 32 times the brightness they did at age 25.

- Older drivers and older pedestrians are a significant and rapidly growing segment of the highway user population with a variety of age-related diminished capabilities.
- Older road users deserve mobility and they should be accommodated in the design of highway facilities to the extent practical.
- Research findings show that enhancements to the highway system to improve its usability for older drivers and pedestrians can also improve the system for all users.
- Thus, designers and engineers should be aware of the capabilities and needs of older road users and consider appropriate measures to aid their performance.

The Driving Task

- The ***driving task*** is complex and demanding.
- This is particularly so when vehicle speeds are high, time pressure bear on the drivers, locations are unfamiliar, and when environmental conditions are adverse.
- Therefore, ***Driver Performance*** is one of the essential components to be considered when designing highways.

Driver Performance

- Driver performance activities fall into three levels:

Driving Task

- ***Control tasks***
- ***Guidance tasks***
- ***Navigation***

Complexity of task

&

Importance of safety

Levels of Driver Performance

❖ *Control tasks* include the driver's interaction with the vehicle and the lateral and longitudinal control of the vehicle through the steering wheel, accelerator, and brake.

❖ *Guidance tasks* include the driver's performance of selecting an appropriate and safe path on the highway, as well as driver evaluation of immediate conditions and decisions for control actions relating to lane changes, headways, overtaking, and speed change.

❖ Control and guidance errors by drivers contribute directly to crashes.

Levels of Driver Performance

❖*Navigation* includes the driver's execution of a trip, along the course of the highway, using information from maps, guide and information signs, and landmarks.

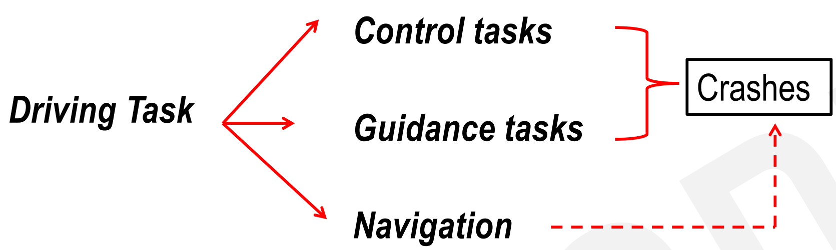
❖Navigational errors resulting in delay contribute to inefficient operation and may lead indirectly to crashes.

Driver Errors

- Driving often occurs at high speeds, under time pressure, in unfamiliar locations, and under adverse environmental conditions.
- The driving task may at other times be so simple and undemanding that a driver becomes inattentive.
- ***A key to effective driver performance*** in this broad range of driving situations is ***error-free information handling***.

Driver Errors

- Driver error results from many drivers, vehicle, roadway, and traffic factors.
- For example, deficient or inconsistent designs or information displays may cause confusions.



Driver Errors

- Some driver errors occur because:
  - ***drivers may not always recognize what actions are appropriate in particular roadway traffic situations***
  - ***situations may lead to task overload or inattentiveness***
  - ***deficient or inconsistent designs or information displays may cause confusion.***

- Driver errors may also result from complexity of decisions, profusion of information, or inadequate time to respond

The Guidance Task

- Of the three major components of the driving task, highway design and traffic operations have the greatest effect on guidance.

- An appreciation of the guidance component of the driving task is needed by the highway designer to aid driver performance.

The Guidance Task Activities

a. **Lane Placement and Road Following Decisions**
b. **Car Following Decisions**
c. **Passing Maneuvers Decisions**
d. **Other Guidance Activities**

a. Lane Placement and Road Following Decisions

- Include steering and speed control judgments
- Basic to vehicle guidance
- Drivers use a feedback process to follow alignment and grade within the constraints of road and environmental conditions.
- Obstacle-avoidance decisions are integrated into lane placement and road-following activities.
- Continually performed for following cases:
  - ***Singularly*** ***(when no other traffic is present)***
  - ***Integrated*** ***(when it is shared with other activities)***

b. Car Following Decisions

- Process by which drivers guide their vehicles when following another vehicle.
- More complex than road-following decisions
- Involve speed-control modifications
- Drivers need to constantly modify their speed to maintain safe gaps between vehicles.
- To proceed safely, they have to assess:
  - ***the speed of the lead vehicle***
  - ***the speed and position of other vehicles in the traffic stream***
  - ***continually detect, assess, and respond to changes***

c. Passing Maneuvers Decisions

- The driver decision to initiate, continue, or complete a passing maneuver
- More complex than the decisions involved in lane placement or car following.
- Involve modifications in road and car-following behavior and in speed control.
- Drivers must judge:
  - ***the speed and acceleration potential of their own vehicle***
  - ***the speed of the lead vehicle***
  - ***the speed and rate of closure of the approached vehicle***
  - ***the presence of an acceptable gap in the traffic stream***

d. Other Guidance Activities

- Other guidance activities include:
  - ***merging***
  - ***lane changing***
  - ***avoidance of pedestrians***
  - ***response to traffic control devices***
- These activities also involve complex decisions, judgments, and predictions

The Information System

- Each element that provides information to drivers is part of the information system of the highway.

The Information System

Formal source → ***Traffic control devices***

specifically designed to display information to drivers

Informal source → ***Roadway and roadside design features, pavement joints, tree lines, and traffic.***

- *Interrelated*
- *should reinforce and augment each other to be most useful*

Traffic Control Devices

- Provide guidance and navigation information that often is not otherwise available or apparent.
- Include:
  - Regulatory
  - Warning
  - Guide signs + other route guidance information
- Other traffic control devices:
  - Markings and delineation > supplements particular roadway or environmental feature by displaying additional information

The Roadway and Its Environment

- Selection of speeds and paths is dependent on drivers being able to see the road ahead.
- Drivers need to see the road directly in front of their vehicles and far enough in advance to perceive the alignment, profile gradeline, and other related aspects of the roadway.
- The view of the road also includes the environment immediately adjacent to the roadway.
- Such appurtenances should be clearly visible to the driver as they affect driving behavior
  - E.g. Shoulders and roadside obstacles (including sign supports, bridge piers, abutments, guardrail, and median barrier)

Information handling

- Throughout the driving task, drivers perform several functions almost simultaneously (look at information sources, make numerous decisions, and perform necessary control actions). Sources of information compete for their attention (attention-sharing process).
- Geometric Design Engineers should know that needed information should be in
  - the driver's field of view,
  - available when and where needed,
  - available in a usable form, and
  - capable of capturing the driver's attention.

Reaction time

- Drivers' reaction times increase as a function of decision complexity and the amount of information to be processed. The longer the reaction time, the greater the chance for error.
- Thus, highway designs should take reaction times into account and recognize that drivers take longer to respond when decisions are complex or events are unexpected.

Figure 2-26. Median Driver Reaction Time to Expected and Unexpected Information

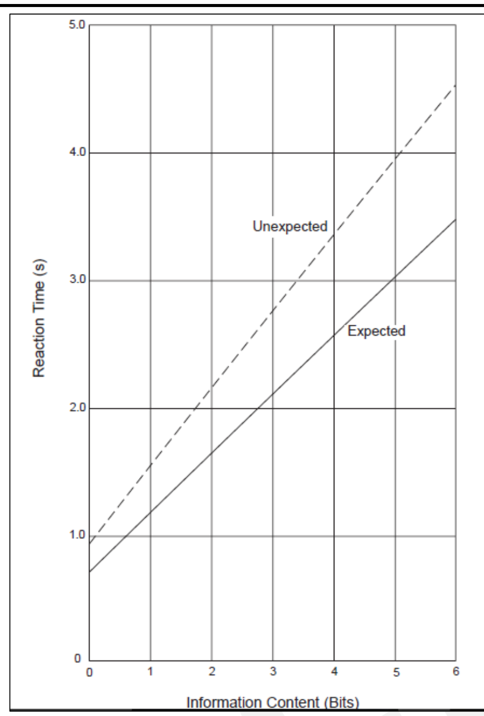
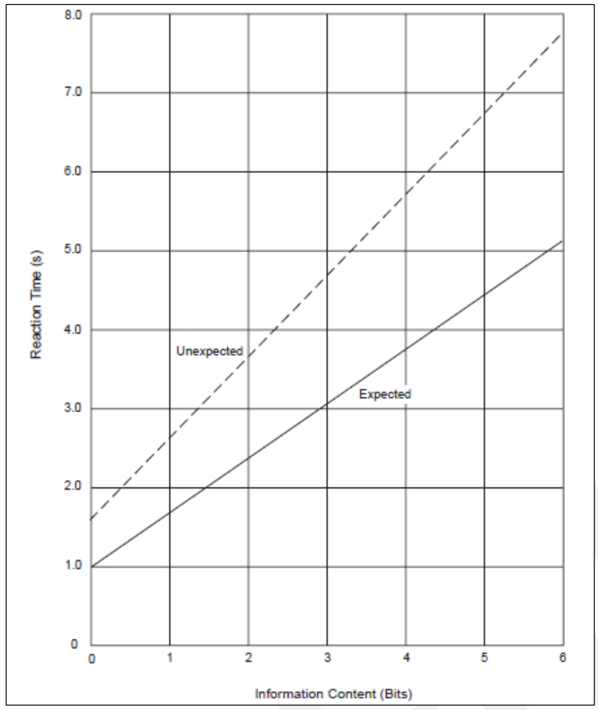


Figure 2-27. 85th-Percentile Driver Reaction Time to Expected and Unexpected Information



Primacy

- Primacy indicates the relative importance to safety of competing information.
- The driver control and guidance information are most important because the related errors may contribute directly to crashes.
- Navigation information has a lower primacy because driver errors may lead to inefficient traffic flow, but are less likely to lead to crashes.
- Accordingly, the design should focus the drivers' attention on the design elements and high-priority information sources that provide control and guidance information.
- This goal may be achieved by providing clear sight lines and good visual quality.

Expectancy

- Reinforced expectancies help drivers respond rapidly and correctly.
- To aid driver performance,

❖ Develop designs in accordance with prevalent driver expectancies.

❖ Unusual design features should be avoided.

❖ Design elements should be applied consistently.

- Where drivers don't get what they expect, or get what they don't expect, errors may result.

Driver Performance

Where ***positive guidance*** is applied to design, competent drivers, using well-designed highways with appropriate information displays, can perform safely and efficiently.

Properly designed and operated highways, in turn, provide positive guidance to drivers.

Speed and Driver Error

Speed reduces the visual field, restricts peripheral vision, and limits the time available for drivers to receive and process information.

Simplify ***control*** and ***guidance*** activities by

- aiding drivers with appropriate information,
- placing information within the cone of clear vision,
- eliminating need for peripheral vision,
- simplify the decisions required, and
- spacing them farther apart to decrease information processing demands

Speed and Driver Error

At the same time, these ***high design standards***, which aim to provide safe, efficient transportation, can lead to

- driver fatigue and
- slower reaction time, as well as a
- reduction in attention and vigilance,

particularly when drivers overextend the customary length and duration of a trip.

Design Controls for Older Drivers

•Older drivers should be accommodated by the design and operational characteristics of a highway to the extent practical.

•For every decade after age 25, drivers need twice the brightness at night to receive visual information. Hence, by age 75, some drivers may need 32 times the brightness they did at age 25.

•Thus, designers and engineers should be aware of the capabilities and needs of older road users and consider appropriate measures to aid their performance.

•In roadway design, perhaps the most practical measure related to better accommodate older drivers is an ***increase in sight distance***, which may be accomplished through increased use of decision sight distance.

•Older Driver Highway Design Handbook: Recommendations and Guidelines

•*The Pakistani context?*

1. Operational deficiencies of older drivers

- slower information processing
- slower reaction times
- slower decision making
- visual deterioration
- hearing deterioration
- decline in ability to judge time, speed, and distance
- limited depth perception
- limited physical mobility
- side effects from prescription drugs

2. Crash Frequency

- Older drivers are involved in a disproportionate number of crashes where there is a higher-than-average demand imposed on driving skills. The driving maneuvers that most often precipitate higher crash frequencies among older drivers include:
- making left turns across traffic
- merging with high-speed traffic
- changing lanes on congested streets in order to make a turn
- crossing a high-volume intersection
- stopping quickly for queued traffic
- parking

3. Countermeasures

- The following countermeasures may make driving easier for older drivers:

- assess all guidelines to consider the practicality of designing for the 95th- or 99th-percentile driver, as appropriate, to represent the performance abilities of an older driver
- improve sight distance by modifying designs and removing obstructions, particularly at intersections and interchanges
- assess sight triangles for adequacy of sight distance provide decision sight distances
- simplify and redesign intersections and interchanges that involve multiple information reception and processing
- consider alternate designs to reduce conflicts
- increase use of protected left-turn signal phases
- increase vehicular clearance times at signalized intersections

3. Countermeasures (contd.)

- provide increased walk times for pedestrians
- provide wider and brighter pavement markings
- provide larger and brighter signs
- reduce sign clutter
- provide more redundant information such as advance guide signs for street name, indications of upcoming turn lanes, and right-angle arrows ahead of an intersection where a route turns or where directional information is needed
- provide centerline and shoulder rumble strips and edge line rumble stripes
- provide intersection channelization
- reduce intersection skew
- enforce speed limits
- increase driver education

Design Assessment for Drivers

To close, potential driver problems can be anticipated before a facility is built by using information about the driving tasks and possible drivers to assess the design. Designers should consider :

- **How the highway will fit into the existing landscape**
- **How the highway should be signed**
- **The extent to which the information system will complement and augment the proposed design**
- **Visual qualities of the road**

3. TRAFFIC CHARACTERISTICS

- **General Considerations**
- **Volume**
- **Directional Distribution**
- **Composition of Traffic**
- **Projection of Future Traffic Demands**
- **Speed**
- **Traffic Flow Relationships**

General Considerations

- The design of a highway and its features should explicitly consider traffic volumes and traffic characteristics.
- Traffic volumes can:
  - indicate the need for the improvement
  - directly influence the selection of geometric design features
    - e.g. number of lanes, widths, alignments, and grades

VOLUME

- Geometric features of design, such as no. of lanes, width, alignment, and grade, are all directly affected by the traffic composition and volume.
- Types of Volume measurement:
  - Average daily traffic (ADT)
  - Average Annual Daily Traffic (AADT)

Types of Volume Measurement

- **ADT**: (> 1 day **-** < a year)
- An average 24-hour traffic volume at a given location for some period of time less than a year. It may be measured for six months, a season, a month, a week, or as little as two days.
  - Average daily traffic (ADT) is not adequate
  - An ADT is a valid number only for the period over which it was measured
- **AADT**: The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365.

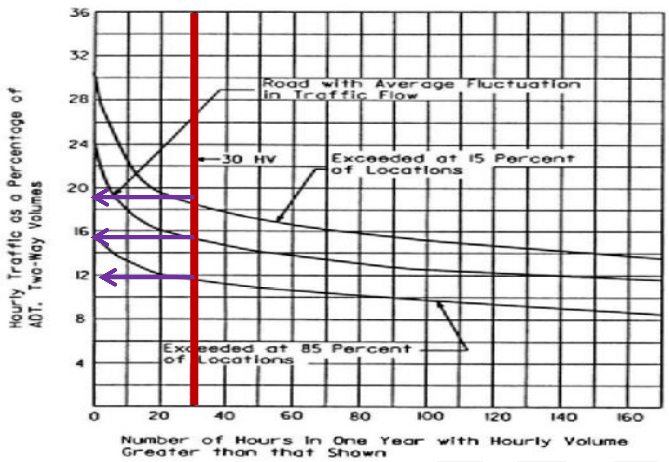
Peak-Hour Traffic

- Traffic volumes for an interval of time shorter than a day more appropriately reflect the operating conditions that should be used for design.
- The peak-hour volume is the generally accepted criterion for use in GD. It is the traffic volume expected to use the facility and is called the design hourly volume (DHV).

Determining DHV

- Which Hourly Traffic Volumes Should be used in design?
  - Wasteful to predict the design on the max. peak-hour traffic
  - Inadequate to design on the avg. hourly traffic

Relationship b/w Peak-hour and Avg. Daily Traffic Volume



Recommended HTV to be used in design is the 30th highest hourly volume of the year (30HV).

Design Hourly Volume (DHV)

- Thus, typically Design hourly volume (DHV) is the 30th-highest hourly volume (30-HV) in one year. The criterion typically applies to both rural and urban roads

○ Exceptions: seasonal traffic fluctuation, recreational areas, morning and afternoon peak hours etc.

- The DHV is generally expressed as a percentage of (K) of the ADT (8-12% urban, 15% rural)

Directional Distribution

- For two-lane highways, the DHV is the total traffic in both directions of travel. However, knowledge of the hourly traffic volume for each direction of travel (i.e. directional distribution; *D*) is essential
  - For highways with more than two lanes
  - On two-lane roads with important intersections, or
  - Where additional lanes are to be provided

Directional Distribution

- Directional Distribution during the design hour (DDHV):
- $k \times D \times ADT$
- Typical values of *D*:
  - Rural and urban highways: 60% - 80%
  - CBD: 50%

In class examples

1. For design volume of 4000 vehicles/hour (vph) in both directions, determine no. of lanes for 50% and 80% uni-directional split by applying 1000 vehicles per lane criterion.

2. The DHV is 15% of the ADT, and the DD at the peak hour is 60:40.

Traffic Counting

Tally counter

Pneumatic road tube

Pocket radar

COMPOSITION

- Heterogeneous traffic
- ***Passenger cars*** – including mini-vans, vans, and sport/utility vehicle
- ***Trucks*** – all buses, single-unit trucks, combination trucks, and recreation vehicle
- Passenger Car Unit/Equivalency (PCU/PCE)
- Suggested PCU/PCE values

SPEED

- For the trip maker, speed is one of the most important factors in choosing a route or selecting a transportation mode.
- The main objective of highway design is to satisfy the demands of the user in the safest and most economical way.
- Economy, travel time, and convenience are directly related to speed.
- Design features such as curvature, super elevation, and sight distance are directly related to, and vary appreciably with, design speed.

Speed

- The aggregate effect of following conditions determines the speed on that stretch of highway:

  1. The capability of drivers using the highways
  2. The characteristics of the vehicle fleet using the highway
  3. The physical characteristics of the highways and its roadside
  4. The weather
  5. The presence of other vehicles (density), and
  6. The speed limitations

Operating Speed

- **Operating Speed** (safe speed) is the highest overall speed at which a driver can travel on a given highway under favourable weather conditions, and under prevailing traffic conditions on a section-by-section basis.

  It is the 85th percentile of the distribution of observed speeds associated with a particular location or geometric feature.

Running and Free Flow Speeds

- When drivers observed traveling under low-volume conditions, the operating speed is recognised as the **Free Flow Speed (FFS)**.
- **Running Speed** is the speed at which an individual vehicle travels over a highway section.

It is used for evaluating

- ❖ LOS and
- ❖ Road user cost

Design Speed

- **Design speed** is the maximum safe speed that can be maintained over a specified section of a highway when conditions are so favourable that the design features of the highway govern.

❖ (Heterogeneous) Mixed traffic, different types of vehicle but single design value is required.

❖ Selected value should satisfy requirements of most of the drivers/conditions.

Factors to consider for SELECTION OF Design Speed

- **In selection of design speed, every effort should be made to attain a desired combination of:**
- **Safety**
- **Mobility**
- **Efficiency**
- **within the constraints of:**
- **Environmental quality**
- **Economics**
- **Aesthetics**
- **Social or political impacts**

Design Speed

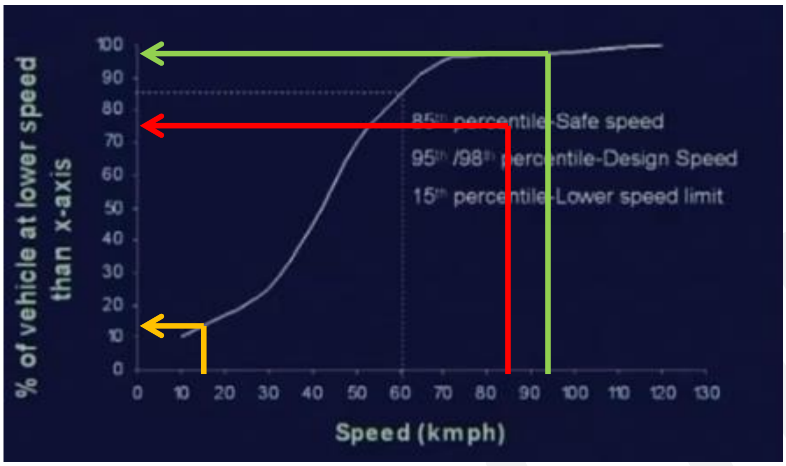
- It is a ***selected speed*** and used to determine the various geometric design features of the roadway.

❖ Once the design speed is selected, all of the pertinent highway features should be related to it to obtain a balanced design (e.g. limiting values of curve radius, min. sight distance)

❖ 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.

Design Speed

- Cumulative distribution of speed has a typical 'S' shape



Design Speed

- The selection of a suitable design speed depend on
  - 1. The terrain and
  - 2. Functional class of the highway

Design Speed and Topography

- It is easier to construct roads with required standards for a plain terrain.
- However, for a given design speed, the construction cost increases multiform with the gradient and the terrain.
- Therefore, GD standards are different for different terrain to keep the cost of construction and time of construction under control. This is characterized by sharper curves and steeper gradients.

Design Speed and Topography

- The way terrain is classified may vary from place to place.

❖ IRC Specifications

Plain	0 to 10%
Rolling	10 to 25%
Mountainous	25 to 60%
Steep	> 60%

❖ AASHTO Specifications

Level

Rolling

Mountainous

Design Speed

- A few pointers to keep in mind
- 1. DS should be consistent with the speed an average driver is likely to expect.
- 2. It should be consistent over a substantial length of road.
- 3. Drivers should be warned well in advance of what to expect.
- 4. The max. limit for low or lower design speed is 45mph, and the minimum limit for high-speed design is 50mph.

Speed

- **Operating Speed** - typically the 85th percentile speed
- Free-flow Speed - close to zero density
- Running Speed - actual speed
- Design Speed - as high as practical

Speed Measurement

Radar Gun

Safety Speed Camera

Confused road design

Design Assessment for Drivers

- Potential driver problems can be anticipated before a facility is built by using information about the driving tasks and possible drivers to assess the design. Designers should consider :
  - How the highway will fit into the existing landscape
  - How the highway should be signed
  - The extent to which the information system will complement and augment the proposed design
  - Visual qualities of the road

ACCESS CONTROL AND ACCESS MANAGEMENT

- **Regulating access is called "access control."**
- **It is achieved through the regulation of public access rights to and from properties abutting the highway facilities.**
- **These regulations generally are categorized as:**
- **full control of access**
- **partial control of access**
- **access management**
- **driveway/entrance regulations**

ADVANTAGES OF ACCESS CONTROL

- **The principal advantages of controlling access are:**
- ***the preservation or improvement of service***
- ***the reduction of crash frequency and severity***

- **The functional advantage of providing access control on a street or highway:**
- ***the management of the interference with through traffic***

Design Controls and Criteria: The Pedestrians

- Pedestrians are a part of every roadway environment, and attention should be paid to their presence in rural as well as urban areas.

  Walk to work 1.5km, to catch a bus 1.0km

  Shopper 50% of the time, commuter 11% of the time

- Pedestrian facilities to deal with in geometric design include sidewalk, crosswalks, traffic control features, curb cuts and ramps, bus stops, sidewalks on grade separations, stairs, escalators, elevators

The Pakistani Pedestrians?

Factors to Consider

- Pedestrian actions are less noticeable than those of motorists
- Inadequate pedestrian rules and regulations
- Tend to walk in a path representing the shortest distance
- Resist to changes in grade or elevation
- Tend to avoid using special underpass or overpass pedestrian facilities
- Pedestrian's age is also an important factor
- Pedestrians with an ambulatory difficulty, visual or developmental impairment

Design Considerations for The Pedestrians

- Use simple designs that minimize crossing widths, use of complex elements such as channelization
- Assume lower walking speeds (avg. pedestrian walking speed 2.5-6.0 ft/sec; older pedestrians 2.8 ft/sec)
- Provision of median refuge islands of sufficient widths
- Provide lighting and eliminate glare sources
- Use enhanced traffic control devices
- Provide oversize retro-reflective signs with suitable legibility
- Provide enhanced markings and delineation

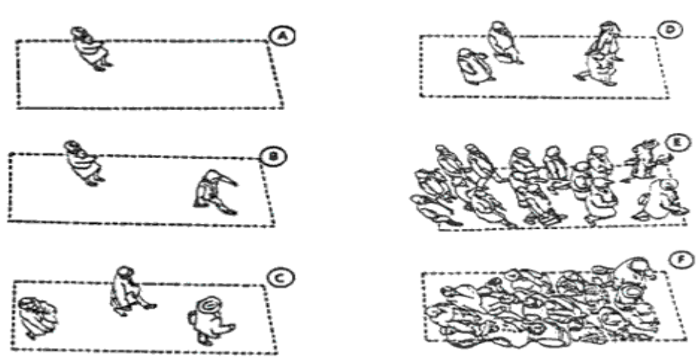
Design Considerations to Reduce Pedestrian -Vehicular Conflicts

- Eliminate left and/or right turns
- Prohibit free-flow right-turn movements
- Prohibit right turn on red
- Convert from two-way to one-way street operation
- Provide separate signal phases for pedestrians
- Eliminate selected crosswalks
- Provide grade separations for pedestrian

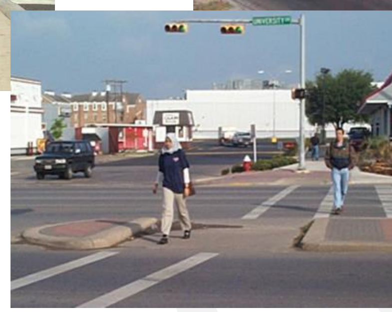
Walkway Capacities

- Capacity is defined as the maximum number of passengers (or vehicles) per unit time, which can be accommodated under given conditions with a reasonable expectation of occurrence
  - LOS A, pedestrians choose a desired walking speed and can avoid conflicts
  - LOS B, pedestrians begin to be aware of other pedestrians
  - LOS C, requires minor adjustment to speed and direction by pedestrians to avoid conflicts
  - LOS D, frequent changes in speed and position are required
  - LOS E, very crowded walking, reduced speed, shuffling, making reverse, cross traffic flow very difficult
  - LOS F, frequent, unavoidable contact with other pedestrians, stationary standing pedestrian in waiting area

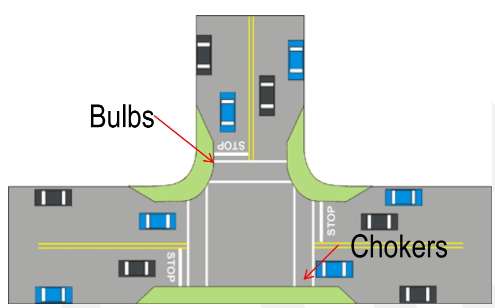
Walkway Capacities



Medians and Islands



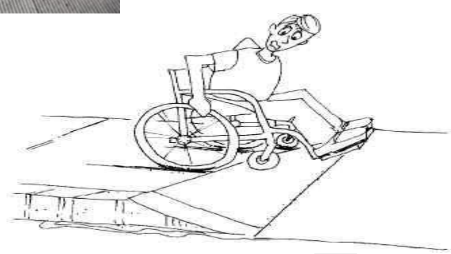
crosswalks



Pedestrian Visibility

Pedestrian Crossing

Crossings for Impaired Pedestrians



Bicycle Facilities

- The bicycle has become an important element for consideration in highway design process
- Low-cost improvements
    - Paved shoulders
    - Wider outside traffic lanes (14 ft)
    - Bicycle-safe drainage grates
    - Adjusting manhole covers to the grade
    - Marinating a smooth, clean riding surface

Bicycle Facilities

Flexible GEOMETRIC DESIGN

UC Davis