Cairo University
Faculty of Engineering
Public Works Department

Highway and Traffic Engineering
PBW 401
2013 - 2014

Quick Review: Human Response Process, Braking Distance, Sight Distances

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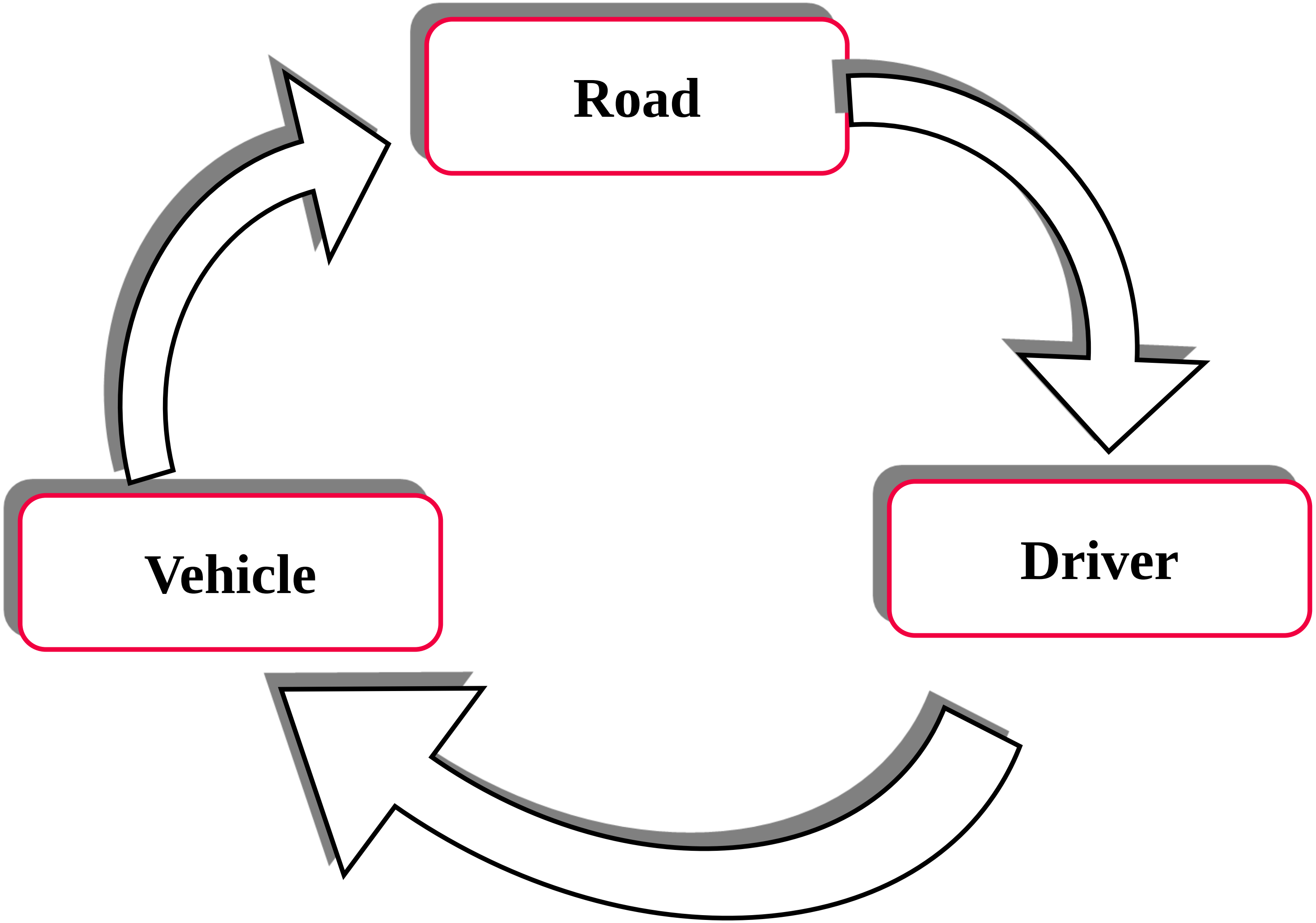
Main Components of the Transportation System:



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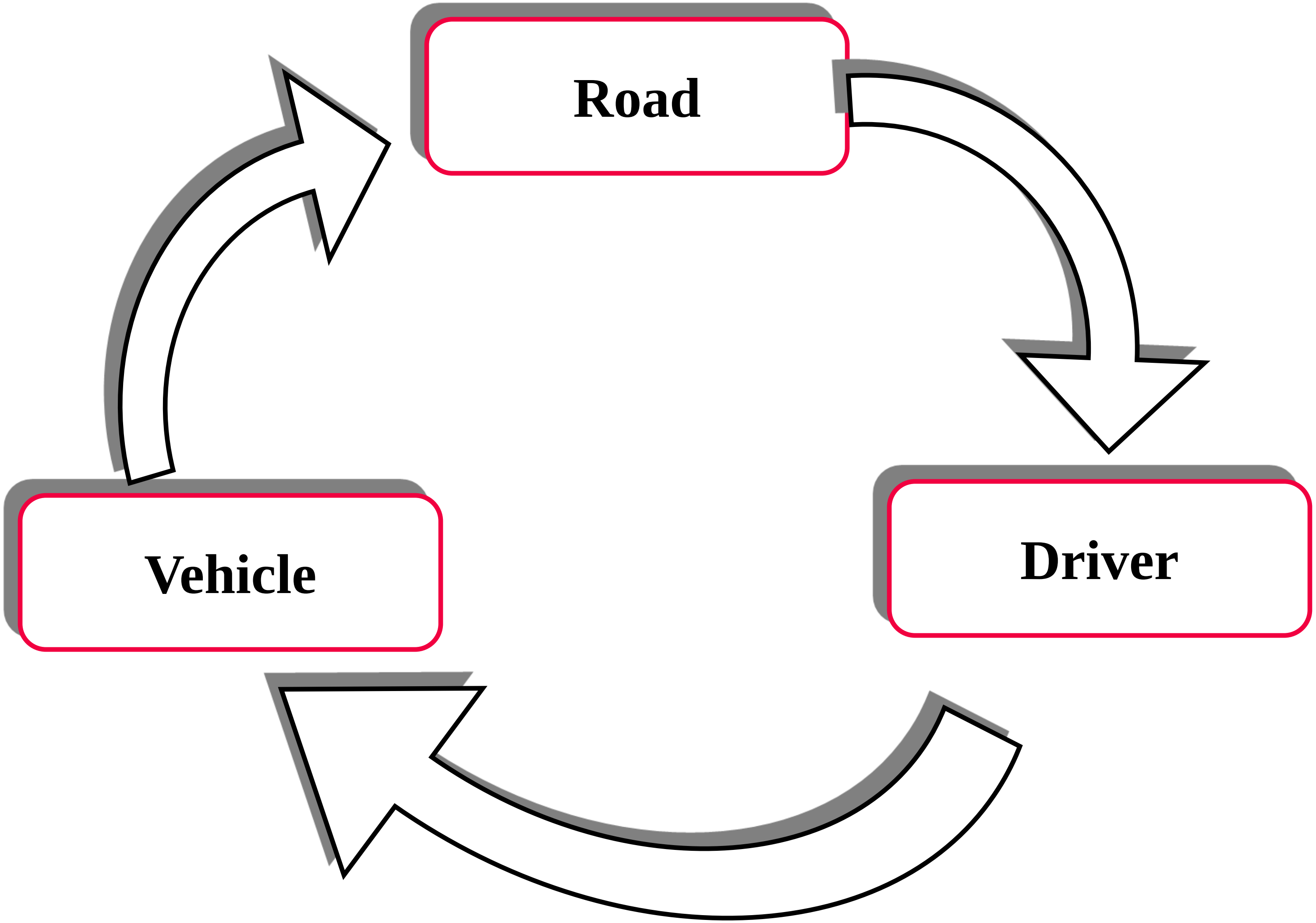
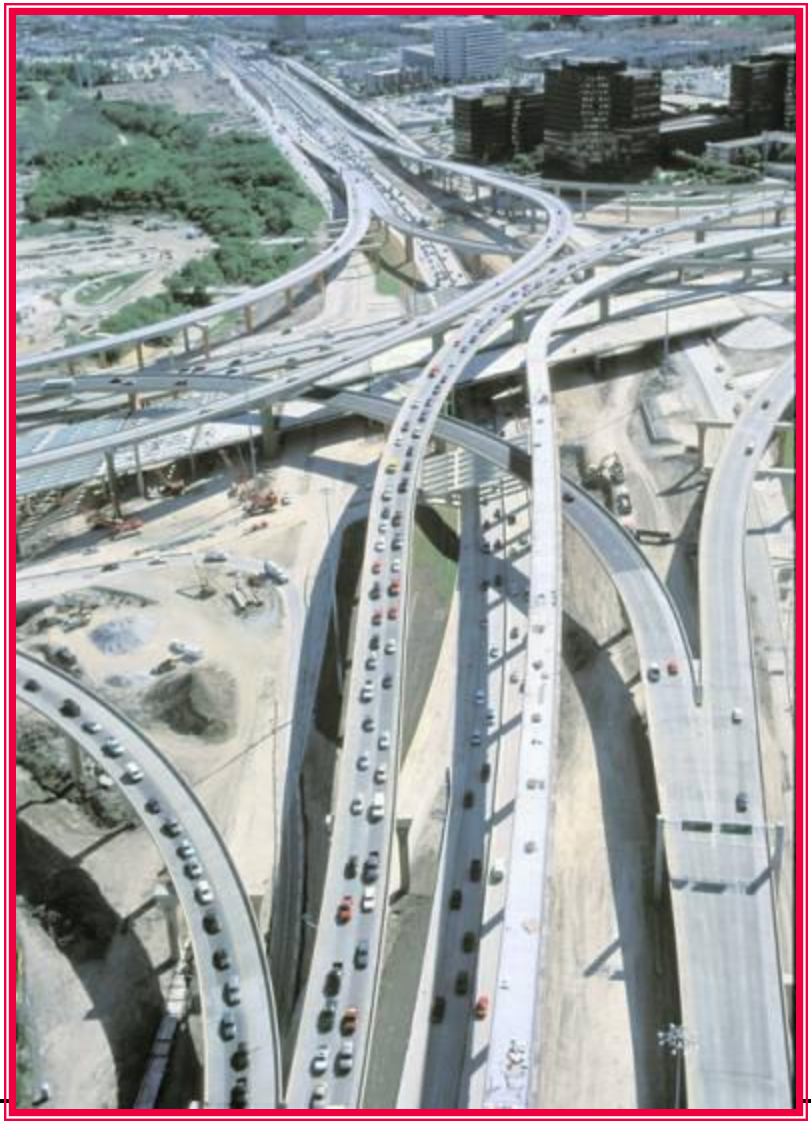


Evolution of Vehicles

Model –T Ford (1908)

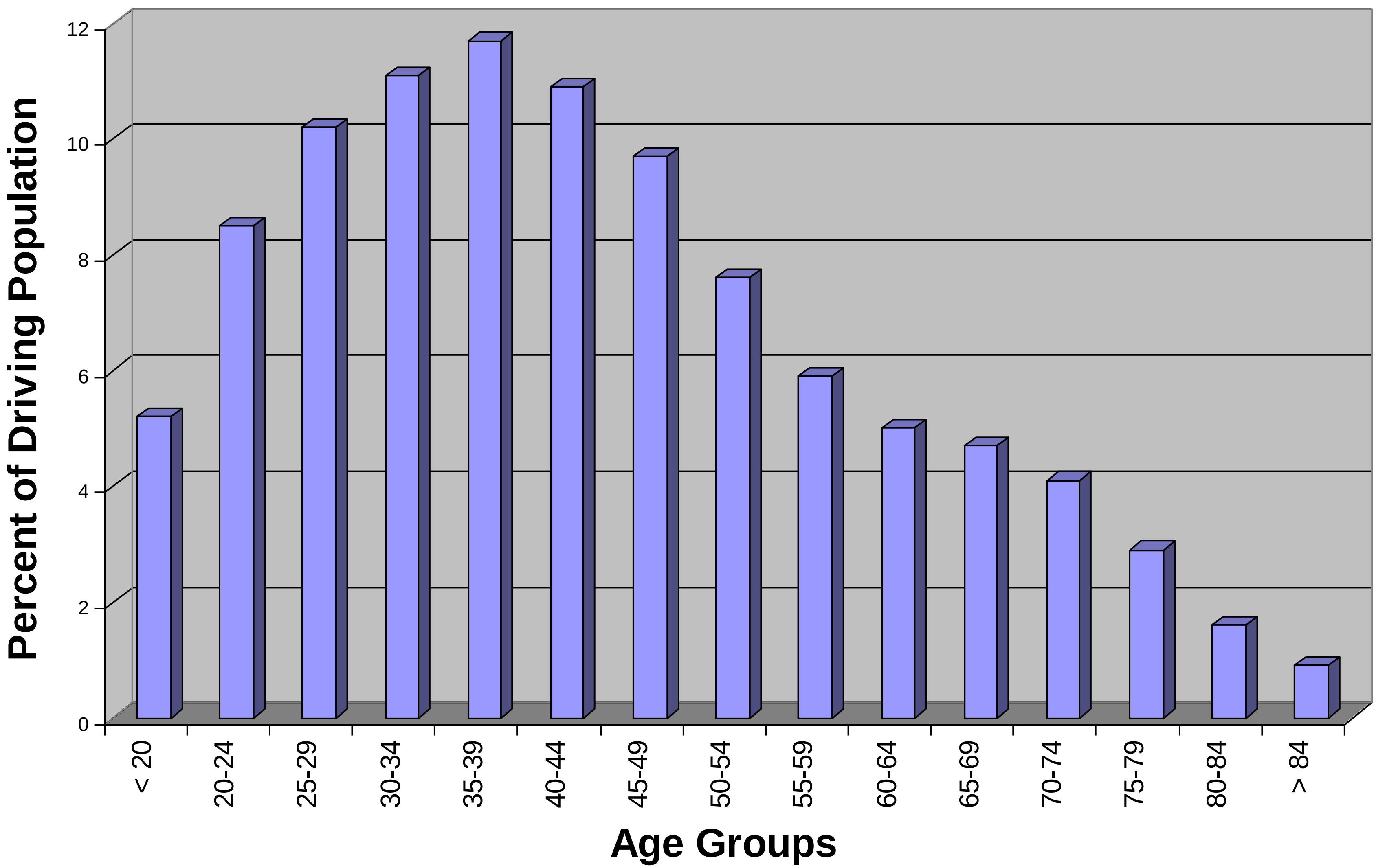
Morris Minor (1953)

Evolution of Roads



- Main components of highway system are:
  -
  -
  -
- Efficient and safe highway transportation system requires:
  - Knowledge of the highway system components and their limitations
  - Interrelationships among these components
- Design challenges:
  - Varying skills and limitations of road users
  - Varying abilities within individuals depending on several conditions: mood, environment, …
  - Wide range of abilities required to process information and drive: hear, see, evaluate, react, …
  - Varying abilities and limitations of vehicles
  - Average values are not suitable

1. Road Users: Drivers & Pedestrians



1. Road Users: Drivers & Pedestrians

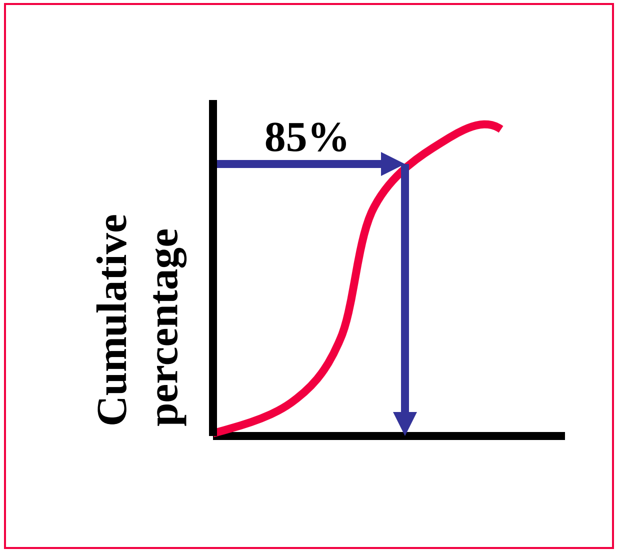
Driver Characteristics:

1. **<u>Driver's Physiological Characteristics</u>**:
   - Reaction time
   - Visual Abilities
   - Fatigue Level

2. **<u>Mental Characteristics:</u>**
   - Reaction time
   - Expectancy Level
   - Attention Level
   - Workload Capacity

Variability among the users

- Variability among the drivers is the most concerned one
- Average values miss 50% of the driver population ➔ the 85th percentile often used (meaning that at least 85% of the user population must be safely covered)



Examples:

1. **Speed limit = Use the 85th percentile speed of the sampled speeds**
2. **Pedestrian walking speed = Use the 15th percentile speed of the sampled pedestrian walking speeds (Can you tell why the 15th percentile is used?)**

Driver Characteristics

- The Human Response Process
  - Actions taken by drivers are responses to information they received and evaluated
  - The information are obtained mainly through ………....and …………perception

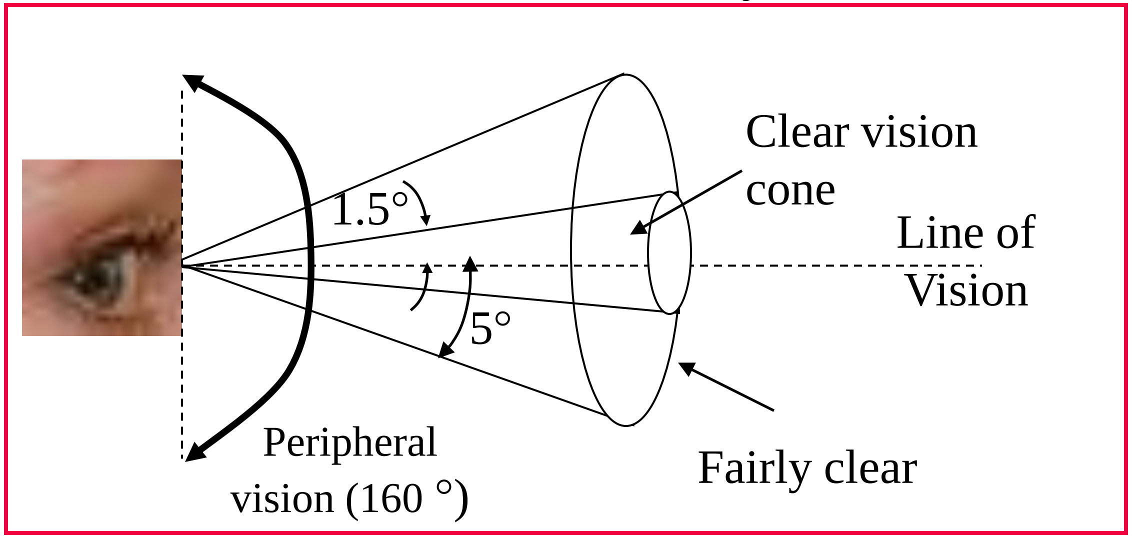
1. Hearing Perception

- Ability to detect warning sounds as sirens, horns
- Important to detect emergency vehicles

The Human Response Process:

2. Visual Perception

- The most important source of information
- About 95% of information are received visually



Principal characteristics of the eye are:

1. Static visual acuity
2. Dynamic visual acuity
3. Depth perception
4. Glare vision & recovery
5. Color vision
6. Peripheral vision

The Human Response Process:

1.

- The ability to see fine details of an object
- Static visual acuity is related to the driver's ability to identify an object when both the driver and object are stationary
- It increases with an increase in illumination up to a background brightness of 3 candles/ft2

2.

- Related to the driver's ability to detect moving objects
- Most people have a clear vision within a conical angle of 3° to 5 ° and a fairly clear vision within a conical angle of 10 ° to 12 °
- Key criteria in determining placement of traffic signs

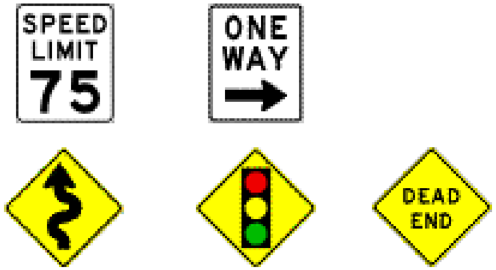
The Human Response Process:

3.

- The ability to see objects beyond the cone of clearest vision
- The cone of peripheral vision could be one subtending up to 160°
- Objects can be seen within this zone but details and colour are not clear

4.

- The ability to differentiate one colour from the other
- Combinations to which the eye is the most sensitive
  - Black and white
  - Black and yellow
- Key in determining traffic signs colours



The Human Response Process:

5.

- **Ability to recover from the effects of glare**
- **Time required to recover from the effects of glare is known as glare recovery**
  - **Dark to light : 3 seconds -- headlights in the eye**
  - **Light to dark: 6 seconds – turning lights off**
- **Usually a concern for night driving**

6.

- **The ability to estimate speed and distance.**
  - **Passing on two-lane roads**
  - **Judging gaps**
  - **Signs are standardized to aid in perceiving distance**
- **Very young and old have trouble judging gap**

Perception-Reaction Process

PRT = Perception-Reaction Time

= (Detection + Identification + Decision making) +

(Time needed to initiate the physical response)

PIEV = Perception + Identification + Emotion + Reaction (or volition)

1. **Perception: use of visual perception to see a control device, warning sign, or object on the road**
2. **Identification: the driver identifies the object and understands the stimulus**
3. **Emotion: the driver decides the proper action to take in response to the stimulus (stop, slow, pass,…)**
4. **Volition (or Reaction): the driver actually executes the action already decided**

Perception-Reaction Process

– PIEV is important for safety of cars, drivers, and pedestrians

– Examples of uses:

-
-
-

PIEV = f (Complexity of the task, Level of expectancy, Variability of the drivers)

1.
2.
3.
4.
5.
6.
7.

– For design purposes:

- AASHTO (American Association of State Highway and Transportation Officials) and TAC (Transportation Association of Canada) recommended 2.5 sec for stopping sight distance
- Accommodates about 90% of drivers

– PIEV distance = PIEV time × Speed

- Example:

A driver with a PIEV time of 2.5 sec is driving at 100 km/h when she observes that an accident has blocked the road ahead. Determine the distance the vehicle would move before the driver could activate the brakes.

Vehicle Characteristics

- Static characteristics:
  - They include:
  - Static characteristics affect the design of several physical components of the highway such as:
  - A number of design vehicles with standard dimensions and turning radii are identified in the design guides

Static Characteristics

Truck stuck under rail bridge

Article from: The Courier Mail

Font size: Email article: Print article: Submit comment:

By Neil Hickey
January 07, 2008 04:45pm

TRAFFIC in and around the Gabba was halted for almost two hours today when a truck became lodged under a low-lying bridge.

The truck became wedged under the bridge at Logan Rd, Woolloongabba, just after 1pm, not far from the Stones Corner shopping precinct.

Police were called in to divert traffic as the truck was removed and a safety inspection of the bridge was carried out by officials from Queensland Rail.

The scene was cleared about 3pm, police said, just in time for this afternoons busy peak hour.

OOPS ... the truck wedged beneath the rail overpass. Picture: Peter Wallis

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What is this? »

Static Characteristics

Semi-Truck Gets Stuck Under West Chester Railroad Overpass

Reported by: Bill Price
Email: bprice@wcpo.com
Contributor: Ian Preuth
Last Update: 12/10/2007 4:40 pm

West Chester Road, north of Cincinnati Dayton Road has been reopened this afternoon, after a tractor-trailer got stuck trying to get through a railroad bridge.

It happened just before noon when the truck, heading southbound on West Chester Road, tried to maneuver through the short narrow bridge and the rear section of the trailer got stuck.

West Chester Police brought in two large tow trucks and a truck dolly to help wedge the trailer out from under the bridge.

We could see the road has warning signs about the 13 foot, 6 inch clearance for the older concrete underpass, but it appeared the length of the trailer(53-feet) may have played a bigger role in getting the truck stuck.

The truck had scrapes along its side and the trailer's roof was badly dented in multiple places by the encounter with the underpass. The truck's driver was not injured.

While police and tow truck operators were working to free the truck, a freight train passed overhead, giving crews a few anxious moments. But building inspectors on the scene say the railroad bridge and underpass for West Chester Road did not suffer any visible damage in the incident.

Vehicle Characteristics

- **There are four general classes of design vehicles.**

(1) Passenger car (passenger cars of all sizes, sport/utility vehicles, minivans, vans, and pickup trucks)

(2) Buses (inter-city motor coaches, city transit, school, articulated buses)

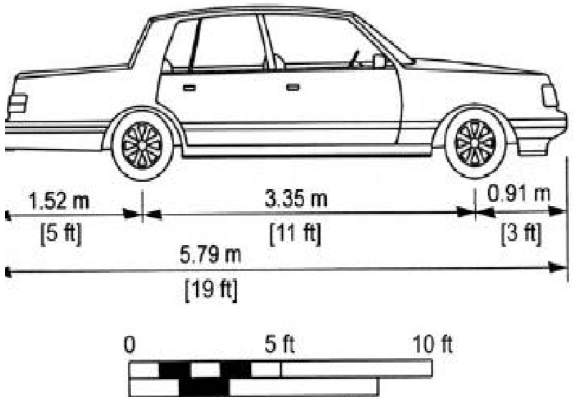
(3) Trucks (single-unit trucks, truck tractor-semitrailer combinations, truck tractors with semitrailers in combination with full trailers).

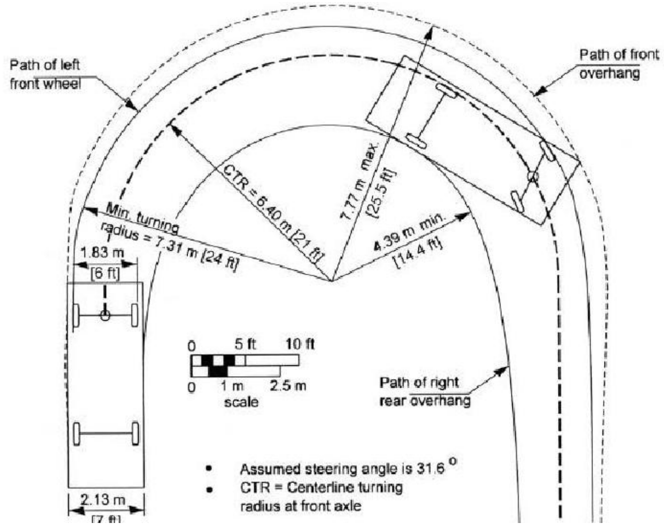
(4) Recreational vehicles (motor homes, cars with camper trailers, cars with boat trailers, motor homes with boat trailers, motor homes pulling cars).

Passenger Car Characteristics

Table 1.2.4.1	Design Dimensions for Passenger Cars
Length (m)	5.6
Front Overhang (m)	1.1
Rear Overhang (m)	1.3
Wheelbase (m)	3.2
Minimum Turning Radius (m)	6.3
Width (m)	2.0

TAC (1999)





AASHTO (2004)

Commercial Vehicle Characteristics

Table 1.2.4.2 Design Dimensions for Commercial Vehicles

	Single-Unit Trucks			Tractor-Semitrailers		Doubles	
	Light	Medium	Heavy	WB-19	WB-20	A-trains	B-trains
Length (m)	6.4	10.0	11.5	20.7	22.7	24.5	25.0
Front Overhang (m)	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Rear Overhang (m)	2.2	2.7	2.3	1.7	3.3	1.5	1.3
WB1 (m)	3.4	6.5	8.4	6.2	6.2	5.1	6.1
WB2 (m)	-	-	-	12.0	12.4	6.9	9.0
WB3 (m)	-	-	-	-	-	6.9	7.0
WB4 (m)	-	-	-	-	-	3.3[1]	0.8[2]
Width (m)	2.6[3]	2.6[3]	2.6[3]	2.6[3]	2.6[3]	2.6[3]	2.6[3]
Minimum Turning Radius - see Table 1.2.4.4							

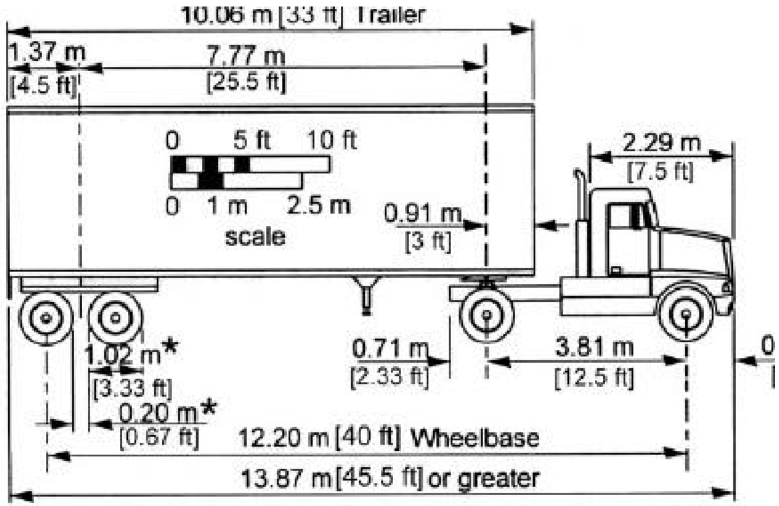
[1] Includes 1.2 m from the rear effective axle to the hitch point, and 2.1 m from the hitch point to the lead effective axle of the following unit.

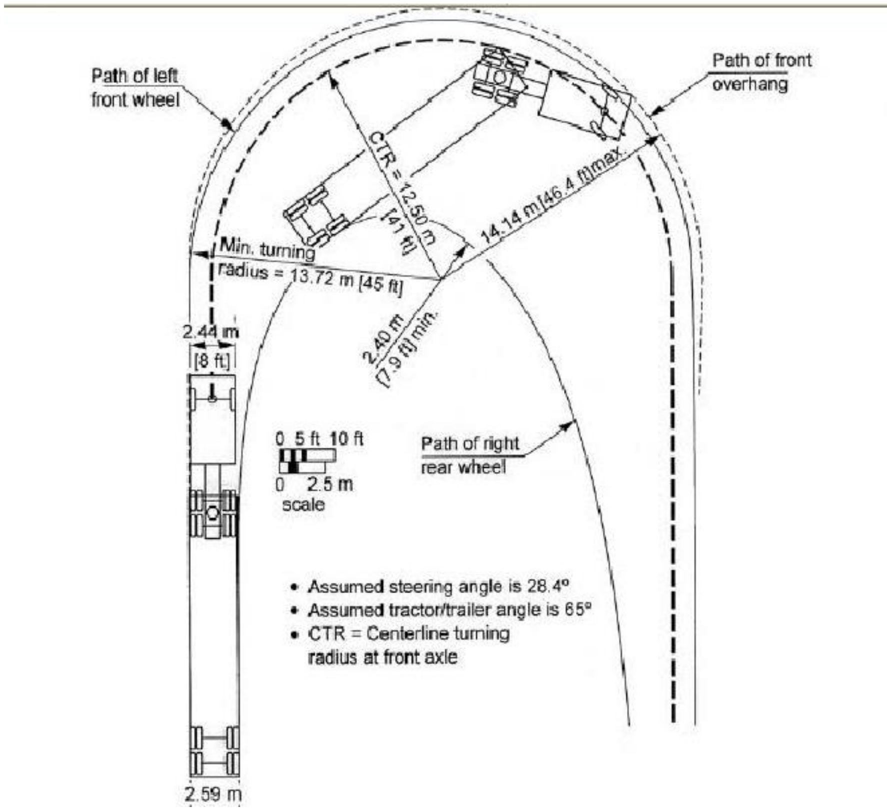
[2] Represents the distance from the hitch point to the lead effective axle of the following unit.

[3] Maximum dimension allowed without permit. Statistical data not available.

TAC (1999)

Commercial Vehicle Characteristics





AASHTO (2004)

Commercial Vehicle Characteristics

Table 1.2.4.4 Minimum Design Turning Radii for Representative Trucks, for 180° Turns

Truck Type	Wheelbase	Minimum Turning Radius (m) Centre of Axle	Minimum Turning Radius (m) Outside Front Wheel
Light SU	3.4	5.3	6.3
Medium SU	6.5	10.1	11.1
Heavy SU	8.4	13.1	14.1
Tractor Unit	6.2	9.6	10.7

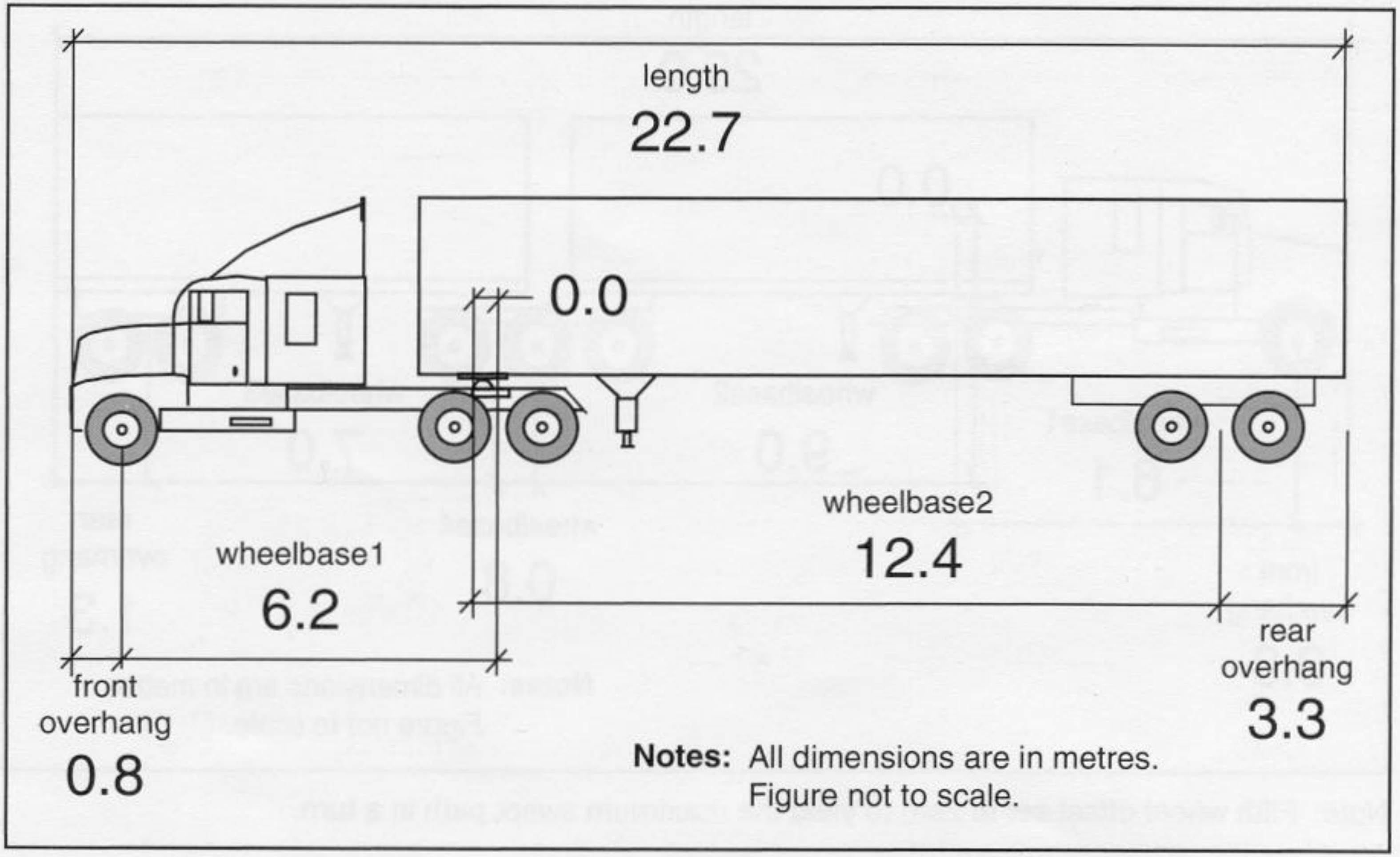
Truck Type	Degree of Turn	Minimum Turning Radius (m) Centre of Axle	Minimum Turning Radius (m) Outside Front Wheel
WB-19	90	9.6	10.7
	180	12.8	14.0
WB-20	90	9.6	10.7
	180	13.1	14.3
A-train	90	9.6	10.7
	180	11.2	12.3
B-train	90	9.6	10.7
	180	12.5	13.6

Note: Data from this table should be used to develop the swept path of the design vehicle, for use in geometric design.

TAC (1999)

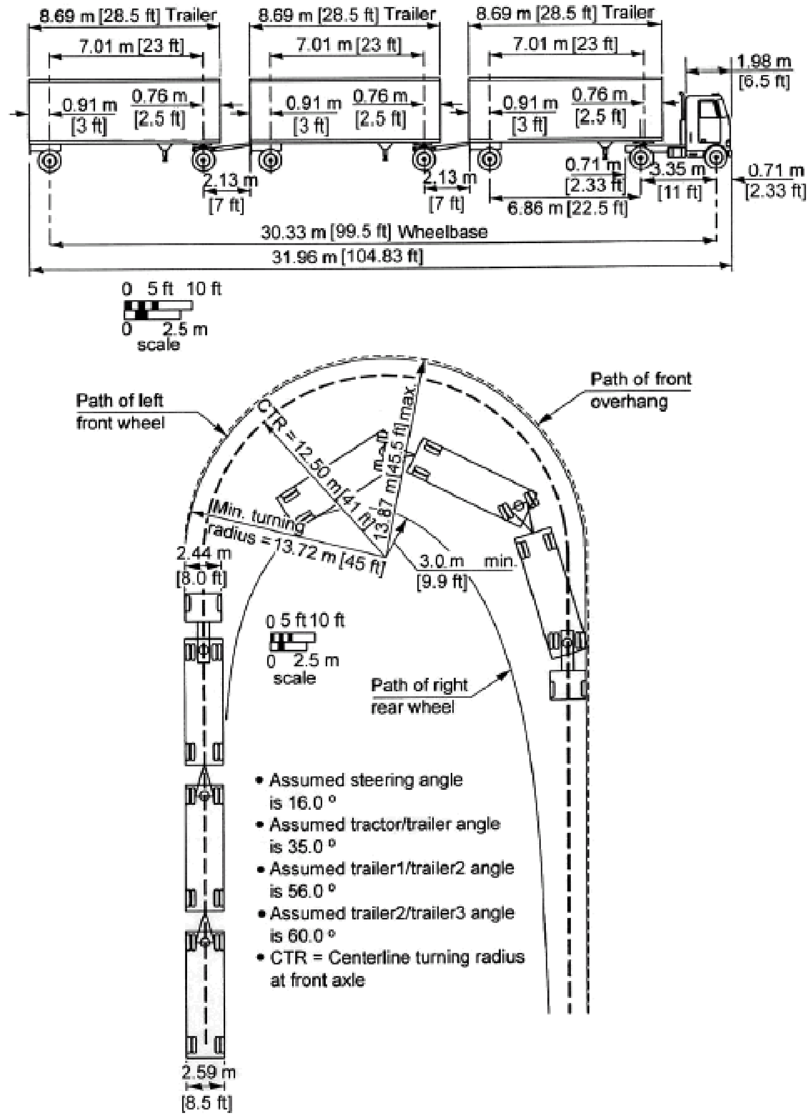
Commercial Vehicle Characteristics

Figure 1.2.4.6 WB-20 Tractor-Semitrailer Dimensions



Note: Fifth wheel offset set to zero to yield the maximum swept path in a turn.

(1999)



AASHTO (2004)

Exhibit 2-18. Minimum Turning Path for Triple-Trailer Combination (WB-30T [WB-100T]) Design Vehicle

Bus Characteristics

Table 1.2.4.3 Design Dimensions for Buses

	Single-Unit Buses	Articulated Buses	Intercity Buses
Length (m)	12.2	18.3	14.0
Front Overhang (m)	2.2	3.2	1.8
Rear Overhang (m)	2.8	3.0	4.0
WB1 (m)	7.2	5.5	8.2
S[1] (m)	-	1.8	-
T[2] (m)	-	4.8	-
Minimum Turning Radius (m)	12.9	13.1	13.9
Width (m)	2.4	2.4	2.4

[1] Distance from the rear effective axle to the hitch point.
[2] Distance from the hitch point to the lead effective axle of the following unit.

TAC (1999)

Vehicle Characteristics

General guidelines for selecting a design vehicle:

- The largest vehicle that is likely to use the facility with considerable frequency
- passenger car: parking lot or series of parking lots.
- A single-unit truck : intersection design of residential streets and park roads (to accommodate moving, shopping delivery, house maintenance needs etc.)
- A city transit bus : state highway intersections with city streets that are designated bus routes and that have relatively few large trucks using them
- Depending on expected usage, a large school bus (84 passengers) or a conventional school bus (65 passengers) : intersections of highways with low-volume county highways and local roads under 400 ADT (Annual Daily Traffic. The school bus may also be appropriate for the design of some subdivision street intersections)
- The WB-20 [WB-65 or 67] truck SHOULD generally be the minimum size design vehicle considered for intersection of freeway ramp terminals with arterial crossroads and for other intersections on state highways and industrialized streets that carry high volumes of traffic and/or that provide local access for large trucks.

Braking Distance

Σ Forces $= m\ a$

$$W \sin\alpha - f\ W \cos\alpha = m\ a = \frac{W}{g}\ a$$

$$\because v_f^2 = v_0^2 + 2\ a\ D$$

$$\therefore a = \frac{v_f^2 - v_0^2}{2\ D}$$

Combining the two equations:

$$\tan\alpha - f = \frac{v_f^2 - v_0^2}{2\ g\ D \cos\alpha}$$

tan $\alpha \cong \alpha \cong G$ (grade) & cos $\alpha \cong 1.0$

$$\therefore G - f = \frac{v_f^2 - v_0^2}{2\ g\ D}$$

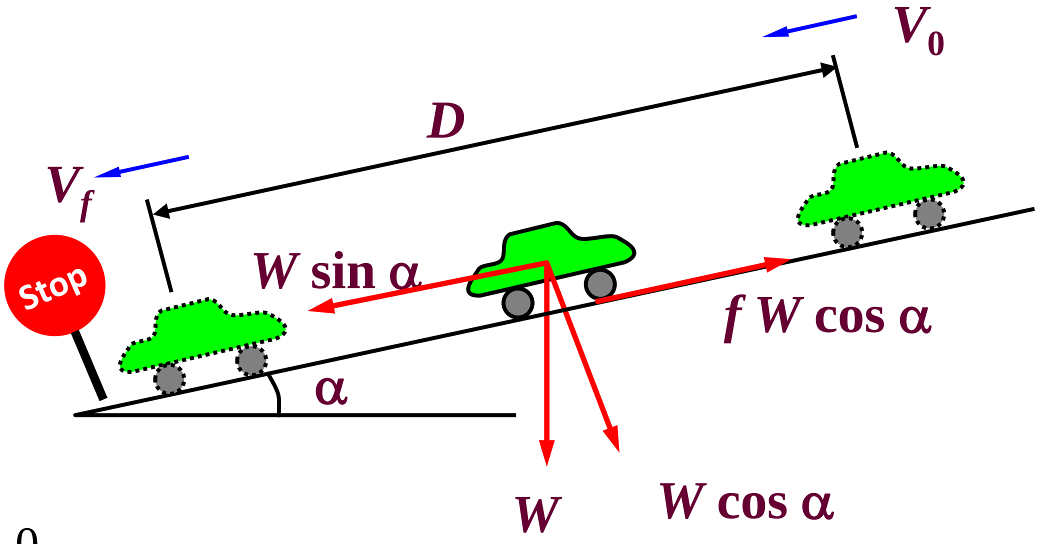
Or:

$$D = \frac{v_0^2 - v_f^2}{2\ g\ (f - G)}$$

[downward slope]

For upward slope:

$$D = \frac{v_0^2 - v_f^2}{2\ g\ (f + G)}$$



- For g = 9.81 m/s^2 and converting v (m/s) into V (km/h):

$$D = \frac{V_0^2 - V_f^2}{255(f \pm G)}$$

- For complete stopping: $V_f = 0$

$$D = \frac{V^2}{255(f \pm G)}$$

- Example:

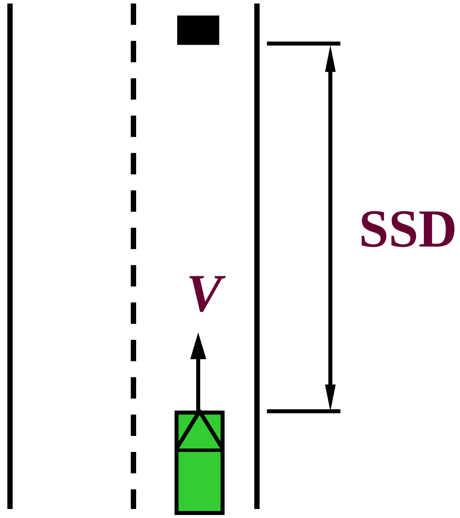
  A student, trying to test the braking ability of his car, determined that he needed 32 ft more to stop his car when driving downhill on a particular road than when driving uphill at 55 mph. Determine the braking distance downhill and the percent grade of the highway at that section of the road ($f = 0.3$)

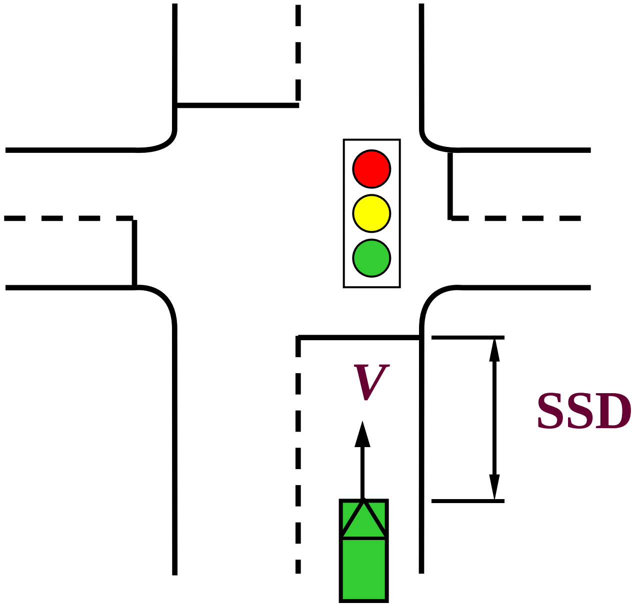
Road Characteristics: SIGHT DISTANCE

– Sight distance is the most important road characteristic affecting highway geometric design

1. Stopping Sight Distance (SSD)

– The minimum sight distance required for a below-average driver to stop before hitting an unexpected object on the road ahead





1. Stopping Sight Distance (SSD)

– SSD = PIEV Distance + Braking Distance

$$\text{SSD} = 0.278\,P\,V + \frac{V^2}{254\,(f \pm G)}$$

P = PIEV time (s)

V = design speed (km/h)

f = coefficient of longitudinal friction

G = longitudinal grade (decimal fraction) (-ve $\rightarrow$ downhill & +ve $\rightarrow$ uphill)

- Example:

If the design speed of a highway is 120 km/h, what is the minimum SSD that should be provided on the road for (a) a flat road and (b) 5% maximum grade?

Table 1.2.5.3 Stopping Sight Distance for Automobiles[4] and Trucks with Antilock Braking Systems[8]

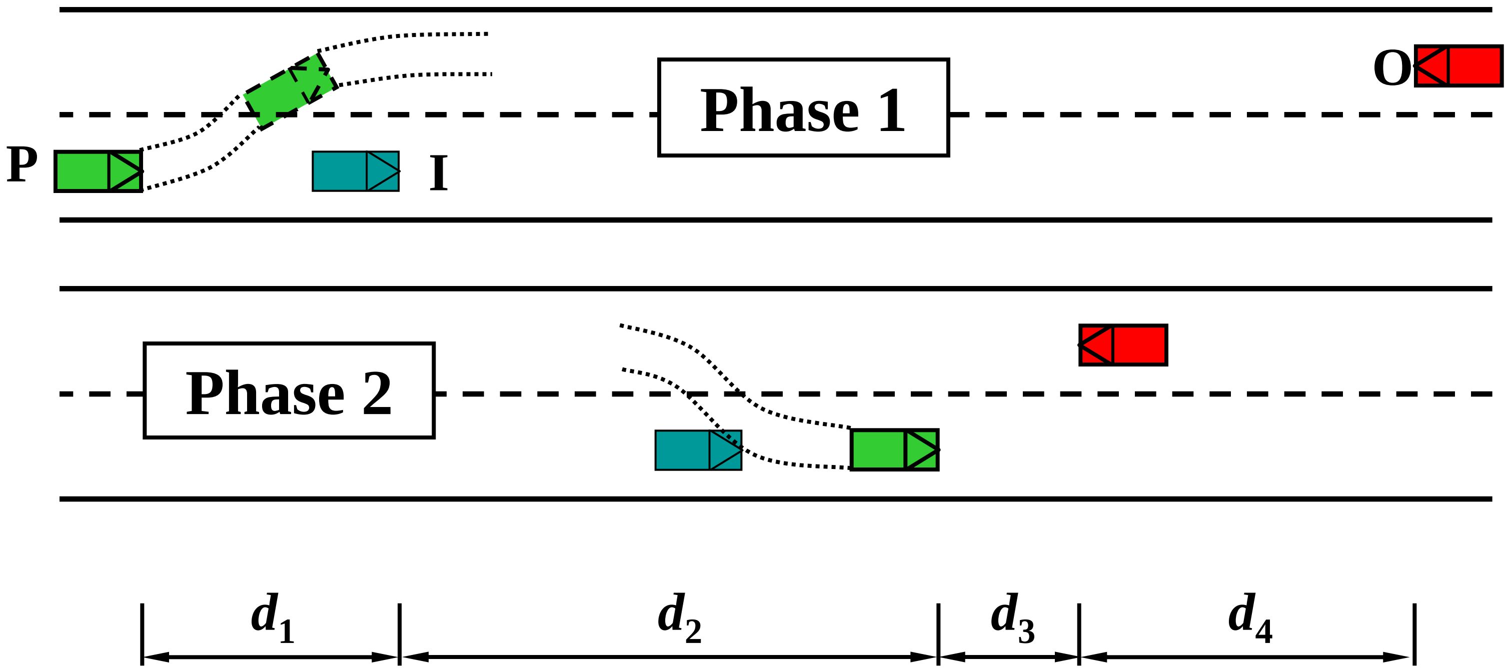
Design Speed (km/h)	Assumed Operating Speed* (km/h)	Perception and Reaction time (s)	Perception and Reaction distance (m)	Coefficient of Friction	Braking Distance (m)	Stopping Sight Distance (rounded) (m)
40	40	2.5	27.8	0.38	16.6	45
50	47 - 50	2.5	32.7 - 34.7	0.35	24.8 - 28.1	60 - 65
60	55 - 60	2.5	38.2 - 41.7	0.33	36.1 - 42.9	75 - 85
70	63 - 70	2.5	43.7 - 48.6	0.31	50.4 - 62.2	95 - 110
80	70 - 80	2.5	48.6 - 55.5	0.30	64.2 - 83.9	115 - 140
90	77 - 90	2.5	53.5 - 62.5	0.30	77.7 - 106.2	130 - 170
100	85 - 100	2.5	59.0 - 69.4	0.29	98.0 - 135.6	160 - 210
110	91 - 110	2.5	63.2 - 76.4	0.28	116.3 - 170.0	180 - 250
120	98 - 120	2.5	68.0 - 83.3	0.28	134.9 - 202.3	200 - 290
130	105-130	2.5	72.9 - 90.3	0.28	155.0 - 237.6	230 - 330

Note: * Range of assumed operating speed is from average running speed for low-volume conditions to design speed.

TAC (1999)

2. Passing Sight Distance (PSD)

– The distance required by an overtaking vehicle on a two-lane, two-way highway to pullout, pass, and return to the driving lane
– Percentage of length with enough PSD is a measure of quality of two-lane highways



2. Passing Sight Distance (PSD)

- Assumptions for calculating PSD:
  - V_I (impeder) = $V - m$ ($m \cong 17$ km/h)
  - V_P (passer) = $V - m$ (initially) & accelerates to V
    - Time elapsed = t_1 (time of initial manoeuvre)
    - Distance traveled = d_1 (initial manoeuvring distance)

$$d_1 = 0.278\, t_1 \left[(V - m) + \frac{a\, t_1}{2} \right]$$

      » t_1 = 3.5 - 4.5 sec
      » a = average acceleration = 2.5 – 2.65 km/h/sec
  - Time elapsed while occupying left lane = t_2
    - Distance traveled = d_2

    $\boldsymbol{d_2 = 0.278\, V\, t_2}$
  - Clearance distance between passing and opposing vehicles at the end of the pass = d_3 = 30 – 90 m
  - Distance traveled by the opposing vehicle = d_4
    - $V_o = V$ & $t_4 = ⅔\, t_2$

    $\boldsymbol{d_4 = ⅔\, d_2}$

- PSD = $d_1 + d_2 + d_3 + d_4$

2. Passing Sight Distance (PSD)

- Example:

  A driver traveling on a two-lane highway behind another car travelling at 60 km/h observes on the opposing direction a vehicle at a distance about 300 m. Can the driver overtake the car in front of him?

  - Speed limit = 80 km/h
  - Initial manoeuvring time = 4 sec
  - Average acceleration = 2.5 km/h/sec
  - Clearance distance = 50 m
  - Overtaking time = 10 sec

2. Passing Sight Distance (PSD)

Table 4.4: Minimum passing sight distance for design of 2-lane highways (Level Grade)

Design Speed, kph	50	65	80	100	115	130
Assumed Passing Speed, kph	60	71	82	95	105	112
Minimum Passing Sight Distance:	332	451	561	652	759	835
Rounded	330	450	560	655	760	835

2. Passing Sight Distance (PSD)

Terrain	Minimum Percent Passing Sight Distance	
	Collectors	Local
Level	50%	40%
Rolling	30%	20%

GUIDELINES FOR PERCENT PASSING DISTANCE
(Rural)

3. Decision Sight Distance (DSD)

- SSD is enough only in simple situations
- In complex situations (information is difficult to perceive or decision is complex), a longer sight distance may be required
- DSD is "the distance required for a driver to detect an information source or hazard which is difficult to perceive in a roadway environment that might be visually cluttered, recognize the hazard or threat potential, select appropriate action, and complete the manoeuvre safely and efficiently" (TAC 1999)
- Should be evaluated on a single-situation-basis

3. Decision Sight Distance (DSD)

- "Designers should use decision sight distance whenever information may be perceived incorrectly, decisions are required or where control actions are required. Some examples of where it could be desirable to provide decision sight distance are:
  - complex interchanges and intersections
  - locations where unusual or unexpected manoeuvres occur
  - locations where significant changes to the roadway cross section are made
  - areas where there are multiple demands on the driver's decision making capabilities from: road elements, traffic control devices, advertising, traffic, etc.
  - construction zones."

Table 1.2.5.6 Decision Sight Distance[4]

Design Speed (km/h)	Decision Sight Distance for Avoidance Manoeuvre (m)				
	A	B	C	D	E
50	75	160	145	160	200
60	95	205	175	205	235
70	125	250	200	240	275
80	155	300	230	275	315
90	185	360	275	320	360
100	225	415	315	365	405
110	265	455	335	390	435
120+	305	505	375	415	470

Notes:
- Avoidance Manoeuvre A: stop on rural roadway.
- Avoidance Manoeuvre B: stop on urban roadway.
- Avoidance Manoeuvre C: speed/path/direction change on rural roadway.
- Avoidance Manoeuvre D: speed/path/direction change on suburban roadway.
- Avoidance Manoeuvre E: speed/path/direction change on urban roadway.