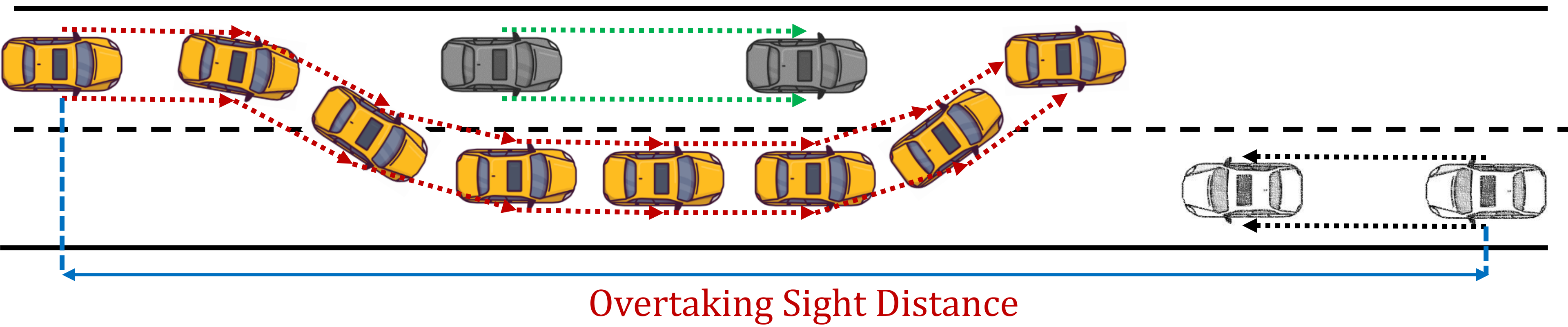
Overtaking Sight Distance



Note: Some photos are taken from internet for illustrative and educational purposes only

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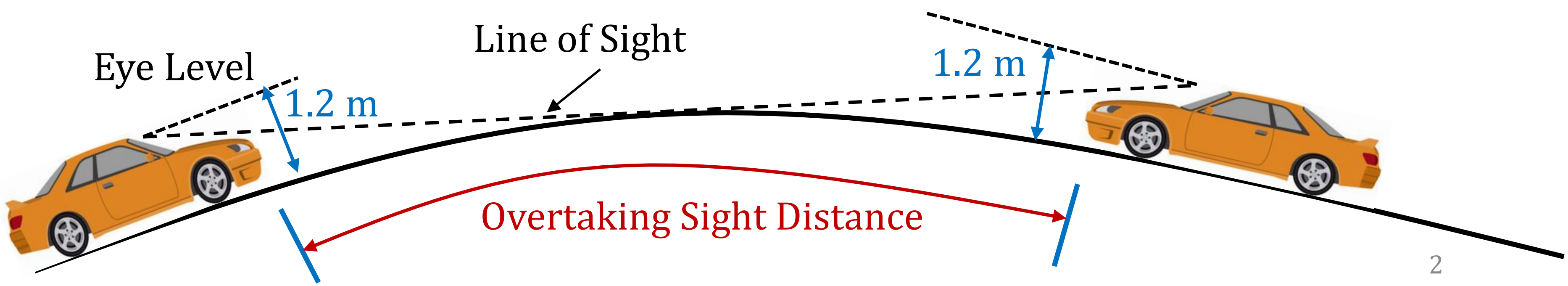
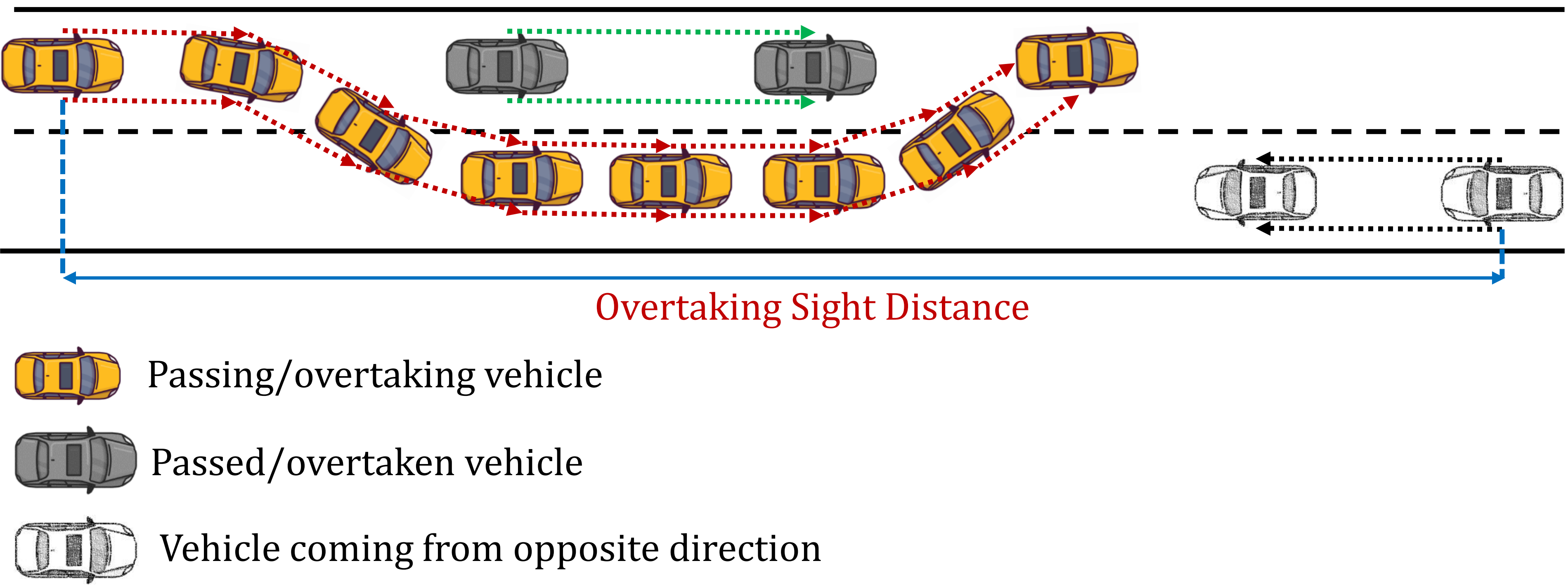
Overtaking/Passing Sight Distance

- If all the vehicles travel at the same speed, there is no need for providing Overtaking Sight distance (OSD)
- However, different vehicles as well as different drivers, travel with different speeds, and therefore, it is necessary to provide OSD. OSD is provided so that vehicles travelling at the design speed can safely overtake slow-moving vehicles without collision with the vehicle coming from the opposite end
- Definition: It is the minimum distance open to the vision of the driver of a vehicle intending to overtake a slow-moving vehicle ahead with safety against the traffic of the opposite direction.
- The OSD is also known as Passing Sight Distance (AASHTO Green Book)
- It is the distance measured along the centre of the road which a driver with his eye level at 1.2 m above the road surface can see the top of an object 1.2 m (basically eye level of another passenger car) above the road surface.



Overtaking/Passing Sight Distance

- Conceptual Diagram



- The yellow car (overtaking car) wants to overtake the grey car (overtaken car) without colliding with the white car coming from the opposite direction.
- The sight distance needed for doing this maneuver safely is called overtaking sight distance (OSD) or Passing sight distance(PSD).
- Can you outline the factors affecting the OSD??

Overtaking/Passing Sight Distance

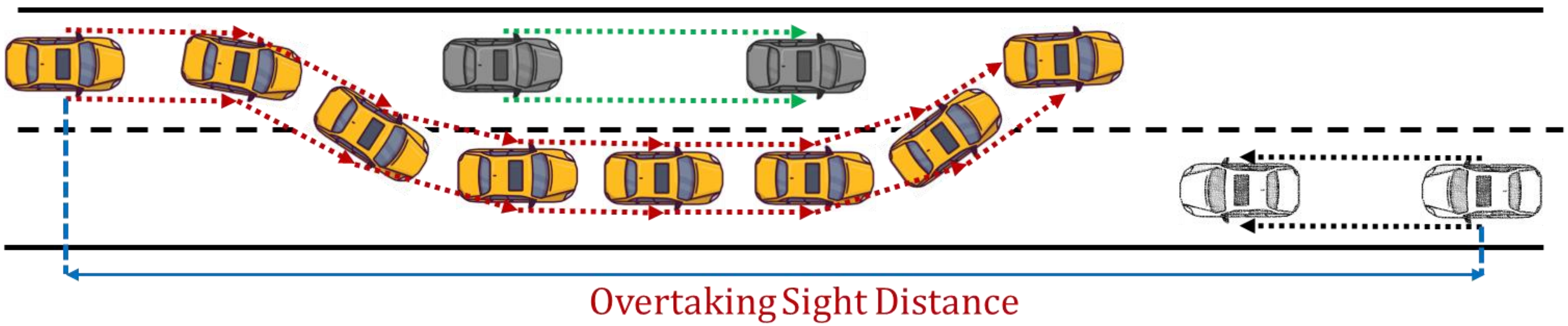
❖ Factors affecting the overtaking sight distance

- Speed of all the vehicles (overtaking, overtaken, and vehicle coming from opposite end)
- Distance between the vehicles; this also depends on the speed
- Skills and reaction time of the driver
- Rate of acceleration of overtaking vehicle
- Gradation of the road (higher requirement)

❖ Lets derive the expression for OSD

Overtaking/Passing Sight Distance

❖ Deriving expression for OSD



➢ There are three methods for deriving the OSD/PSD

- AASHTO Method for PSD
- Glennon Model for PSD
- IRC Method for OSD

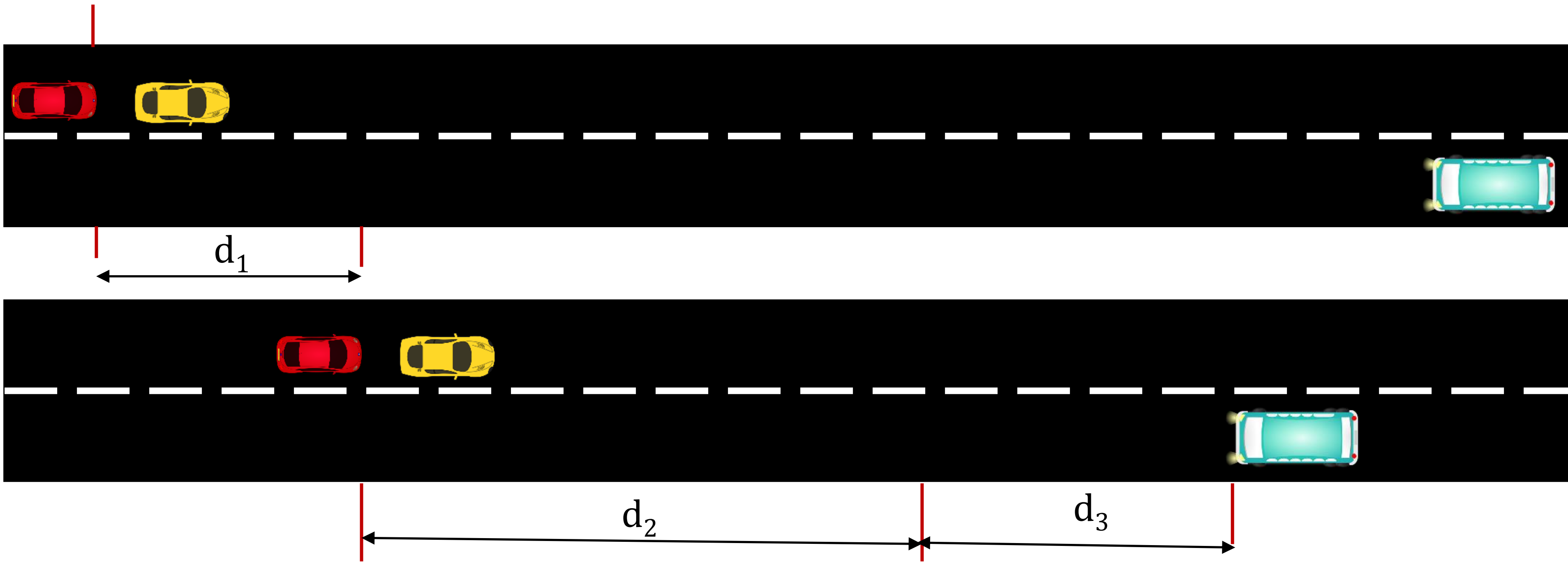
- Let's discuss these methods

Overtaking Sight Distance

❖ Indian Roads Congress Method

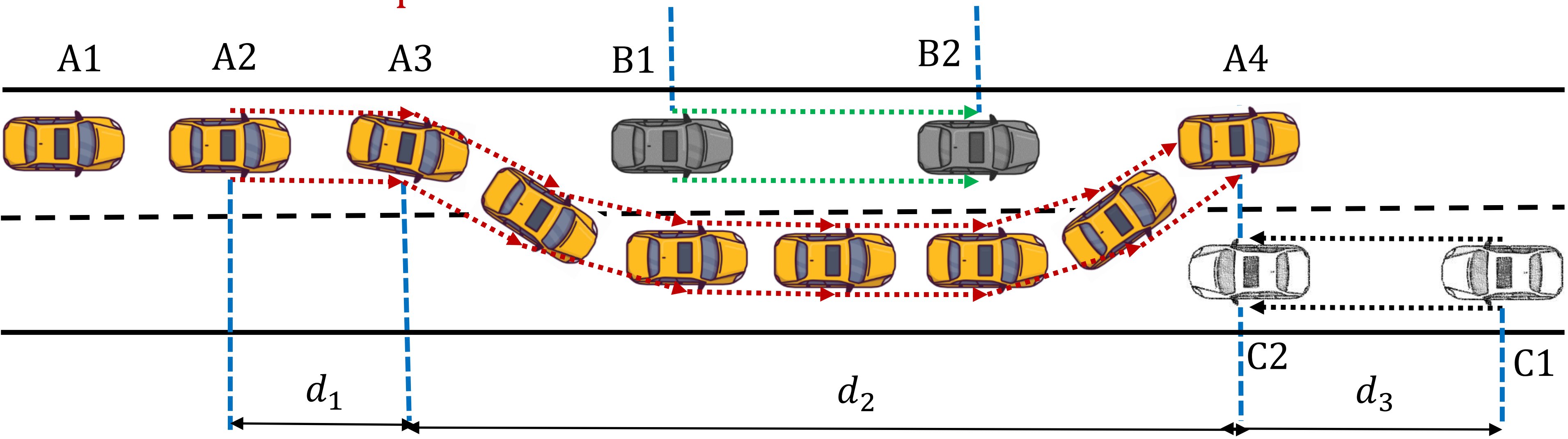
➢ The OSD can be split in three distances:

- d_1 = Distance travelled by overtaking vehicle during the reaction time of driver from the moment he realizes that he can overtake the vehicle safely
- d_2 = Distance travelled by the overtaking vehicle during the actual overtaking (i.e. accelerating the speed, going to opposite lane, crossing the overtaken vehicle and coming back the the left lane)
- d_3 = Distance travelled by the vehicle coming from opposite direction



Overtaking Sight Distance: IRC Method

❖ Lets derive the expression for OSD



Location: A1 to A2

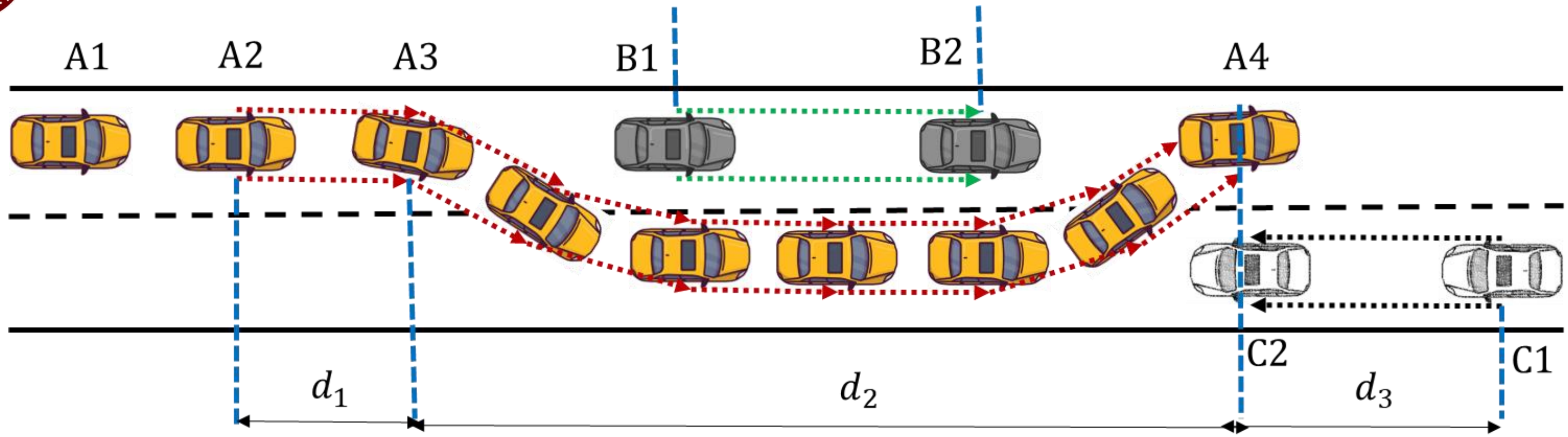
- The overtaking vehicle is forced to reduce its speed from the design speed (v m/sec) to v_b (m/sec) of the slow vehicle and move behind it, maintaining a clear spacing of s metres till there is an opportunity for safe overtaking operation. This distance will not be included in the OSD since no overtaking is done

Location: A2 to A3

- The driver finds an opportunity to overtake. During this perception-reaction time (t), the driver travels some distance with the reduced speed only i.e. v_b (m/sec) before giving any acceleration – distance covered is d_1

$$\boxed{d_1(m) = v_b\, t}$$

Overtaking Sight Distance: IRC Method

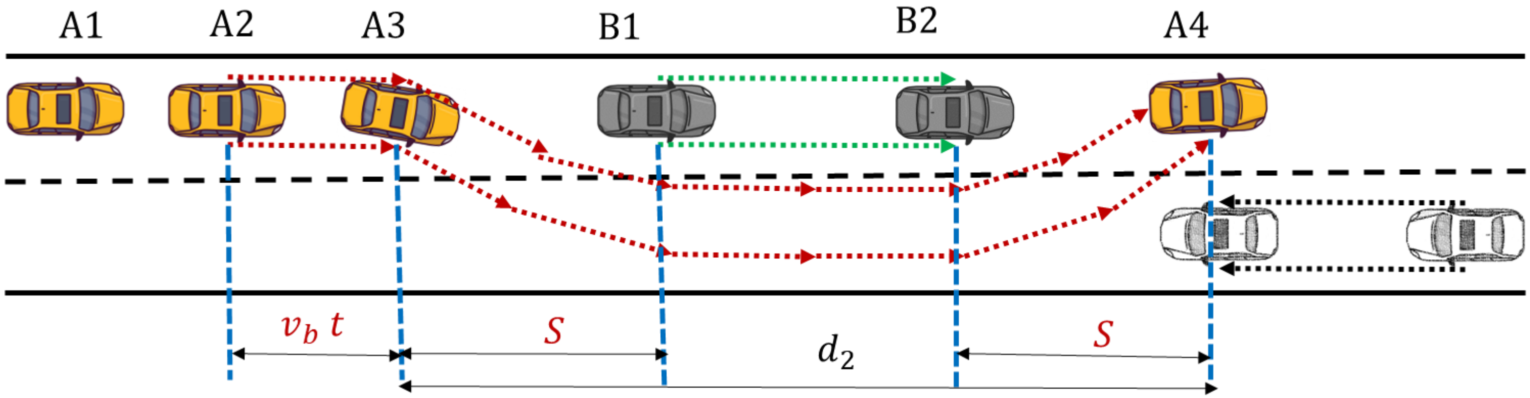


Location: A2 to A3 continue

$$\boxed{d_1(m) = v_b\, t}$$

- Since the aim of the driver is only to find an opportunity to overtake, the reaction time t can be assumed to be 2 sec (for SSD, t was 2.5 seconds) i.e. $t = 2$ seconds
- As per IRC, the average speed of the overtaken vehicle is 4.5 m/sec or 16 kmph lower than the design speed of the highway i.e. $v_b = (V - 4.5)\ m/\sec$ or $(V - 16)\ kmph$ where V is the design speed of the highway

Overtaking Sight Distance: IRC Method



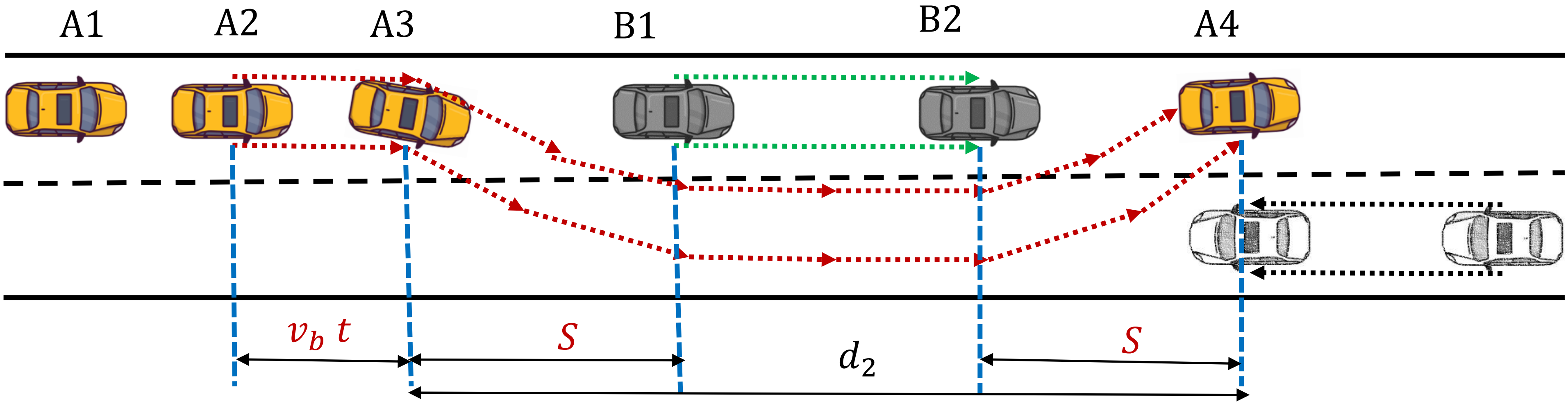
Location: A3 to A4

- The vehicle starts accelerating, shifts to the adjoining lane, overtakes the slow-moving vehicle, and shifts back to the left lane while maintaining a clear spacing of S meteres with the overtaken vehicle. This maneuver is carried out in a time duration of T seconds and the distance travelled is d_2 metres.
- The overtaking vehicle has to keep a clear spacing from the overtaken vehicle both before and after the overtaking maneuver. i.e. $2S$

Location: B1 to B2

- During the T duration (i.e. overtaking maneuver), the slow-moving vehicle travels a distance maintaining a constant speed of v_b m/sec
- Distance (in metres) travelled by slow-moving vehicle $= v_b T$
- Therefore, the distance d_2 can be written as $v_b T + 2S$

Overtaking Sight Distance: IRC Method



Location: A3 to A4 and B1 to B2

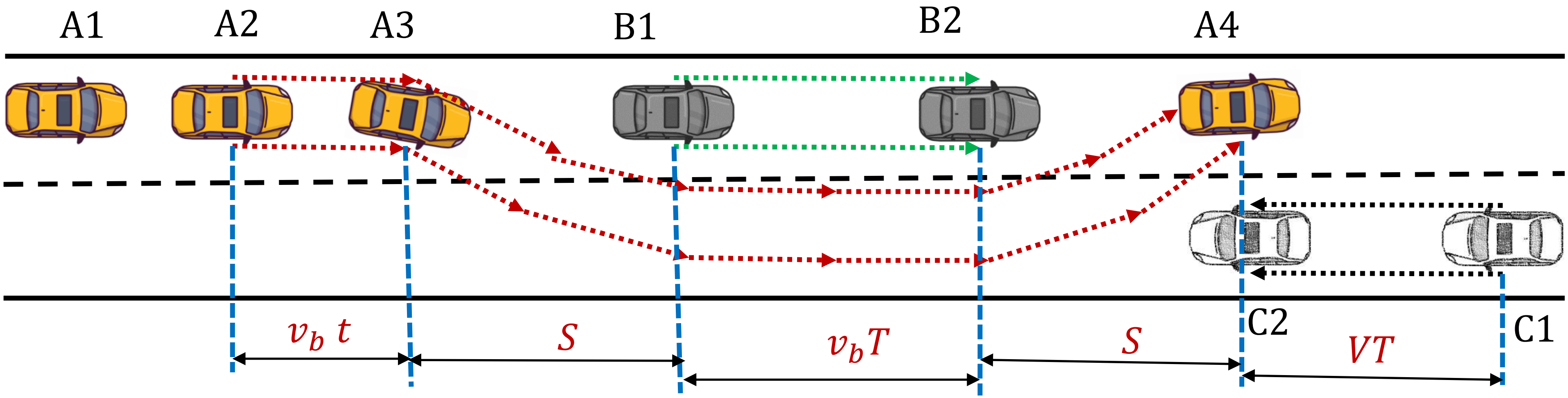
$$\boxed{d_2 = v_b T + 2S}$$

- As per IRC, the clear spacing between overtaking and overtaken vehicles depends on their speeds and can be computed using the empirical formula

$$\boxed{S = (0.7v_b + 6)}$$

Here S is in metres and 6 metres is the length of the vehicle

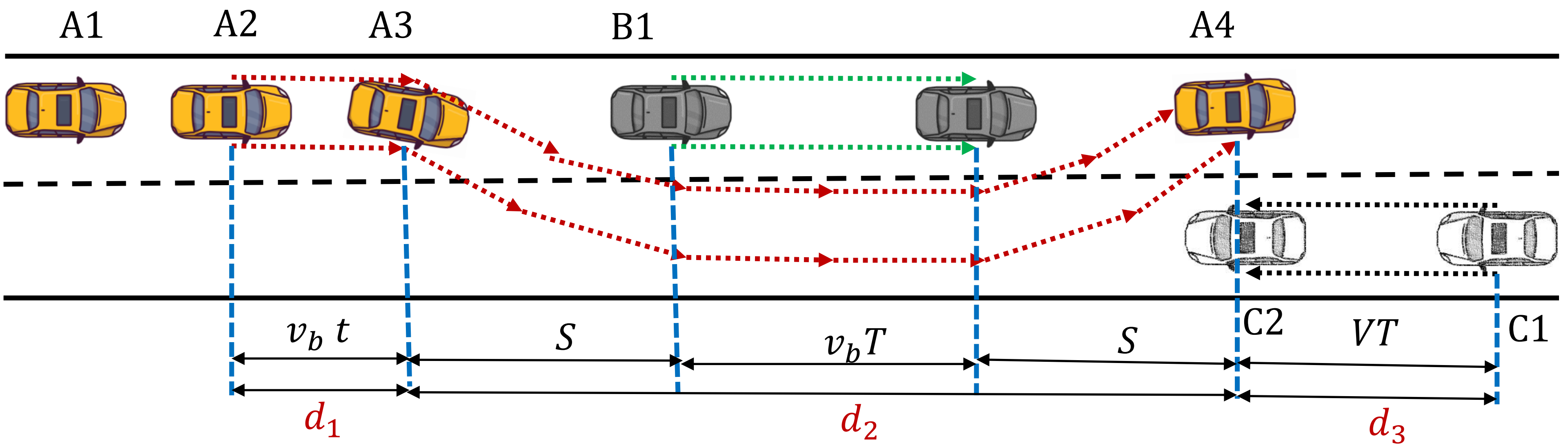
Overtaking Sight Distance: IRC Method



Location: C1 to C2

- During the T duration (i.e. overtaking maneuver), the vehicle coming from the opposite direction travels a distance with the design speed of V m/sec
- Distance (in metres) travelled by vehicle coming from opposite direction = VT

Overtaking Sight Distance: IRC Method



$$d_1 = v_b\ t \qquad d_2 = S + S + v_b T = 2S + v_b T \qquad d_3 = VT$$

$v_b = (V - 4.5/16)$

$t = 2$ seconds

$$S = (0.7 v_b + 6)$$

- The only unknown is T
- Let us derive an expression for T

Overtaking Sight Distance: IRC Method

❖ Expression for T

- We know that in T seconds, the overtaking vehicle accelerates with an acceleration of $a\ m/s^2$ and covers a distance of d_2 metres
- From law of motion

$$S = ut + \frac{1}{2}at^2$$

Where:

- $S =$ distance travelled; in our case it is d_2 metres
- $u =$ initial speed of the vehicle before acceleration; in our case it is v_b m/sec
- $t =$ time taken to cover S distance; in our case it is T seconds
- $a =$ acceleration rate; in our case it is $a\ m/s^2$

➢ Therefore, in our case (replacing with our abbreviations)

$$d_2 = v_b T + \frac{1}{2}aT^2$$

- We already know that

$$d_2 = 2S + v_b T$$

- Equating both

Overtaking Sight Distance: IRC Method

$$\cancel{v_b T} + \frac{1}{2} a T^2 = 2S + \cancel{v_b T}$$

$$\frac{1}{2} a T^2 = 2S$$

$$\boxed{T = \sqrt{\frac{4S}{a}}}$$

Where:

- $S = (0.7 v_b + 6)$
- a depends on the speed and can be predicted from the below table

Table: IRC recommendation for (maximum) acceleration rate values

Speed, kmph	25	30	40	50	65	80	100
$a, m/s^2$	1.41	1.30	1.24	1.11	0.92	0.72	0.53

Note: a shall be selected based on the speed of the overtaken vehicle as fast moving vehicle has to reduce its speed and then accelerate from the reduced speed

IRC Method Formula Sheet for OSD

$$\boxed{d_1 = v_b\, t}$$

- $v_b = (V - 4.5/16)$
- $t = 2$ seconds

Table: Design Speeds (V) on Rural Highways

Road Classification	Design Speed in kmph for various terrains							
	Plain		Rolling		Mountainous		Steep	
	Ruling	Min.	Ruling	Min.	Ruling	Min.	Ruling	Min.
Expressways	120	100	100	80	80	60	80	60
NH & SH	100	80	80	65	65	40	40	30
MDR	80	65	65	50	50	30	30	20
ODR	65	50	50	40	40	25	25	20
VR	50	40	40	35	25	20	25	20

$$\boxed{d_2 = 2S + v_b T}$$

- $S = (0.7 v_b + 6)$
- $T = \sqrt{\frac{4S}{a}}$

Table: Acceleration value (a)

Speed, kmph	25	30	40	50	65	80	100
$a, m/s^2$	1.41	1.30	1.24	1.11	0.92	0.72	0.53

$$\boxed{d_3 = VT}$$

Overtaking Sight Distance: IRC Method

❖ Some Important Points

❖ Effect of Gradient on OSD

➢ Ascending Gradients

- The OSD requirement increases (than level roads) due to reduced acceleration of the overtaking vehicle and increased speed of the vehicle coming from the opposite direction (for him, it will be deceleration and hence higher speed)

- However, in most cases, the overtaken vehicle is a heavily loaded truck which usually loses some speed on appreciable ascending gradients and many drivers are aware of the greater distances needed for overtaking; both these conditions compensate and thus the same OSD provided at the level roads could be provided at ascending mild gradients (upto ruling gradient for plain and rolling terrains)

- On descending gradients, it is easier for the overtaking vehicle to accelerate and pass; however, the overtaken vehicle may also accelerate and cover a greater distance. This compensates to some extent.

- However, at steeper gradients, the OSD shall be increased proportionally

Overtaking Sight Distance: IRC Method

❖ Overtaking Zones

- It is always desirable to have OSD at every point of the road. However, this is practically not possible and may significantly increase the cost of the project

- Efforts should be made to provide overtaking zones at frequent intervals for the vehicles travelling at the design speed

- In this case, sufficient information shall be given to the drivers about the overtaking zones by providing sign boards

- Two sign posts shall be provided at different distances

  - Signpost 1 (SP1): It indicates that overtaking zone is ahead and it must be placed at least OSD metres ahead of the overtaking zone
  - Signpost 2 (SP2): It indicates that the overtaking zone is over and it must be placed at least OSD metres ahead of the end of the overtaking zone

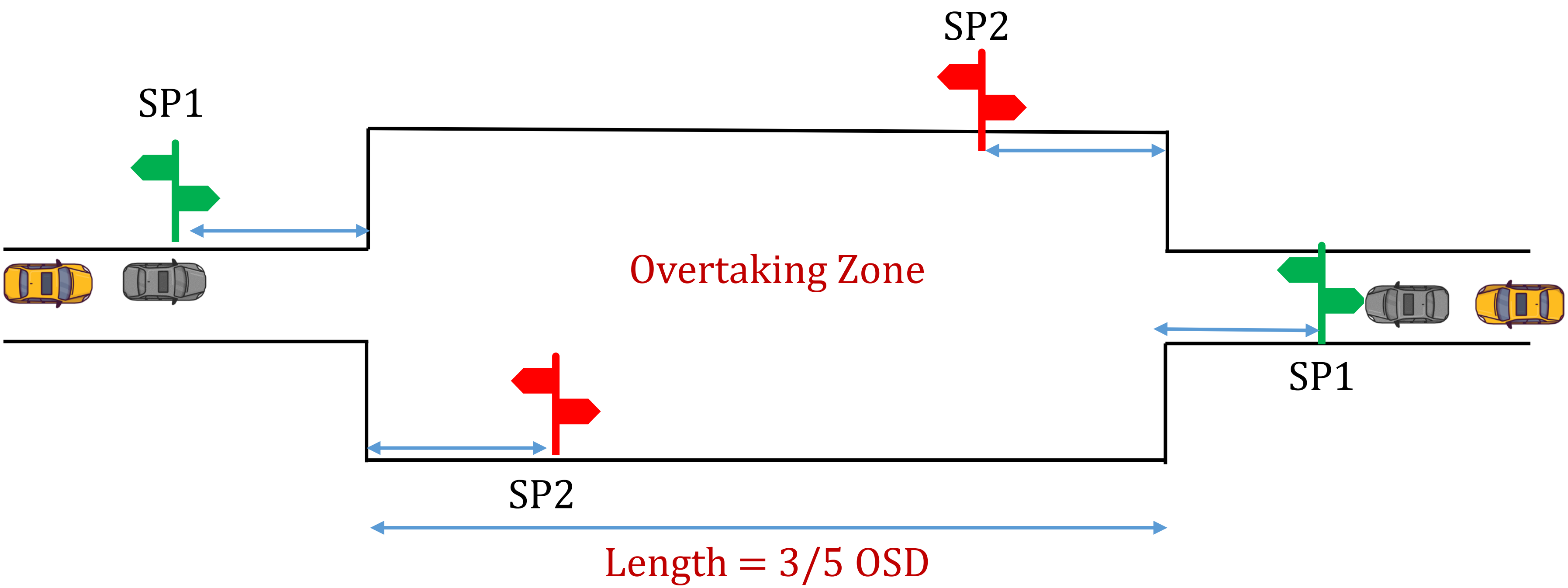
- Minimum length of the Overtaking Zone = $3 \times OSD$

- Desirable length of the Overtaking Zone = $5 \times OSD$

Overtaking Sight Distance: IRC Method

❖ Overtaking Zones

- OSD for undivided roads $= d_1 + d_2 + d_3$
- OSD for divided roads = NO need to provide OSD for divided roads as no vehicle is allowed to come from the opposite direction; however, need to make sure that SSD is always available



Overtaking Sight Distance: IRC Method

- SP1: Overtaking Zone Ahead
- SP2: Overtaking Zone END

https://www.drive.com.au/caradvice/caradvice-college-part-two-safe-overtaking-not-for-pubication/

India Mart

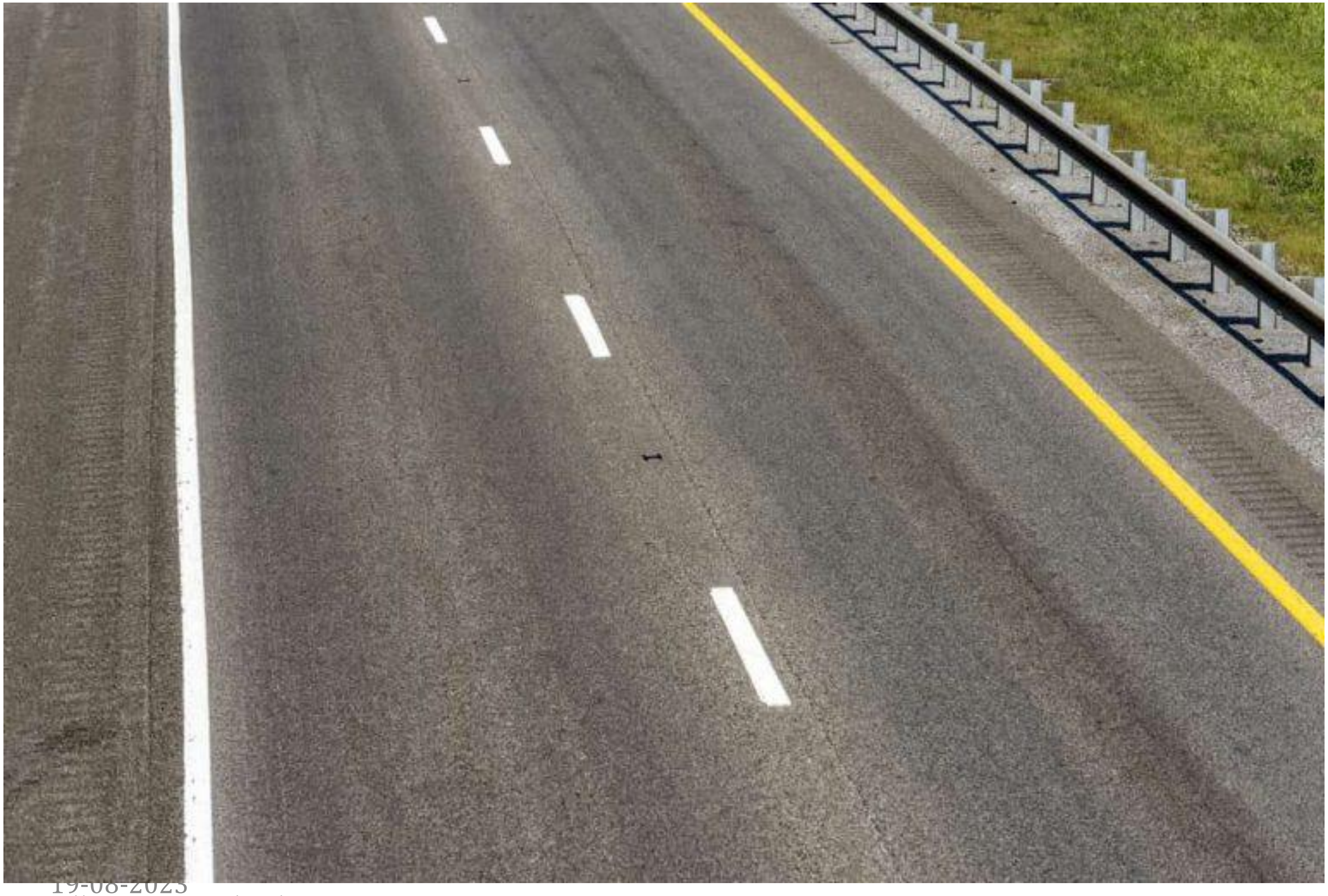
Overtaking Sight Distance: IRC Method

❖ Line Marking used to indicate overtaking

- Broken lines: Overtaking is permitted
- Solid/Continuous lines: Overtaking is NOT permitted
- Solid + Broken Lines: Overtaking is permitted from broken to solid and NOT vice versa
- Two solid lines: Passing this line is STRICTLY NOT permitted (usually used where potential for accidents is more)
- Yellow and White lines: White lines are used in the case where the travel is in the same direction; while, yellow is used for two-way traffic. Also, yellow color is used to increase the visibility of the road in the night time

❖ Line Marking used to indicate overtaking

- Broken lines: Overtaking is permitted



https://www.cars24.com/blog/types-of-roads-lane-system-in-india/#:~:text=Broken%20White%20Line%3A&text=A%20broken%20white%20line%20gives,to%20perform%20such%20a%20maneuver.

Overtaking Sight Distance: IRC Method

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Overtaking Sight Distance: IRC Method

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https://www.rac.co.uk/drive/advice/road-safety/uk-road-markings-what-they-mean-and-what-the-highway-code-says/

IRC Method: Class Activity

❖ On a 2 way-2 lane state highway, two vehicles are travelling at a speed of 70 kmph and 40 kmph, respectively. The fast-moving vehicle decided to overtake the slow vehicle and for doing so, the available sight distance was 300 m. Determine whether this maneuver can be made safely if another vehicle is coming from the opposite direction maintaining a speed of 80 kmph.

➢ Step 1: Choose the unknown parameters

- Speed of overtaking vehicle i.e. $v_a = 70$ kmph or $\frac{70}{3.6} = 19.45\ m/s$
- Speed of overtaken vehicle i.e. $v_b = 40$ kmph or $\frac{40}{3.6} = 11.42\ m/s$
- Speed of vehicle coming from opposite direction i.e. $v_c = 80$ kmph or $\frac{80}{3.6} = 22.23\ m/s$
- Assuming the reaction time of the driver as 2 seconds as per IRC i.e. $t = 2$ s
- Selecting acceleration rate for overtaking vehicle from IRC Table = ??

Table: Acceleration value (a)

Speed, kmph	25	30	40	50	65	80	100
$a,\ m/s^2$	1.41	1.30	1.24	1.11	0.92	0.72	0.53

- a shall be selected based on the reduced speed = $1.24\ m/s^2$

IRC Method: Class Activity

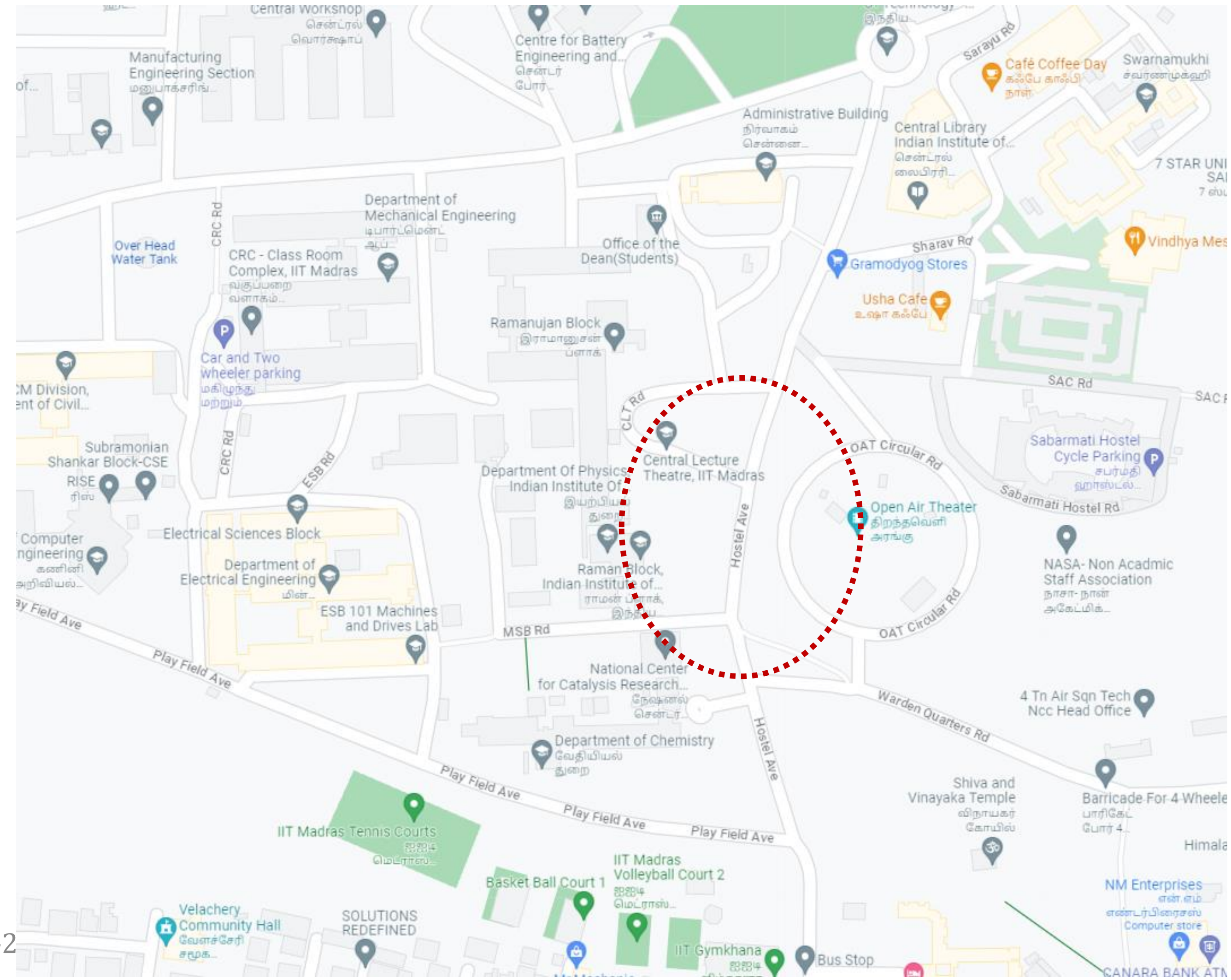
- Clear Spacing between overtaking and overtaken vehicle i.e. $S = ?$
- $S = (0.7v_b + 6) = (0.7 \times 11.42 + 6) = 13.994 \text{ m}$
- Time taken for overtaking maneuver i.e. $T = ?$
- $T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 13.994}{1.24}} = 6.72\ seconds$

➢ Step 2: Calculate the OSD

- $d_1 = v_b\, t = 11.42 \times 2 = 22.84 \text{ m}$
- $d_2 = 2S + v_b T = (2 \times 13.994) + (11.42 \times 6.72) = 104.73\ m$
- $d_3 = VT = 22.23 \times 6.72 = 149.39\ m$
- Minimum OSD required $= d_1 + d_2 + d_3 = 22.84 + 104.73 + 149.39 = 276.96\ m$
- Minimum OSD required (276.96 m) < Available Distance (300 m) and hence overtaking is possible

IRC Method: Class Activity

❖ It is not possible to overtake on Hostel Avenue road; therefore, it is proposed to provide an overtaking zone. Decide the location and design the overtaking zone facility assuming the missing data suitably.



IRC Method: Class Activity

➢ Step 1: Choose the Design parameters

- Tips: Roads inside the campus are urban roads…
- Hostel Avenue Road can be considered a collector street and the design speed as per IRC for collector streets is 50 kmph. However, due to National Park, the maximum speed is restricted to 30 kmph and around 98 percentile traffic travels at this speed.
- Speed of overtaking vehicle i.e. $v_a = 30$ kmph or $\frac{30}{3.6} = 8.34\ m/s$
- Speed of overtaken vehicle i.e. $v_b = ????$
- $v_b\ = (V - 4.5) = (8.34\ - 4.5) = 3.84\ m/s$
- Speed of vehicle coming from opposite direction i.e. $v_c = 8.34$ m/s (design speed only)
- Assuming the reaction time of the driver as 2 seconds as per IRC i.e. $t = 2$ s
- Selecting acceleration rate (a) for overtaking vehicle with reduced speed (we can assume the lowest speed or perform extrapolation)= $1.41\ m/s^2$

Table: Acceleration value (a)

Speed, kmph	25	30	40	50	65	80	100
$a, m/s^2$	1.41	1.30	1.24	1.11	0.92	0.72	0.53

IRC Method: Class Activity

- Clear Spacing between overtaking and overtaken vehicle i.e. $S = ?$
- $\mathrm{S} = (0.7\mathrm{v_b} + 6) = (0.7 \times 3.84 + 6) = 8.688\ \mathrm{m}$
- Time taken for overtaking maneuver i.e. $\mathrm{T} = ?$
- $T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 8.688}{1.41}} = 4.97\ seconds$

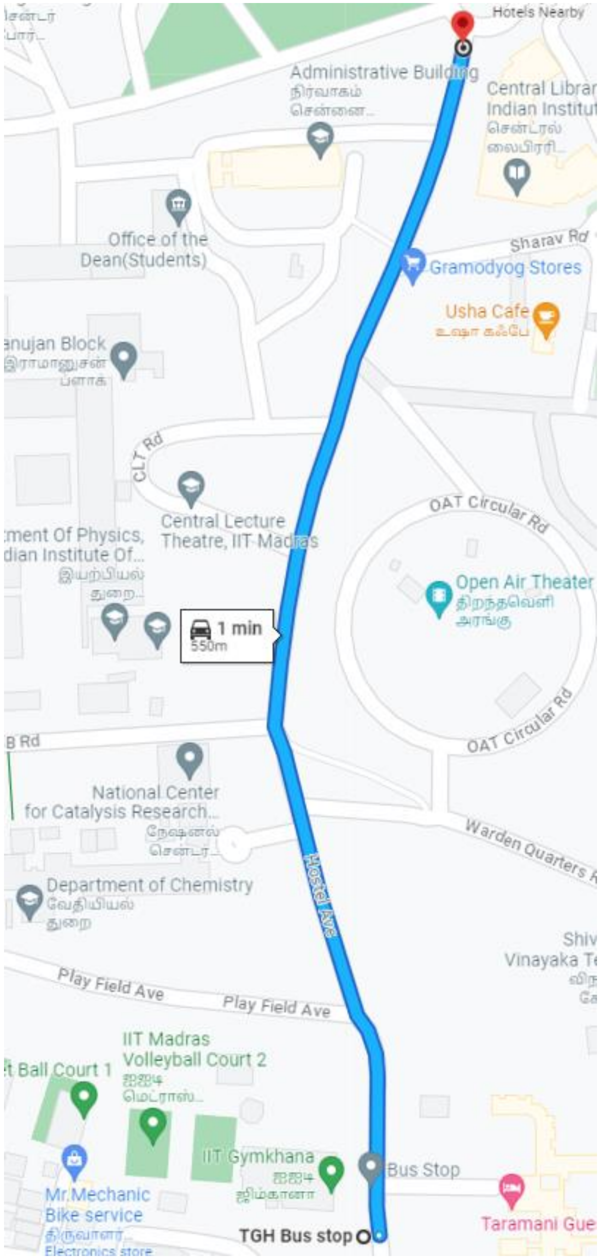
➢ Step 2: Calculate the OSD

- $d_1 = v_b\, t = 3.84 \times 2 = 7.68\ \mathrm{m}$
- $d_2 = 2S + v_b T = (2 \times 8.688) + (3.84 \times 4.97) = 36.46\ m$
- $d_3 = VT = 8.34 \times 5.17 = 43.118\ m$
- Minimum OSD required $= d_1 + d_2 + d_4 = 7.68 + 36.46 + 43.118 = 87.26\ or\ 90\ m$

➢ Step 3: Calculate minimum & desirable overtaking zones

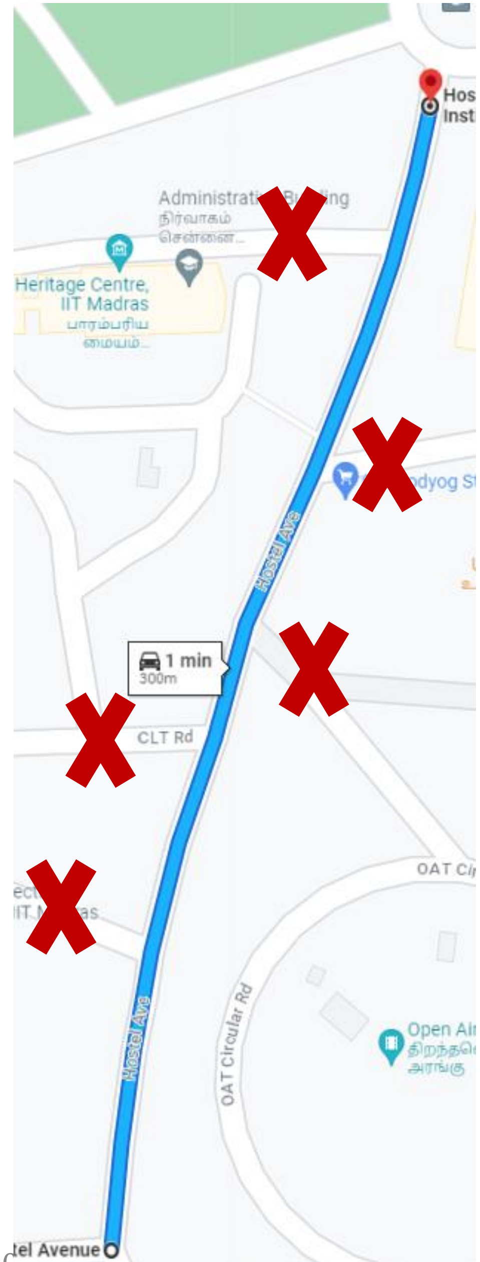
- Minimum length of the Overtaking Zone = $3 \times 90 = 270\ m$
- Desirable length of the Overtaking Zone = $5 \times 90 = 450\ m$

IRC Method: Class Activity



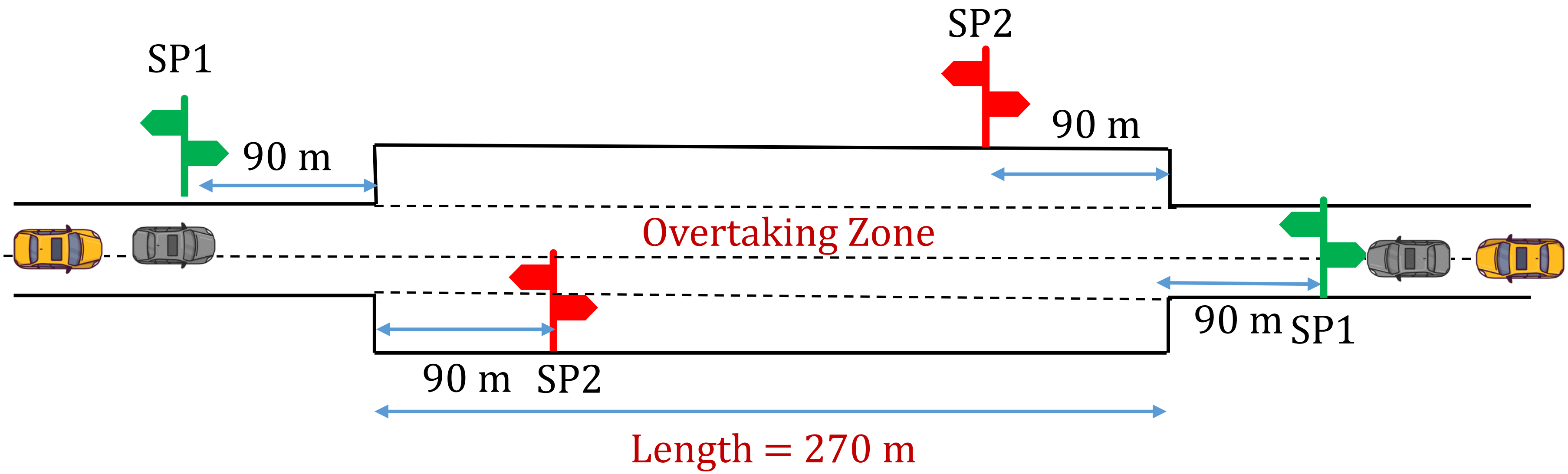
- The road length between Gajendra Circle and TGH Bus stop is 550 m. However, there are around 5 crossings/access points (library, OAT, central lecture theatre, playfield avenue, and MSB road). Therefore, it is not possible to provide the minimum overtaking zone of 270 m. Alternatively, some of the access points maybe closed and an overtaking zone can be provided.

IRC Method: Class Activity



- Controlling the access from the stated 5 locations, we have now 300 m length available for providing overtaking zone which is slightly higher than the minimum overtaking zone of 270 m.

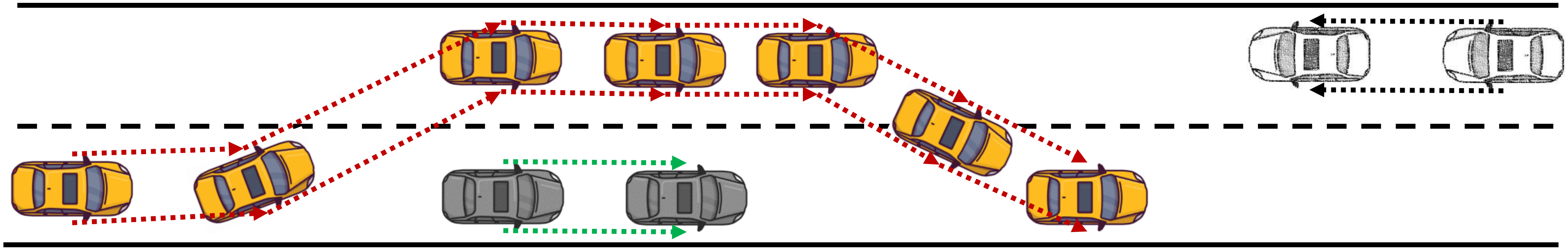
IRC Method: Class Activity



SP1 — Overtaking Zone ahead

SP2 — Overtaking Zone ENDS

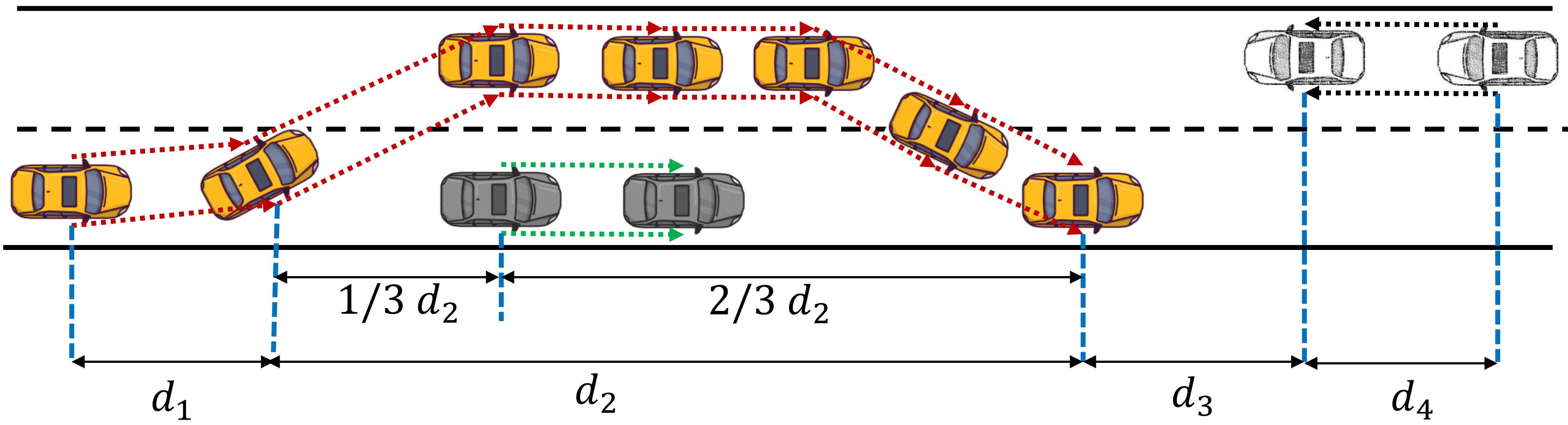
❖ AASHTO Method for PSD



- Assumptions made

1. The overtaken vehicle travels at a uniform speed.
2. The passing vehicle has reduced speed and trails the overtaken vehicle as it enters a passing or overtaking section.
3. When the passing section is reached, the passing driver needs a short period of time to perceive the clear passing section and to react to start his or her maneuver.
4. Passing is accomplished under what may be termed a delayed start and a hurried return in the face of opposing traffic. The passing vehicle accelerates during the maneuver, and its average speed during the occupancy of the left lane is 15 km/h higher than that of the overtaken vehicle.
5. When the passing vehicle returns to its lane, there is a suitable clearance length between it and an oncoming vehicle in the other lane

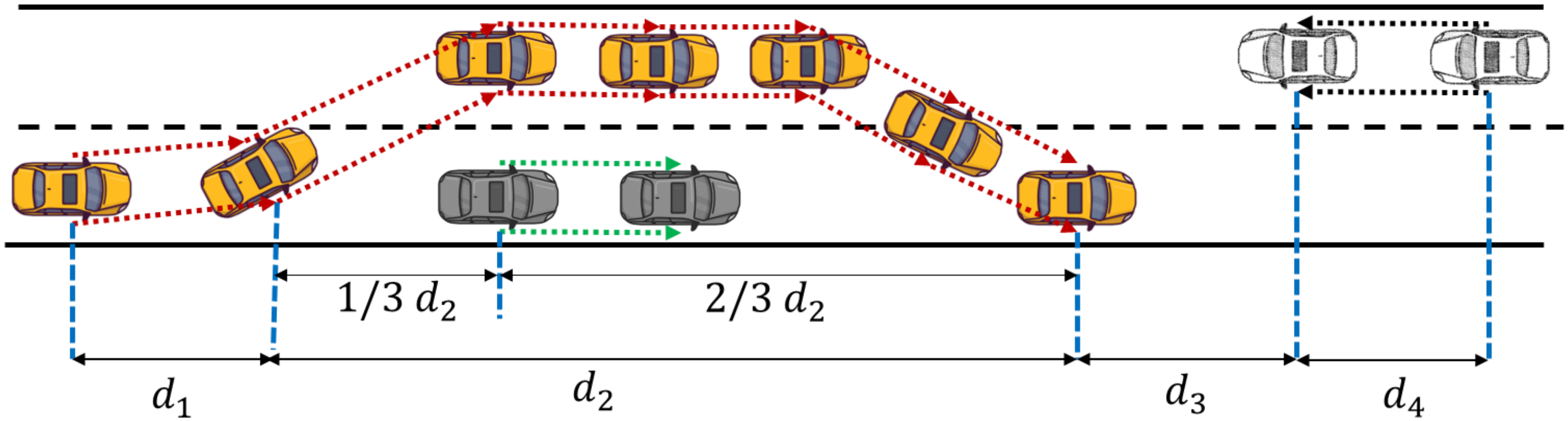
Overtaking/Passing Sight Distance: AASHTO

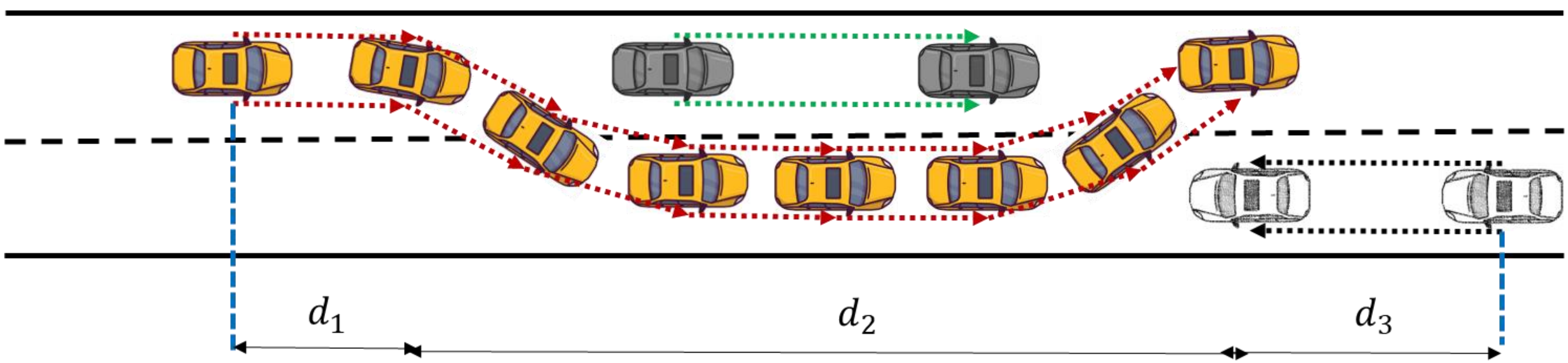


Overtaking Sight Distance (OSD) $= d_1 + d_2 + d_3 + d_4$

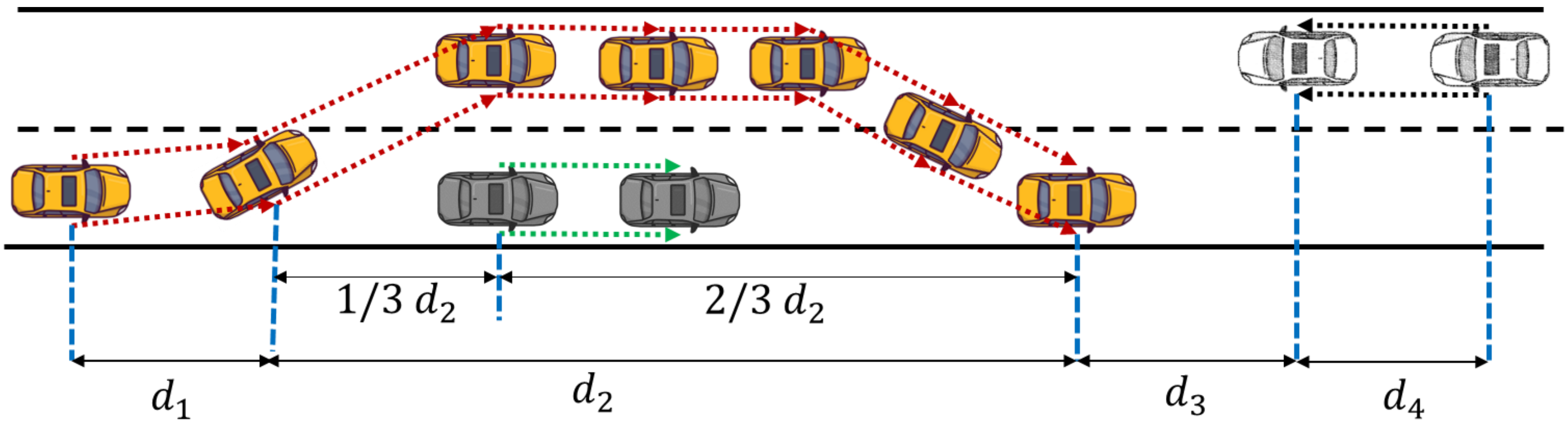
- d_1 = Distance traversed during perception and reaction time and during the initial acceleration to the point of encroachment on the left lane.
- d_2 = Distance travelled while the passing vehicle occupies the left lane
- d_3 = Distance between the passing vehicle at the end of its maneuver and the opposing vehicle.
- d_4 = distance travelled by the vehicle coming from the opposite direction

- Difference between IRC and AASHTO Method??





Overtaking/Passing Sight Distance: AAHSTO Method



- The basic principle of designing the overtaking zone or overtaking sight distance is almost the same to the IRC method with the following differences:

i. In the IRC, the initial distance (d_1) travelled was during the perception-reaction time only i.e. 2 seconds and no acceleration was made by the driver. However, as per AASHTO, there will be some acceleration made by the driver to move towards the centre line of the road; however, this initial acceleration is significantly lower than the maximum potential of the vehicle. Due to the inclusion of initial acceleration, the total duration is between 3.7-4.3 seconds, depending on the speed.

Overtaking/Passing Sight Distance: AAHSTO Method

$$d_1 = 0.278\, t_i \left(v - m + \frac{a t_i}{2}\right)$$

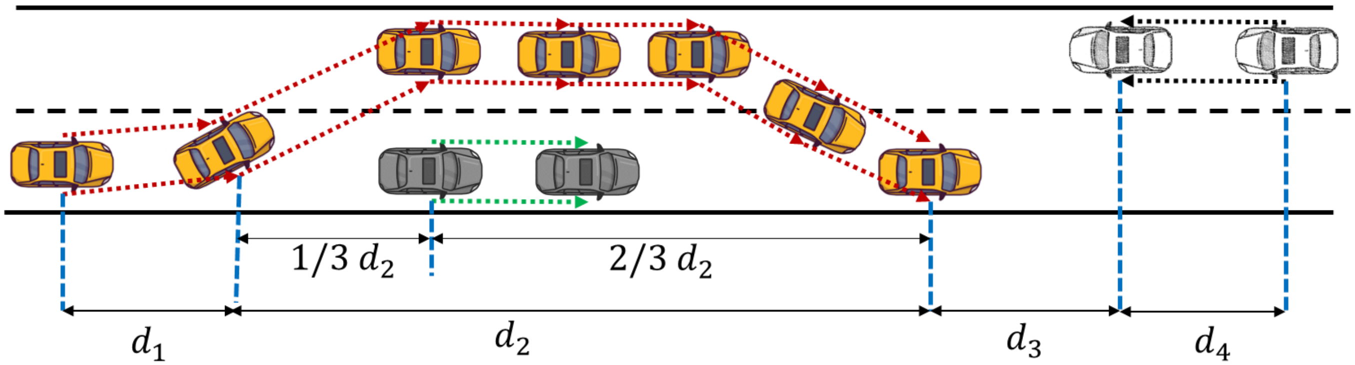
Where

- t_i – initial maneuver time (reaction time + during initial acceleration to reach the centre line of the road). This value is usually 3.7-4.3 seconds
- v – average speed of the overtaking vehicle in km/hr
- m – difference in speed between the overtaking and the overtaken vehicle in km/hr. This value is usually 15 km/hr
- a – average acceleration in km/hr.s. This value is usually between 2.25-2.37 km/hr/s

- If you recall, the IRC formula for d_1 $\quad d_1 = v_b\, t \text{ or } 0.278\, V\, t$

- AASHTO formula is also similar except the following:
  - initial acceleration $\frac{a t_i}{2}$ is added to the speed
  - Speed of the Overtaken vehicle is considered in Kmph and instead of considering the overtaken vehicle speed, they are mentioning $(V - m)$ which is nothing but the speed of the overtaken vehicle

Overtaking/Passing Sight Distance: AAHSTO Method



iii. As per AASHTO, d_2 is the distance travelled by the overtaking vehicle in the opposite lane which is given by

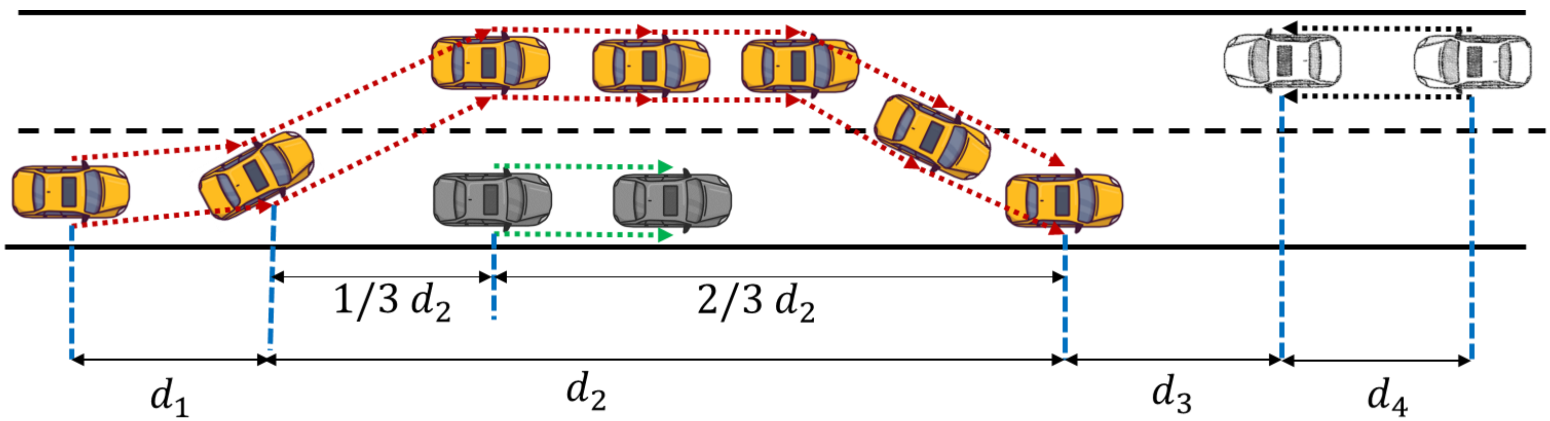
$$d_2 = 0.278 v t_2$$

Where

- t_2 – time spent by the overtaking vehicle in the opposite lane (9.3-10.4 secs)
- v – average speed of the overtaking vehicle in km/hr

- In IRC, d_2 was calculated by adding the distance travelled by the Overtaken vehicle and the spacing maintained by the Overtaking vehicle, before and after the overtaking maneuver (i.e. $v_b T + 2S$)

Overtaking/Passing Sight Distance: AAHSTO Method

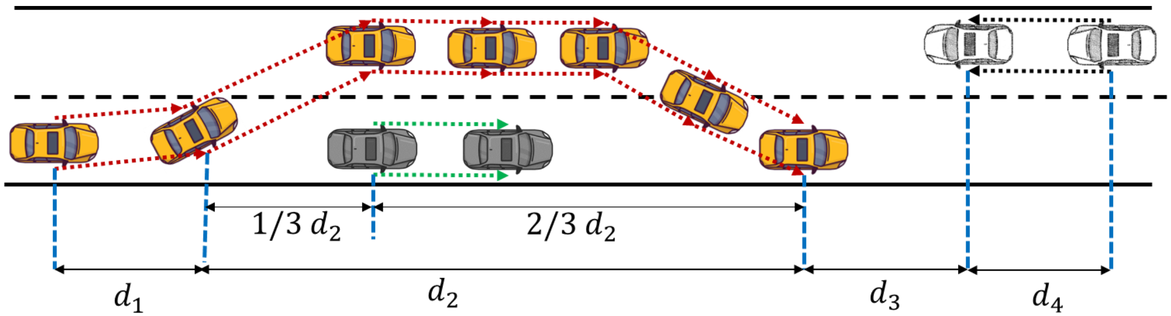


iii. In IRC, the overtaking distance had three components. Whereas in AASHTO, the passing sight distance is split into 4 distances i.e. $d_1 + d_2 + d_3 + d_4$. The extra distance (d_3) is the clear distance between the overtaking vehicle at the end of its maneuver and the vehicle coming from the opposite direction.

- The d_3 distance is generally between 30-75 m depending on the speed of the vehicles.

iv. In IRC, d_3 which is d_4 in AASHTO, is the distance traveled by the vehicle coming from the opposite direction during the overtaking maneuver duration i.e. T seconds. However, as per AASHTO, considering the total duration leads to a large sight distance and would not be cost-effective; especially, when a clear distance (d_3) of 30-75 m is already being considered.

Overtaking/Passing Sight Distance: AAHSTO Method



- In AASHTO, it is considered that the original overtaking maneuver i.e. d_2 is done in two phases:
  - In the first $\frac{1}{3}$ duration, the overtaking vehicle can come back to its lane after seeing the vehicle in the opposite lane
  - In the remaining duration i.e. $\frac{2}{3}$ duration, the actual overtaking is made
- Therefore, the distance (d_4) travelled by the vehicle coming from the opposite side shall be equal to the $\frac{2}{3}\, d_2$

$$\boxed{d_4 = \frac{2}{3}\, d_2}$$

AAHSTO Method: Formula Sheet

$$\text{Passing Sight Distance} = d_1 + d_2 + d_3 + d_4$$

$$d_1 = 0.278\, t_i \left(v - m + \frac{at_i}{2}\right)$$

$$d_2 = 0.278 v t_2$$

$$d_3 = 30\ m - 75\ m$$

$$d_4 = \frac{2}{3} d_2$$

Where

- t_i – initial maneuver time (reaction time + during initial acceleration to reach the centre line of the road). This value is usually 3.7-4.3 seconds
- v – average speed of the overtaking vehicle in km/hr
- m – difference in speed between the overtaking and the overtaken vehicle in km/hr. This value is usually 15 km/hr
- a – average acceleration in km/hr.s. This value is usually between 2.25-2.37 km/hr/s
- t_2 – time spent by the overtaking vehicle in the opposite lane (9.3-10.4 secs)
- v – average speed of the overtaking vehicle in km/hr

AAHSTO Method

Table: Typical Values used in AASHTO for OSD determination

Component of passing maneuver	Metric				US Customary			
	Speed range (km/h)				Speed range (mph)			
	50-65	66-80	81-95	96-110	30-40	40-50	50-60	60-70
	Average passing speed (km/h)				Average passing speed (mph)			
	56.2	70.0	84.5	99.8	34.9	43.8	52.6	62.0
Initial maneuver:								
a = average acceleration[a]	2.25	2.30	2.37	2.41	1.40	1.43	1.47	1.50
t_1 = time (sec)[a]	3.6	4.0	4.3	4.5	3.6	4.0	4.3	4.5
d_1 = distance traveled	45	66	89	113	145	216	289	366
Occupation of left lane:								
t_2 = time (sec)[a]	9.3	10.0	10.7	11.3	9.3	10.0	10.7	11.3
d_2 = distance traveled	145	195	251	314	477	643	827	1030
Clearance length:								
d_3 = distance traveled[a]	30	55	75	90	100	180	250	300
Opposing vehicle:								
d_4 = distance traveled	97	130	168	209	318	429	552	687
Total distance, $d_1 + d_2 + d_3 + d_4$	317	446	583	726	1040	1468	1918	2383

[a] For consistent speed relation, observed values adjusted slightly.

Note: In the metric portion of the table, speed values are in km/h, acceleration rates in km/h/s, and distances are in meters. In the U.S. customary portion of the table, speed values are in mph, acceleration rates in mph/sec, and distances are in feet.

AAHSTO Method

Table: Typical Values for Design of Two-Lane Highways

Metric					US Customary				
Design speed (km/h)	Assumed speeds (km/h)		Passing sight distance (m)		Design speed (mph)	Assumed speeds (mph)		Passing sight distance (ft)	
	Passed vehicle	Passing vehicle	From Exhibit 3-6	Rounded for design		Passed vehicle	Passing vehicle	From Exhibit 3-6	Rounded for design
30	29	44	200	200	20	18	28	706	710
40	36	51	266	270	25	22	32	897	900
50	44	59	341	345	30	26	36	1088	1090
60	51	66	407	410	35	30	40	1279	1280
70	59	74	482	485	40	34	44	1470	1470
80	65	80	538	540	45	37	47	1625	1625
90	73	88	613	615	50	41	51	1832	1835
100	79	94	670	670	55	44	54	1984	1985
110	85	100	727	730	60	47	57	2133	2135
120	90	105	774	775	65	50	60	2281	2285
130	94	109	812	815	70	54	64	2479	2480
					75	56	66	2578	2580
					80	58	68	2677	2680

Limitations of AASHTO and IRC Methods

- It is assumed that the overtaking vehicle once decided to overtake, will Definitely complete the overtaking maneuver. This means the driver has no opportunity to abort the pass.
- This assumption is believed to result in the exaggeration of the overtaking sight distance requirements.

Table: OSD values for two-lane highways

Speed (kmph)	OSD Requirement in metres	
	AASHTO	IRC
40	270	165
50	345	235
60	410	300
80	540	470
100	670	640

- Due to the longer sight distance requirement, the cost of the project increases dramatically and therefore, many researchers have developed models which outline smaller SAFE passing sight distance

Glennon Model

- There are numerous models which consider that the passing sight distance shall give the driver both options viz. to complete the overtaking maneuver as well as to abort the maneuver.

- Glennon model is the most famous among all the available models

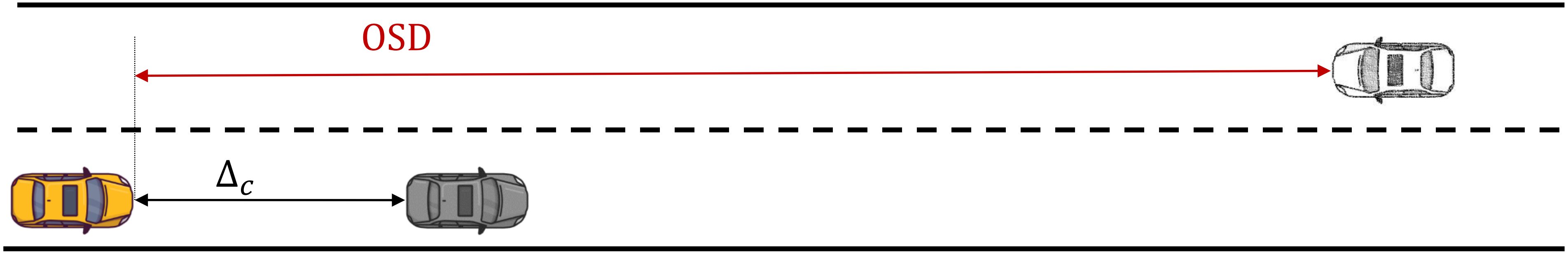
- Glennon model is based on the hypothesis that a critical position exists during the passing maneuver where the passing sight distance requirement to either complete or abort the pass is equal. At this point, the decision to complete the pass will provide the same head-on clearance to an opposing vehicle as will the decision to abort the pass. This distance can be considered as the optimum passing sight distance.

- Considering the critical position concept could reduce the passing sight distance requirement and subsequently the cost of the project

- Lets understand this concept in more detail

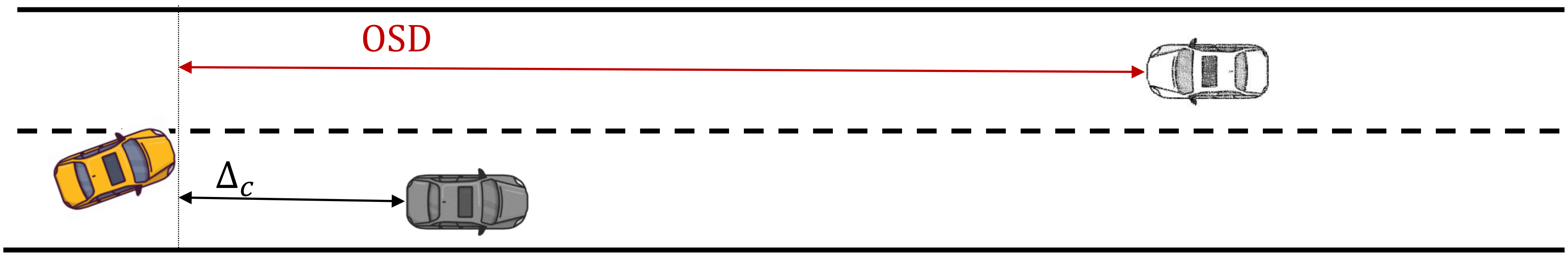
Glennon Model

- Phase I: Start of Pass i.e. when the driver decides to overtake



- When the overtaking vehicle maintaining a critical distance of Δ_c from the overtaken vehicle decides to overtake but sees the opposite vehicle, he will not at all perform the overtaking maneuver. In this case, the OSD/PSD requirement for Aborting will be the minimum but the PSD required for overtaking will the maximum

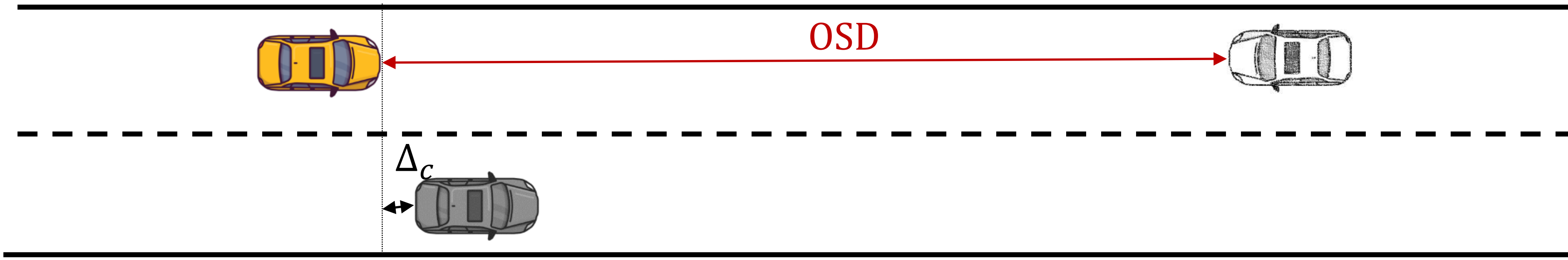
- Phase II: Early Part of Pass i.e. when the driver is on the centre line



- When the driver is on the centre line of the road and sees the opposite vehicle, the time required to ABORT the manuever will be higher than Phase I (because the driver has to return back behind the impeding vehicle) and subsequently, the distance required. In this case, the OSD/PSD requirement for Aborting will be higher than in Phase I.

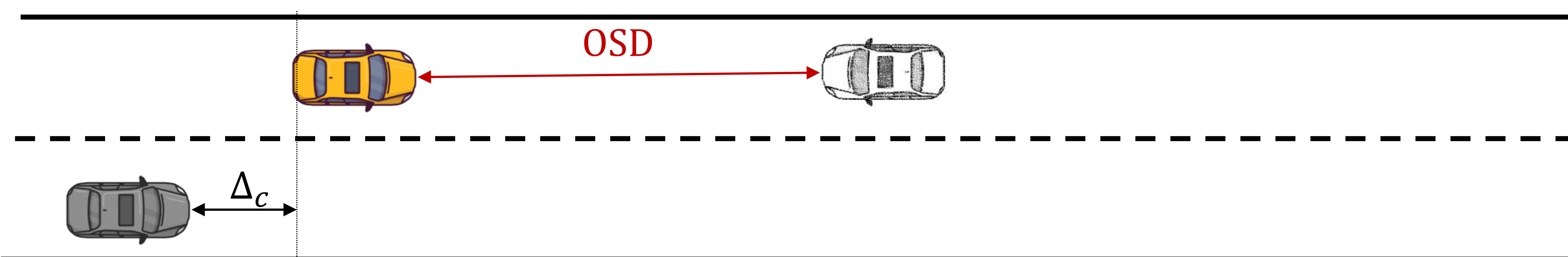
Glennon Model

- Phase III: Middle of Pass i.e. when the driver is completely on the opposite lane



- When the driver is completely on the opposite lane and he can perform both the maneuvers safely i.e. ABORT as well as COMPLETE; this distance is called the Critical Distance.
- Distance required to abort is equal to distance required to abort

- Phase IV: Later Part of Pass i.e. when the driver is ahead of the impeding vehicle



- In this case, the OSD required to abort will the maximum, but the OSD required to COMPLETE will be the minimum.

Glennon Model

- Table: Comparison of different phases

Phase	Overtaking driver position	PSD for Aborting	PSD for completing overtaking
I	Behind impeding vehicle	minimum	Maximum
II	Road Centre line	Higher than Phase I	Lower than Phase I
III	Opposite lane behind impeding vehicle	Optimum	Optimum
IV	Opposite lane ahead of impeding vehicle	Maximum	Minimum

- Out of all these conditions, the critical point/distance wherein the distance required to abort is equal to the distance required to complete the overtaking maneuver, will give the driver both the options and thus, could be considered for designing the OSD or PSD

- Lets understand the Glennon model for estimating the PSD

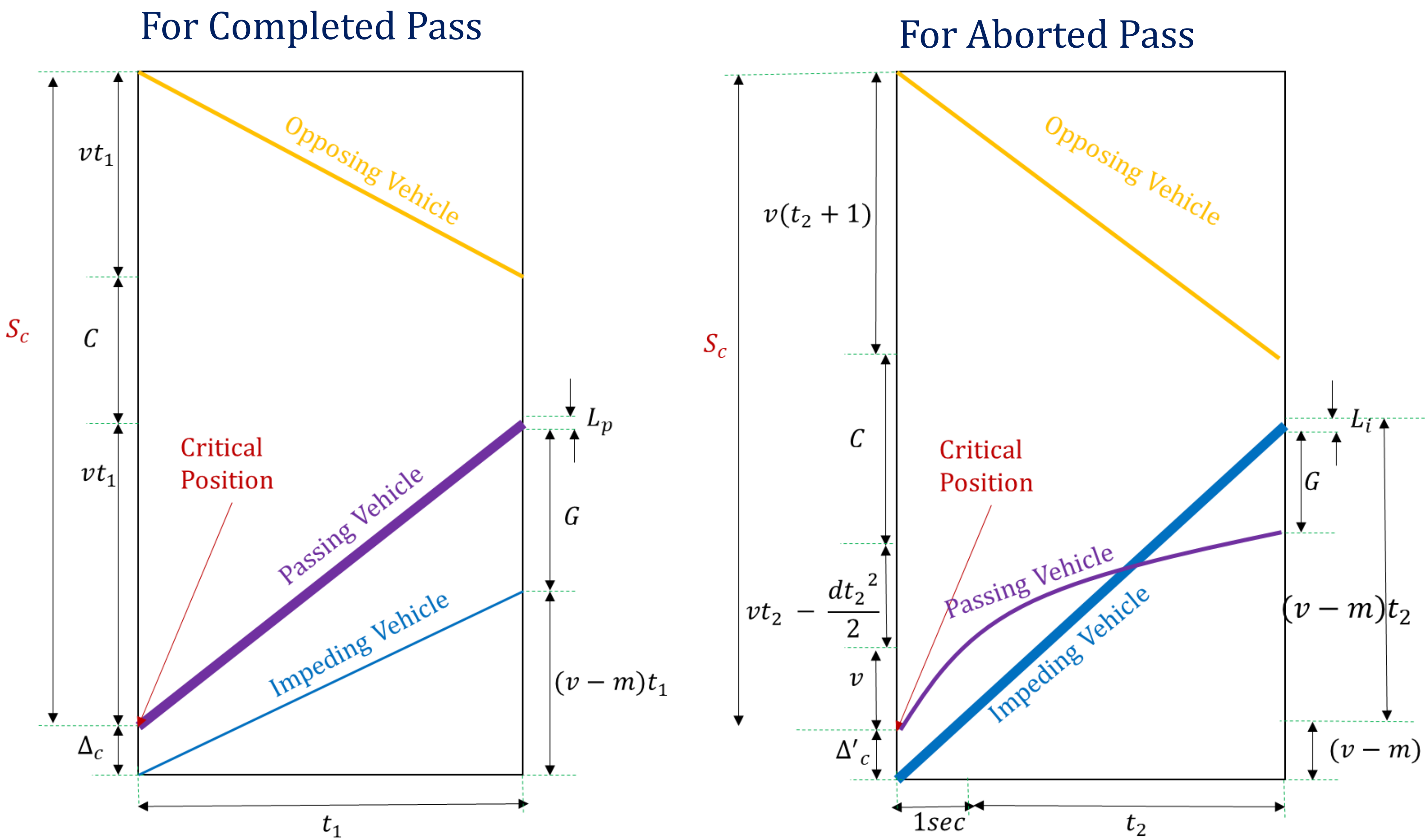
❖ Assumption made by Glennon

1) The overtaking and the vehicle coming from the opposite direction (oncoming/opposing vehicle) are travelling with the same speed i.e. the design speed of the highway (v)
2) The overtaken vehicle (passed/impeding vehicle) travels at a uniform speed which is 19 kmph lower than that of the overtaking vehicle i.e. $m = 19$ kmph
3) The length of the passing (L_p) and the passed/impeding (L_I) vehicles is 5.8 m.
4) The passing driver's perception-reaction time in deciding to abort passing a vehicle is 1 s.
5) If a passing maneuver is aborted, the passing vehicle will use a deceleration rate (a) of 3.4 m/s^2, the same deceleration rate used in stopping sight distance design criteria
6) For a completed or aborted pass, the space headway between the passing and passed vehicles is 1 s.
7) The minimum clearance between the passing and opposing vehicles at the point at which the passing vehicle returns to its normal lane is 1 s

➢ Based on these assumptions, Glennon gave two time-space diagrams; one for completed maneuver and the other for aborted maneuver

Glennon Model

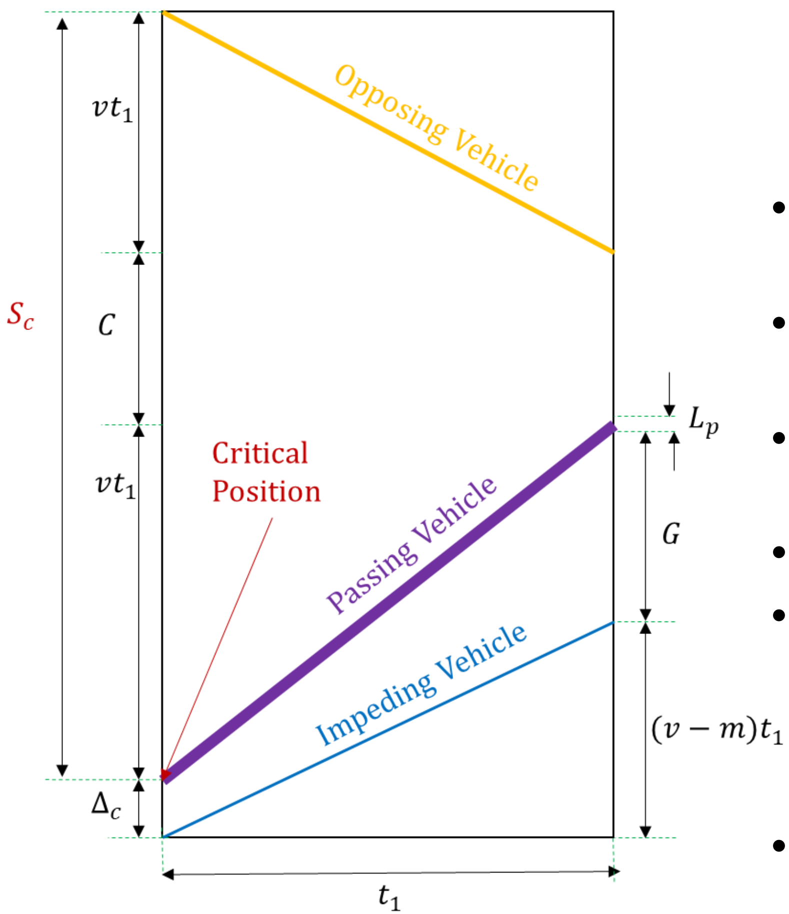
❖ Glennon Time-Space Diagrams



- Lets understand these space-time diagrams separately

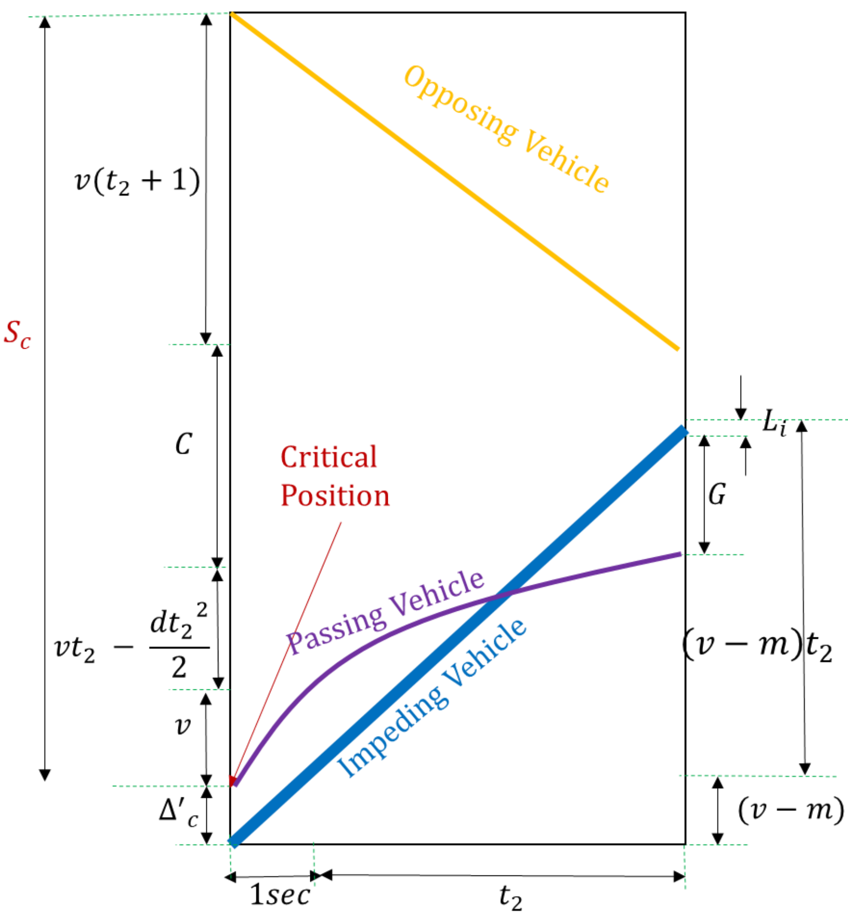
Glennon Model

❖ Glennon Time-Space Diagrams for Completed Pass



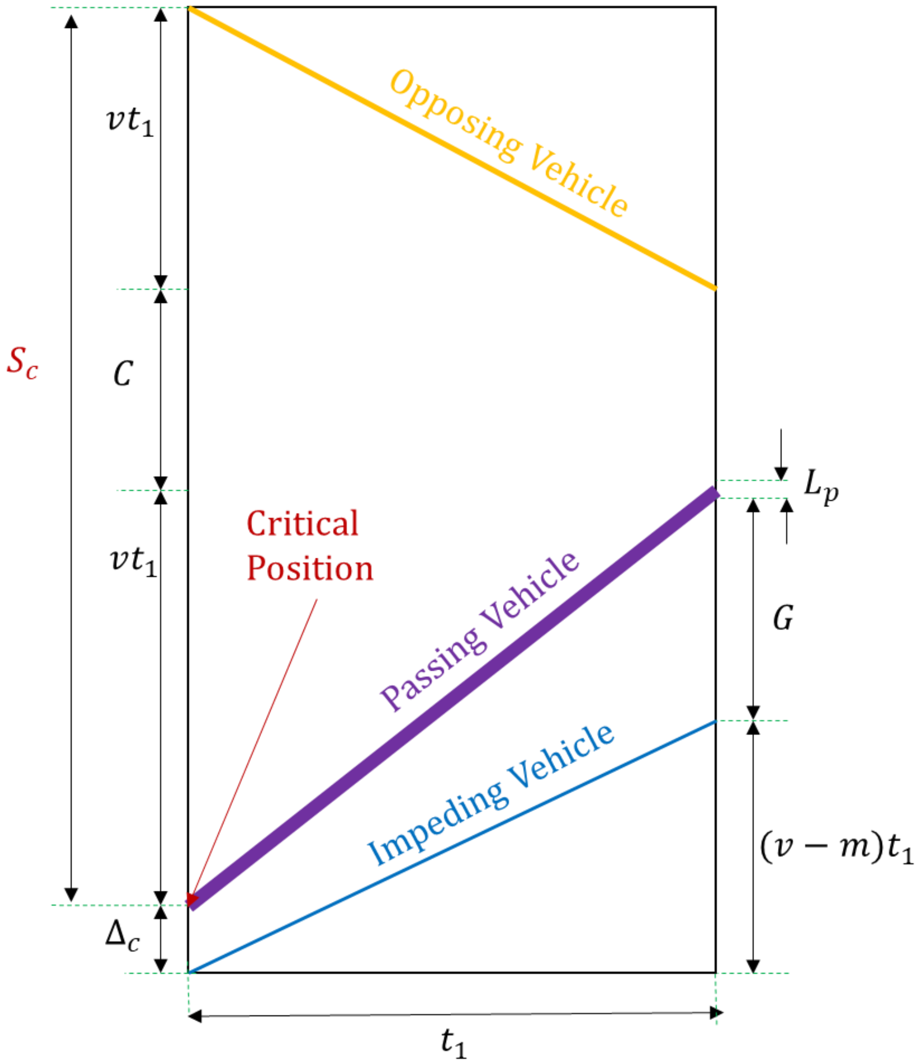
- The passing vehicle maintaining a gap Δ_c with the impeding vehicle, travels with the design speed (v) and safely completes the overtaking maneuver in t_1 seconds.
- Therefore, distance travelled by passing vehicle $= vt_1$
- The distance travelled by impeding vehicle in the same time $= (v - m)t_1$
- The clear spacing with the impeding vehicle post completing the maneuver is G.
- The length of the passing vehicle is L_p
- In the same duration t_i, the opposing vehicles which is travelling at the design speed (v) reaches; the clear spacing between the passing and the opposing vehicle is C.
- Therefore, the distance travelled by the opposing vehicle is the same as that of the passing vehicle i.e. vt_1
- We are not including Δ_c because it is the critical point at which the driver either abort or complete the maneuver safely

❖ Glennon Time-Space Diagrams for Aborted Pass



- The passing vehicle maintaining a gap Δ'_c with the impeding vehicle, travels with the design speed (v). After 1 second of reaching the critical point, he decides to abort the maneuver.
- For doing this, he deaccelerated (d) the speed and returned back to his lane maintaining a gap G with the impeding vehicle
- Therefore, distance travelled by passing vehicle in 1 second $= v \times 1 = v$
- Distance travelled after 1 second in the deacceleration mode $= vt_2 - \frac{dt^2}{2}$
- The distance travelled by impeding vehicle in 1 second $= (v-m) \times 1 = (v-m)$
- The distance travelled by impeding vehicle after 1 second $= (v-m)t_2$
- The length of the impeding vehicle is L_i
- Distance travelled by the opposite vehicle in $t_2 + 1$ seconds $= v(t_2+1)$

❖ Derivation for Completed Pass



- Critical Position for the Completed Pass

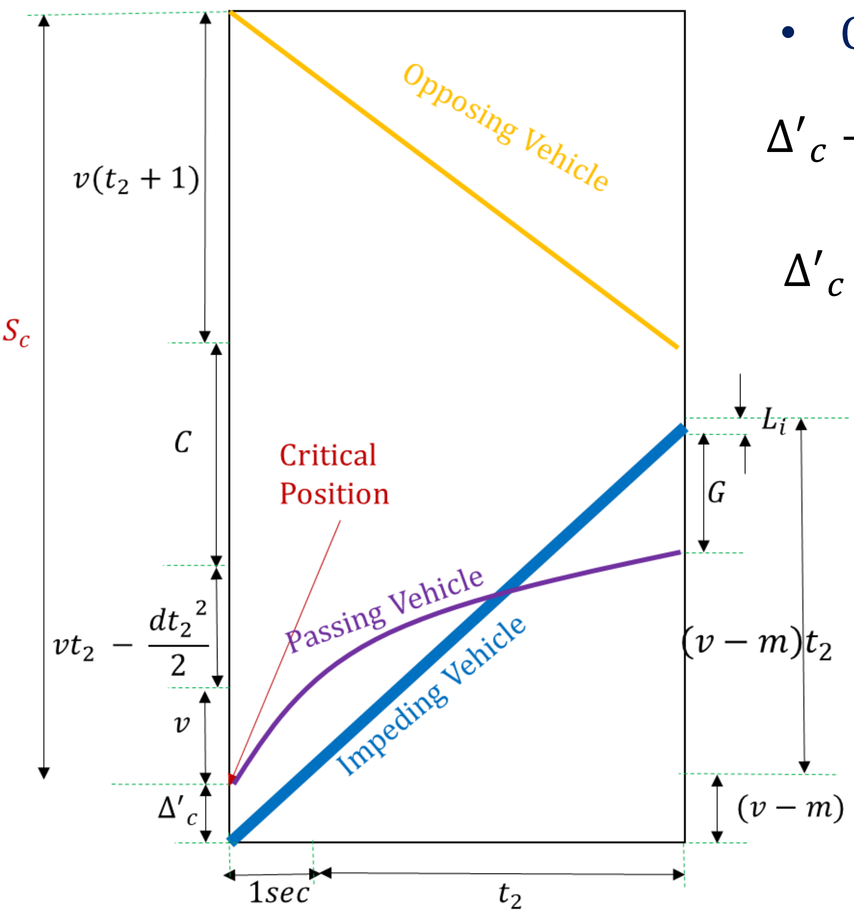
$$\Delta_c + vt_1 = L_p + G + (v-m)t_1$$

$$\Delta_c + vt_1 = L_p + G + vt_1 - mt_1$$

$$\Delta_c + \cancel{vt_1} = L_p + G + \cancel{vt_1} - mt_1$$

$$\Delta_c = L_p + G - mt_1$$

❖ Derivation for Aborted Pass



- Critical Position for Aborted Pass

$$\Delta'_c + v + vt_2 - \frac{dt_2{}^2}{2} = (v-m) + (v-m)t_2 - G - L_i$$

$$\Delta'_c + \cancel{v} + \cancel{vt_2} - \frac{dt_2{}^2}{2} = (\cancel{v} - m) + \cancel{vt_2} - mt_2 - G - L_i$$

$$\Delta'_c = m - mt_2 - G - L_i + \frac{dt_2{}^2}{2}$$

Glennon Model

$$\Delta_c = L_p + G - mt_1$$

$$\Delta'_c = m - mt_2 - G - L_i + \frac{d{t_2}^2}{2}$$

- Since the critical points are the same for both the maneuvers

$$\Delta_c = \Delta'_c$$

$$L_p + \cancel{G} - mt_1 = m - mt_2 - \cancel{G} - L_i + \frac{d{t_2}^2}{2}$$

$$L_p - mt_1 = m - mt_2 - L_i + \frac{d{t_2}^2}{2}$$

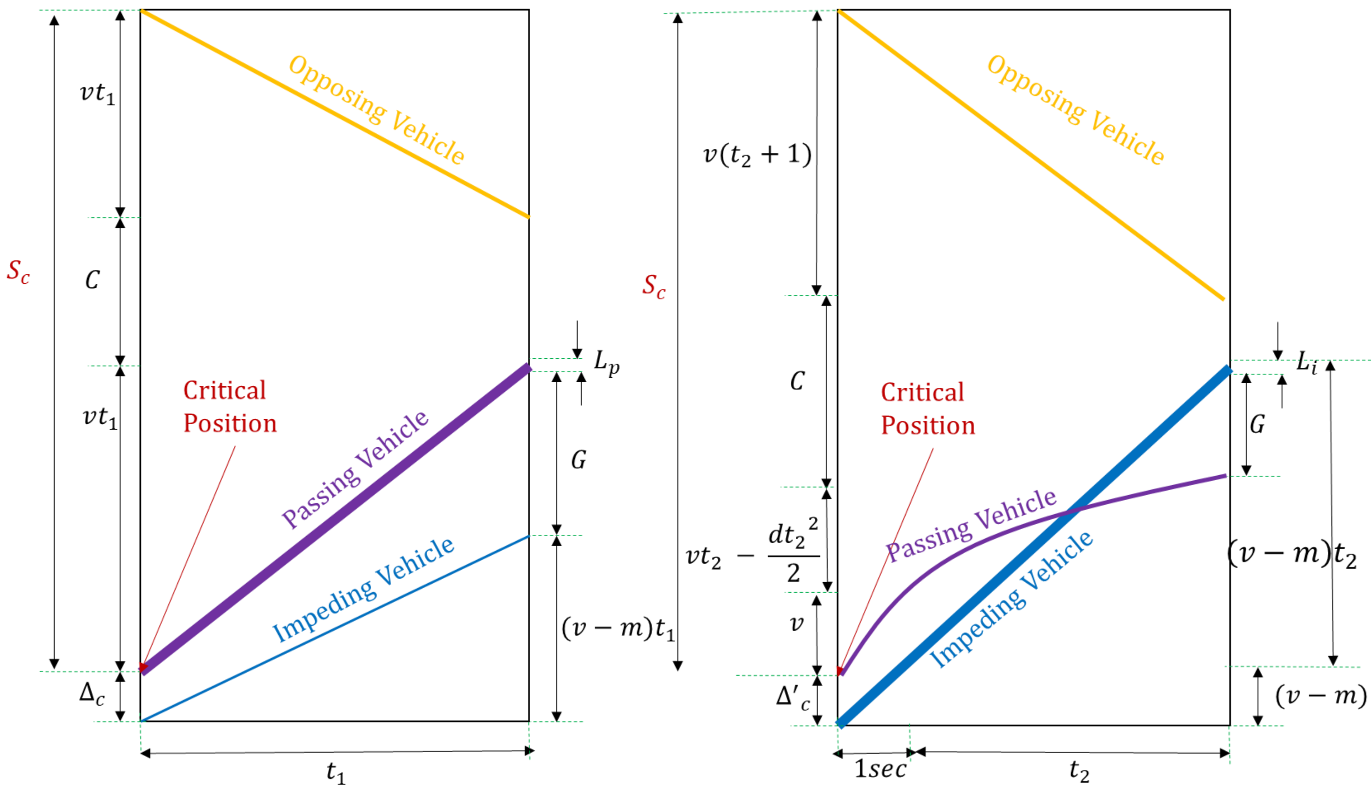
$$mt_1 = m - mt_2 - L_i - L_p + \frac{d{t_2}^2}{2}$$

- Solving this equation for t_1

$$t_1 = t_1 + 1 - \frac{d{t_2}^2}{2m} + \frac{2G + L_i + L_p}{m}$$

Glennon Model

❖ Equating Critical Sight Distances (S_c)



$$vt_1 + vt_1 + C = v + vt_2 - \frac{dt_2^{\ 2}}{2} + C + v(t_2+1)$$

- Solving this equation for t_1

$$t_1 = t_1 + 1 - \frac{dt_2^{\ 2}}{4v}$$

Glennon Model

❖ Solving time relationships simultaneously

$$t_2 = \sqrt{\frac{4v(2G + L_p + L_i)}{d(2v - m)}}$$

$$t_1 = 1 + \sqrt{\frac{4v(2G + L_p + L_i)}{d(2v - m)}} - \frac{2G + L_p + L_i}{2v - m}$$

❖ Solving the critical Sight Distance

$$S_c = 2v\left[2 + \frac{L_p - \Delta_c}{m}\right]$$

$$\Delta_c = 16 + m\left[\frac{(2m + 32)}{2v - m} - \sqrt{\frac{v(2m + 32)}{2(2v - m)}}\right]$$

Glennon Model

❖ PSD/OSD Requirement based on the Glennon Model

Speed (kmph)	OSD Requirement in metres		
	AASHTO	IRC	Glennon Model
40	270	165	140
50	345	235	160
60	410	300	180
80	540	470	245
100	670	640	320