

CIVE 440

Traffic Engineering and Simulation – Traffic Studies pt.2



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MOVING CAR METHOD

Purpose:

- Hourly flow rates
- Space-mean speed
- Travel time

Setup:

- A car(s) is driven on the highway with observers
- Number of cars is dependent on the no. of lanes on the road

**TRAVEL-TIME AND DELAY STUDY
MOVING VEHICLE METHOD
FIELD SHEET**

ROUTE _____ DATE _____
 START POINT _____ END POINT _____
 WEATHER _____

A to B

- vehicles in opposite direction
- vehicles overtaking
- vehicle passing

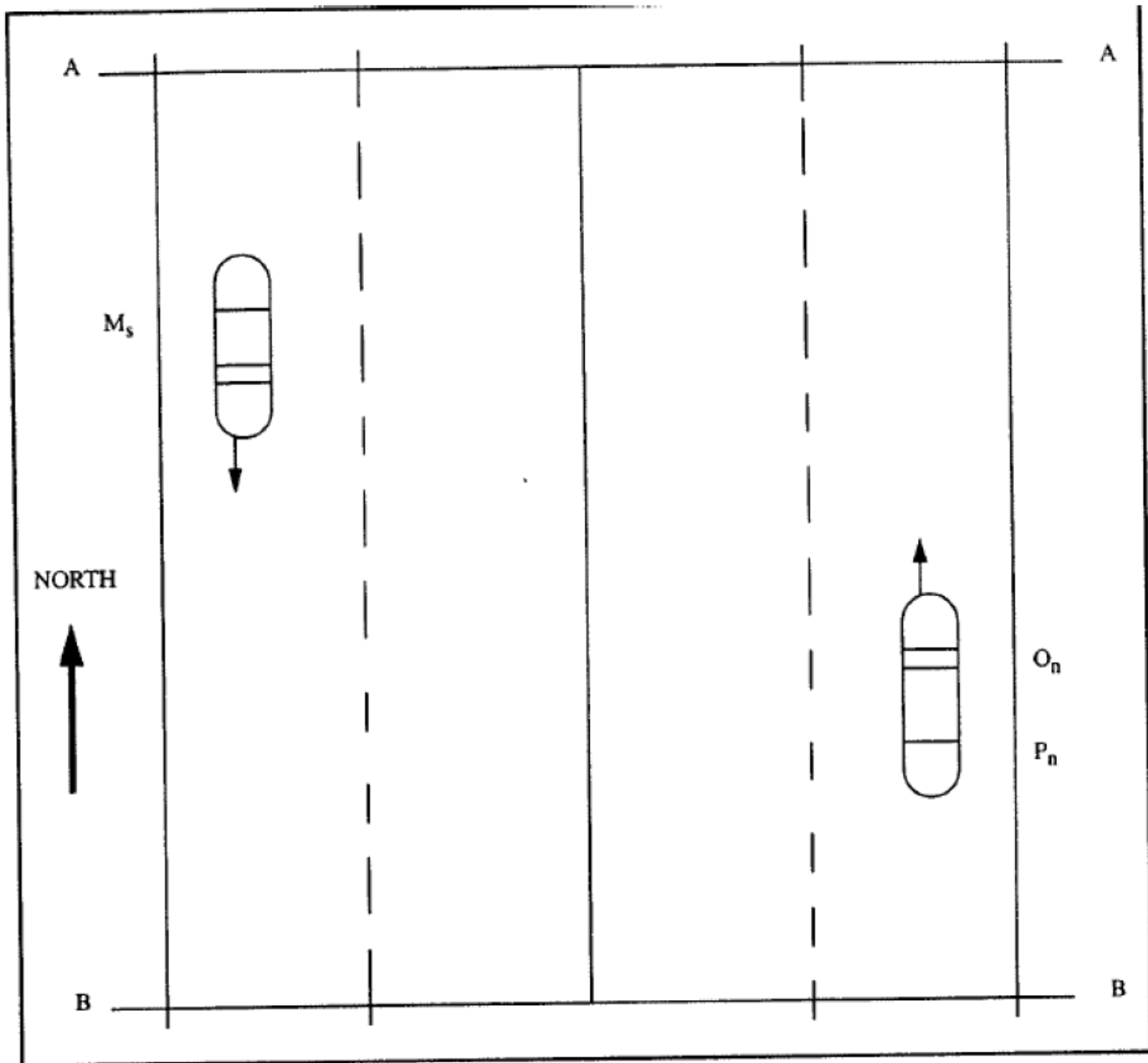
B to A

- vehicles in opposite direction
- vehicles overtaking
- vehicle passing

RUN	START TIME	FINISH TIME	TRAVEL TIME	VEHICLES MET	VEHICLES O.TAKING	VEHICLES PASSED
__BOUND						
1						
2						
3						
4						
5						
6						
7						
8						
TOTAL						
AVERAGE						
__BOUND						
1						
2						
3						
4						
5						
6						
7						
8						
TOTAL						
AVERAGE						

COMMENTS _____

RECORDER(S) _____



$$V_n = 60 \left(\frac{M_s + O_n - P_n}{T_n + T_s} \right)$$

$$\bar{T}_n = T_n - \frac{60(O_n - P_n)}{V_n}$$

$$S_n = \frac{60 d}{\bar{T}_n}$$

V_n = volume per hour, northbound

M_s = opposing count of vehicles met when the test car was traveling south

O_n = number of vehicles overtaking the test car as it traveled north

P_n = number of vehicles passed by the test car as it traveled north

T_n = travel time when traveling north, minutes

T_s = travel time when traveling south, minutes

EXAMPLE

$d = 18.5 \text{ km}$

Direction	Travel time	Vehicles met	Vehicles overtaking	Vehicles passed
North	25 minutes	547	15	30
South	18.5 minutes	2505	57	83

DELAY

Different types/sources of travel delay:

- **Stopped-time delay:**
 - time vehicle is at a complete stop (at stop sign or red traffic signal)
 - artificially slowed down (speed limit or yield)
- **Approach delay:** delays due to deceleration and acceleration at stop
- **Time-in-queue delay:** time between joining the end of the queue and leaving the queue (at stop sign or signal)
 - **Control delay:** total delay due to a control device (approach delay + time-in-queue delay)

Road design focuses on control delay:

- can be optimised without significant impacts on safety

DELAY STUDIES

Strategy:

- Observe no. of vehicles in queue in intervals of 10-20 seconds
- Complete observations every minute
- Add the data and use the correction factor for acceleration and deceleration delay!
- Thus we obtain control delay

INTERSECTION CONTROL DELAY WORKSHEET

General Information

Analyst _____
 Agency or Company _____
 Date Performed _____
 Analysis Time Period _____

Site Information

Intersection _____
 Area Type CBD Other
 Jurisdiction _____
 Analysis Year _____


Input Initial Parameters

Number of lanes, N _____ Total vehicles arriving, V_{tot} _____
 Free-flow speed, FFS (km/h) _____ Stopped-vehicle count, V_{stop} _____
 Survey count interval, I_s (s) _____ Cycle length, C (s) _____

Input Field Data

Clock Time	Cycle Number	Number of Vehicles In Queue									
		Count Interval									
		1	2	3	4	5	6	7	8	9	10

E.g.: 3 intervals
 if $C = 60s$
 and $I_s = 20s$



$$T_Q = \left(I_s * \frac{\sum V_{iq}}{V_T} \right) * 0.9$$

$\therefore T_Q$ = average time-in-queue, s/veh

I_s = time interval between time-in-queue counts, s

$\sum V_{iq}$ = sum of all vehicle-in-queue counts, vehs

V_T = total number of vehicles *arriving* during the study period, vehs

0.9 = empirical adjustment factor

$$FVS = \frac{V_{STOP}}{V_T}$$

FVS = fraction of vehicles stopping
other variables as previously defined

CONTROL DELAY

Control delay corrects the time in queue for acceleration and deceleration:


$$d = T_Q + FVS * AF$$


Table 9.6: Adjustment Factor for Acceleration/Deceleration Delay

Free-Flow Speed (mi/h)	Vehicles Stopping Per Lane, Per Cycle (V_{SLC})		
	≤ 7 vehs	8–19 vehs	20–30 vehs
≤ 37	+5	+2	-1
>37–45	+7	+4	+2
>45	+9	+7	+5

VEHICLES STOPPING PER LANE

$$V_{SLC} = \frac{V_{STOP}}{N_C N_L}$$

- where:
- V_{SLC} = number of vehicles stopping per lane per cycle (veh/ln/cycle)
 - V_{STOP} = total count of stopping vehicles (veh)
 - N_C = number of cycles in survey
 - N_L = number of lanes in survey group

EXAMPLE

This intersection has 2 lanes on all four approaches.

Clock Time	Cycle Number	Number of Vehicles in Queue		
		+0 secs	+20secs	+40secs
5:00 PM	1	4	7	5
5:01 PM	2	6	6	5
5:02 PM	3	3	5	5
5:03 PM	4	2	6	4
5:04 PM	5	5	3	3
5:05 PM	6	5	4	5
5:06 PM	7	6	8	4
5:07 PM	8	3	4	3
5:08 PM	9	2	4	3
5:09 PM	10	4	3	5
	Total	40	50	42
$\Sigma V_{iq} = 132$ vehs		$V_T = 120$ vehs	$V_{STOP} = 75$	FFS = 35 mi/h

How does cycle time influence average delay and capacity?

How is this influenced by the saturation of the intersection?



HCM

The **Highway Capacity Manual** (HCM) provides transportation practitioners and researchers with a consistent system of techniques for the evaluation of the **quality of service** on highway and street facilities.

- The HCM does **not** set policies regarding a desirable or appropriate quality of service for various facilities, systems, regions, or circumstances.
- Its objectives include:
 - providing a logical set of methods for assessing transportation facilities
 - assuring that practitioners have access to the latest research results
 - presenting sample problems.

The fifth edition of the HCM (2010) is intended to provide a systematic and consistent basis for assessing the capacity and level of service for:

- elements of the surface transportation system
- for systems that involve a series or a combination of individual facilities

The manual is the primary source document embodying research findings on capacity and quality of service and presenting methods for analyzing the operations of:

- streets
- highways
- pedestrian and bicycle facilities

CAPACITY

The HCM defines **capacity** as:

"The capacity of a facility is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions"

I.e.: It is traffic **supply**.

LEVEL OF SERVICE

The HCM defines **Level of Service (LOS)** as:

"Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience."

LOS grades A – F

- A is good (free-flow conditions)
- F is bad (heavy congestion)

v/c RATIO

The v/c ratio (demand over supply) represents the ratio of expected demand to the capacity of a facility.

True demand is latent (unobserved). It includes:

- arrival (measured) flows
- flows diverted
 - to alternate routes
 - at alternate times
 - To alternate destinations)

$v/c > 1$ results in queuing (**saturation**)

Queue accumulation/dissipation speed depends on how much $v/c > 1$.

The comparison of true demand to capacity is the objective!

- account for causing congestions elsewhere
- account for delaying people's travel schedule

FACILITY TYPES

Freeways/highways (formally **controlled-access highways**) provide opportunity for uninterrupted flow.

- No at-grade intersections (signalized or unsignalized)
- No private access (parking lots, driveways)
- No parking within the right of way



Multilane facilities:

- If signal spacing < 1 mile, analyzed as urban streets
- Uninterrupted flow occurs if spacing > 2 miles
- If signal spacing between 1 and 2 miles, prevailing conditions determine if uninterrupted flow exists or not



Interrupted facilities

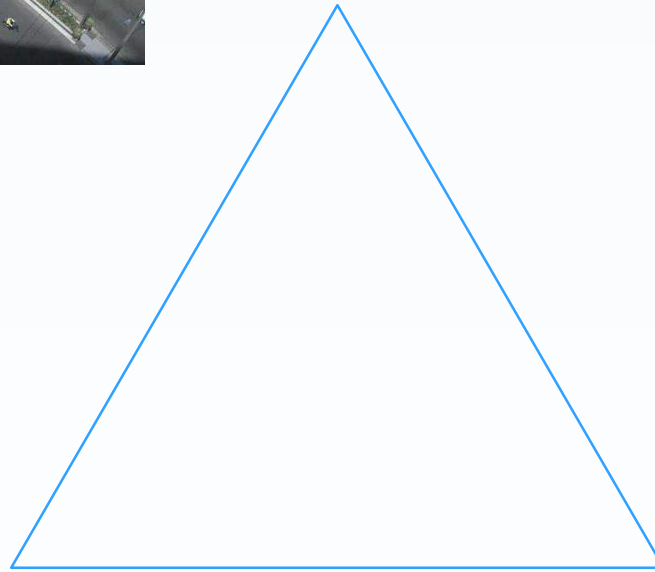
- Facilities with stop signs, yield signs, and traffic signals fall in this group – there are predefined interruptions to traffic flow depending on the control in place.

Table 12.1: Measures of Effectiveness Defining Levels of Service in HCM 2000

Type of Flow	Type of Facility	Measure of Effectiveness
Uninterrupted Flow	Freeways	
	Basic sections	Density (pc/mi/ln)
	Weaving areas	Density (pc/mi/ln)
	Ramp junctions	Density (pc/mi/ln)
	Multilane Highways	Density (pc/mi/ln)
Interrupted Flow	Two-Lane Highways	Average Travel Speed (mi/h)
		Percent Time Spent Following (%)
	Signalized Intersections	Control Delay (s/veh)
	Unsignalized Intersections	Control Delay (s/veh)
	Urban Streets	Average Travel Speed (mi/h)
	Transit	Service Frequency (veh/day)
		Service Headway (min)
		Passengers/Seat
	Pedestrians	Space (ft ² /ped)
	Bicycles	Frequency of (Conflicting) Events
		(events <i>k</i>)



ECONOMY



CAPACITY



ROAD SAFETY



DRIVER CHARACTERISTICS

There is variability in the characteristics of drivers:

- Psychological characteristics
 - Personal preference
 - Mood, hurry, **attentiveness**
 - Patience, **etiquette**, compliance with laws and regulations
 - Experience, skill, spatial-awareness
- Physiological
 - Sight
 - **Reaction time**

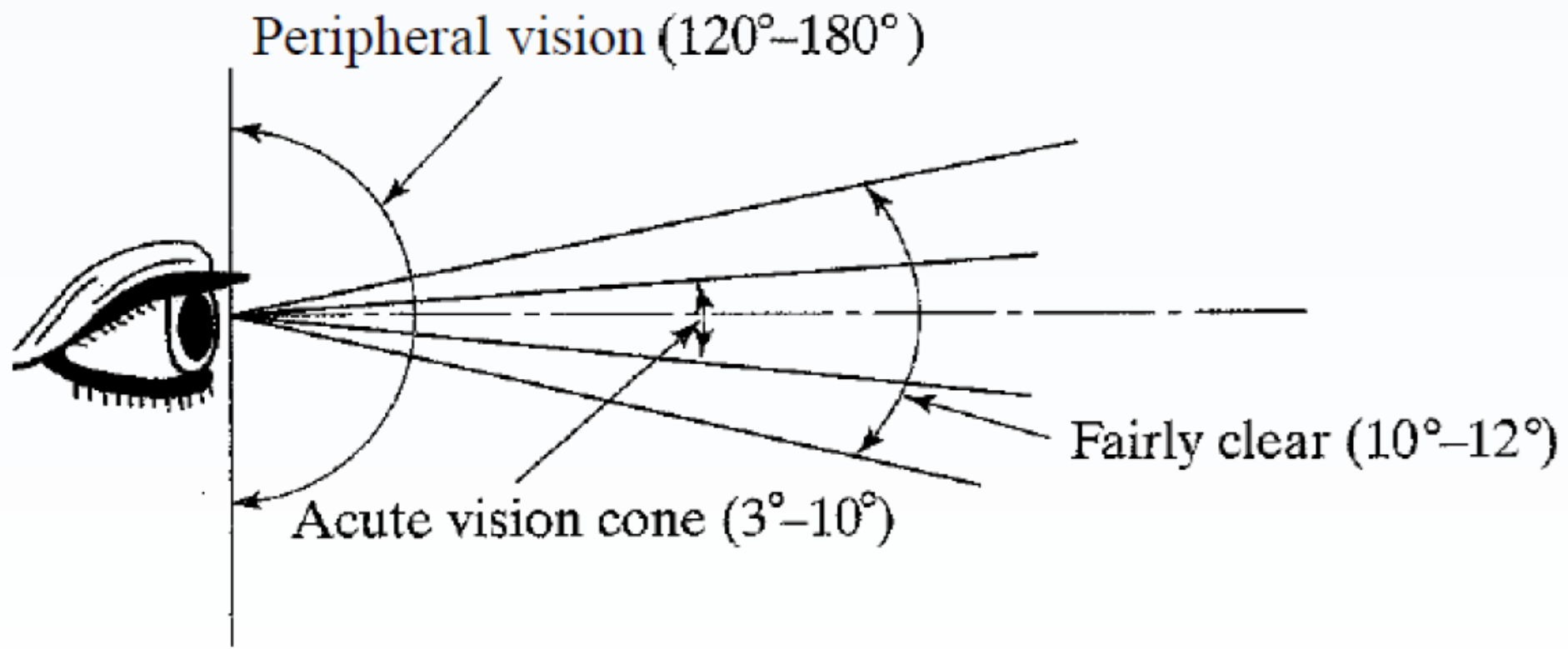
Can't design for everyone's needs simultaneously

- Design for population averages, or 85th or 95th percentile if it affects safety.

VISUAL CHARACTERISTICS

Field of vision:

- *Acute or clear vision cone*
 - 3° to 10° around the line of sight
 - Sign legends can be read only within this narrow field of vision.
- *Fairly clear vision cone*
 - 10° to 12° around the line of sight
 - color and shape can be identified in this field.
- *Peripheral vision*
 - This field may extend up to 90° to the right and left of the centerline of the pupil, and up to 60° above and 70° below the line of sight.
 - Stationary objects are generally not recognized in the peripheral vision field, but the movement of objects through this field is detected.



The field of vision values are for a stationary object.

- The effective peripheral vision field narrows, as speed increases, to as little as 100° at 30 km/h and to 40° at 100 km/h.
- When you design traffic signals you attempt to place them within the acute vision of sight ($<10^\circ$)

Color blindness might result in inability to distinguish between green and red. To resolve this issue to some degree:

- standardization of traffic light order (vertical stack)
- use of shapes in addition to colour (Québec)
- some blue pigment has been added to green lights and some yellow pigment has been added to red lights, making them easier to discern by color blind drivers



50 kmph



65 kmph

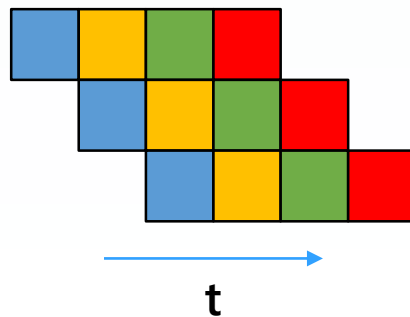
PERCEPTION REACTION TIME

Detection:

- In this phase, **an object or condition** of concern enters the driver's field of vision, and the driver becomes consciously aware that something requiring a response is present.

Identification:

- In this phase, the driver acquires sufficient information concerning the object or condition to allow the consideration of an appropriate response.

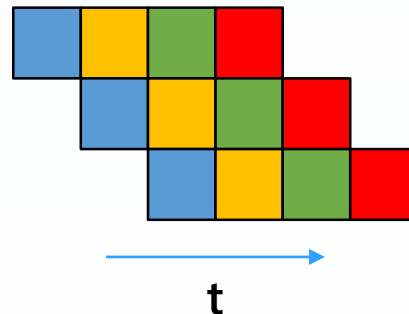


Decision:

- Once identification of the object or condition is sufficiently completed, the driver must analyze the information and make a decision about how to respond.

Response:

- After a decision has been reached, the response is now physically implemented by the driver.



Perception Perception
Intellect Intellect
Evolution Judgment
Volition Reaction

"PIEV" or "PIJR"

- Collectively commonly called *reaction time*
 - The true *reaction process* is a fraction of this time (0.15~0.25 seconds)
- Ranges from 0.5 to 4.0 seconds, depending on driver
- Varies based on gender, age, driving experience, fatigue, distractions, and region
 - Rural area stops are unexpected resulting in longer PIEV times (~2.5 seconds)
 - In urban areas, drivers are more alert (~1 seconds)
 - 1.5 seconds is the standard in academic settings

Why is PIEV important?

- Provides a sense of how far a driver will proceed before initiating a response to a collision course
 - I.e.: the distance a car travels before the driver's foot reaches the brake
- Lets say the car is traveling at V km/h and the PIEV is t seconds; then the distance travelled is (in metres):

$$d_{PIEV} = \frac{5}{18} v t$$


- Automated vehicles are intrinsically safer because they do not have this delay (or it is significantly smaller).
 - Instead, safety is a condition of mechanical and sensor reliability, and ability to process spatial awareness (AI).

STOPPING SIGHT DISTANCE

Stopping sight distance (SSD) should include:

- Distance travelled during PIEV
- Distance to break

Breaking distance component

$$d_{SSD} = \frac{5}{18} v t + \frac{\left(\frac{5}{18} v\right)^2}{19.6F \pm G}$$


where t = PIEV time

F = the coefficient of rolling friction

G = the longitudinal surface grade

EXAMPLE TEST SKID

To determine the value of friction factors on different pavements we can do a test skid

- At a speed of 50km/h, the skid marks are 20 m long.
- Compute F

EXAMPLE

An accident investigator estimates that a vehicle hit a bridge abutment at a speed of 30 km/h, based on his assessment of damage. Leading up to the accident location, he observes skid marks of 40 m on the pavement ($F = 0.35$) and 25 m on the grass shoulder ($F = 0.25$). There is no grade. An estimation of the speed of the vehicle at the beginning of the skid marks is desired.

INTERSECTION CONTROL

More complicated than freeway control

- Because of increased traffic conflict complexity and management needs
- At an ordinary intersection of two two-way streets there are 12 legal vehicular movements. For each approach:
 - Left
 - Through
 - Right
- There is typically also a pedestrian component and there may even be a heavy cyclist component as well.

Role of traffic engineer is to ensure traffic flows smoothly with as few conflicts as possible.

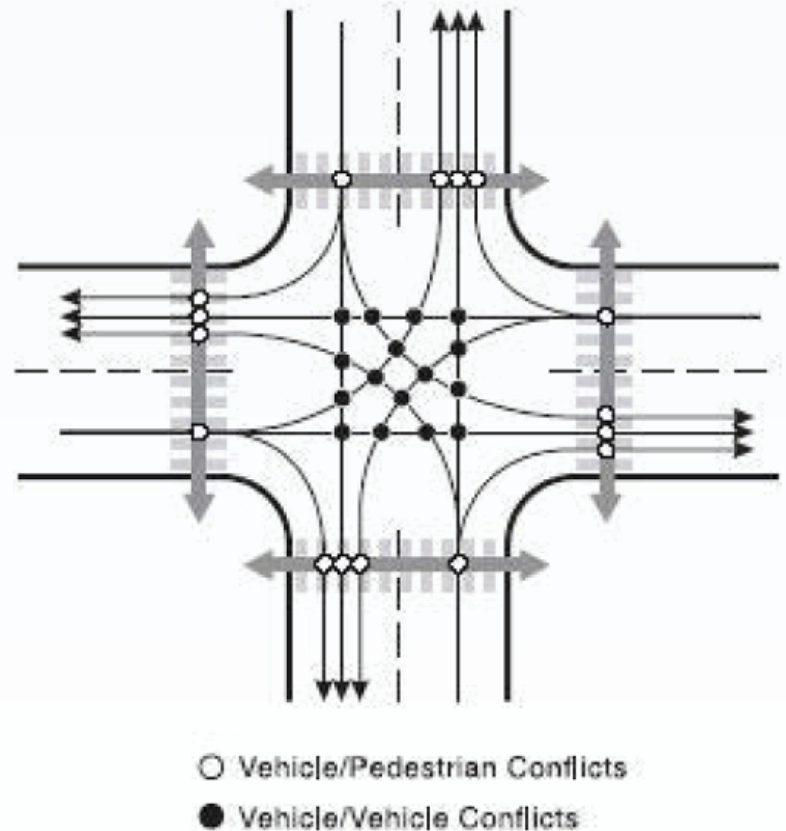
20 vehicle-vehicle conflicts!

- 4 through movement conflicts
- 4 left-turning conflicts
- 8 conflicts between left turning and through movements
- 4 merge conflicts with right-turning movements and through movements

4 pedestrian-vehicle conflicts per approach

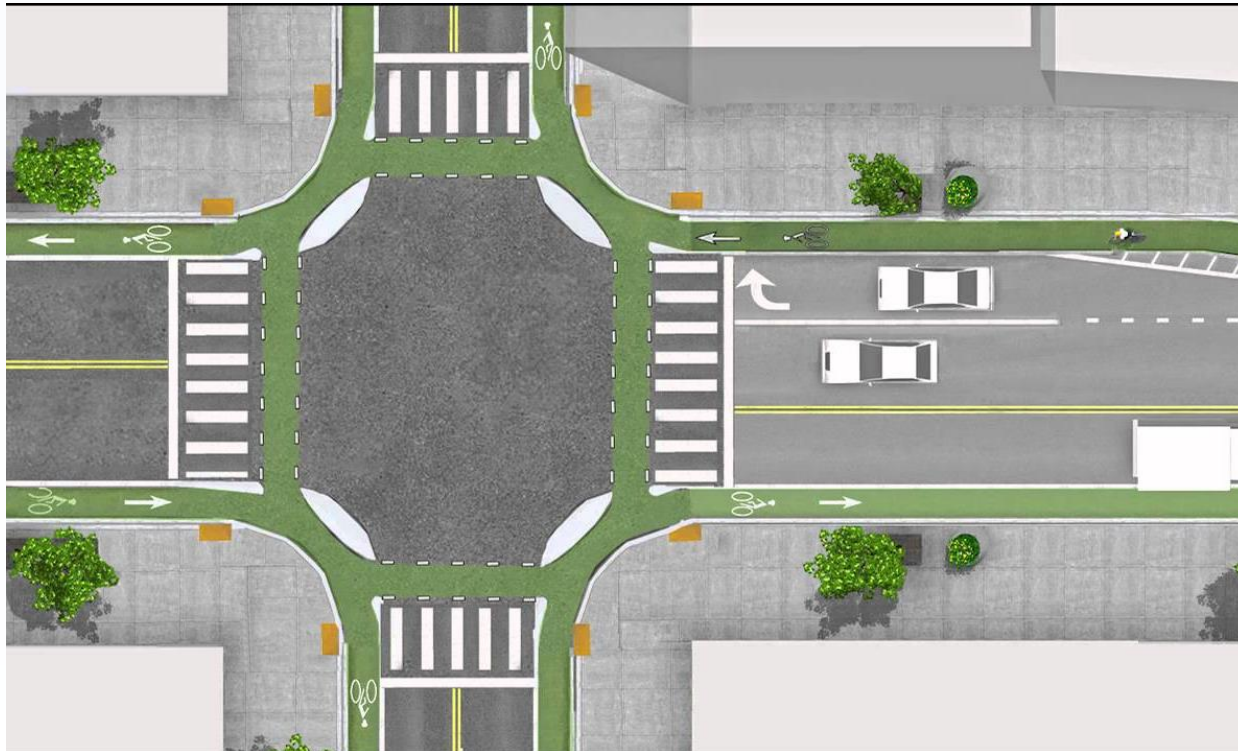
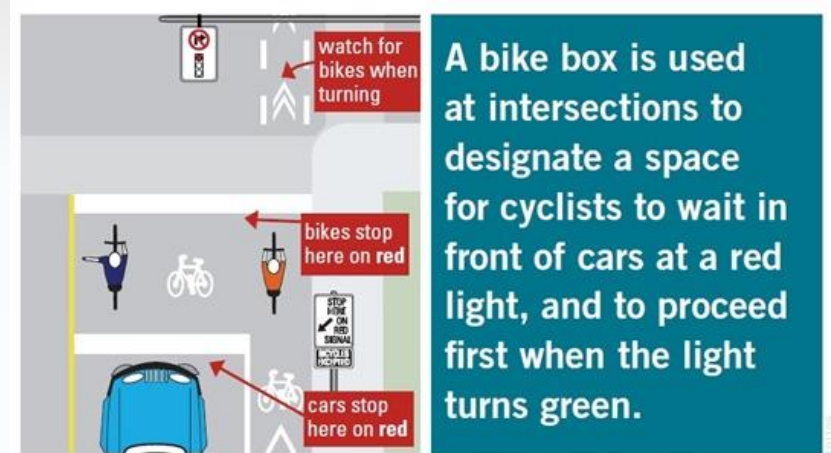
- Exit lane is critical

What about bikes?

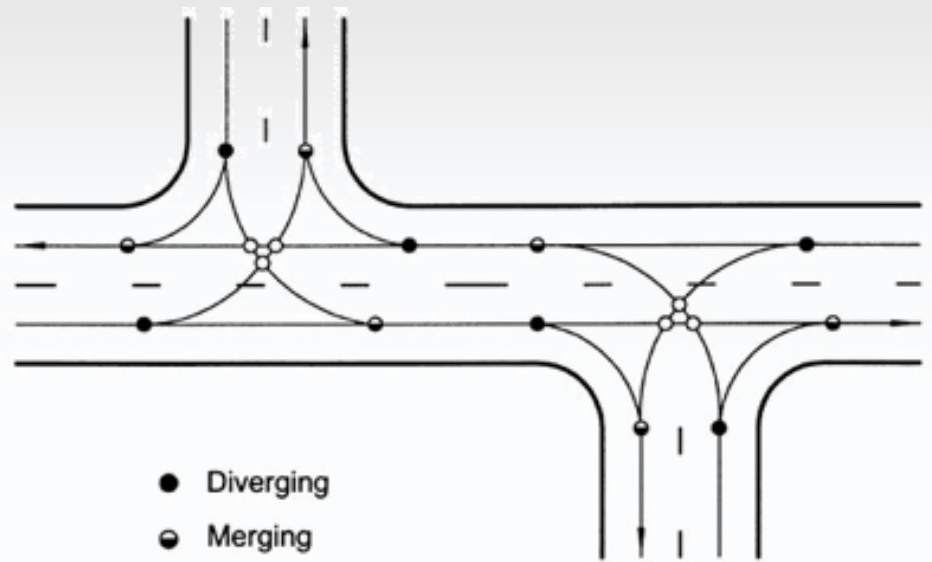


Bike left-turns are particularly challenging:

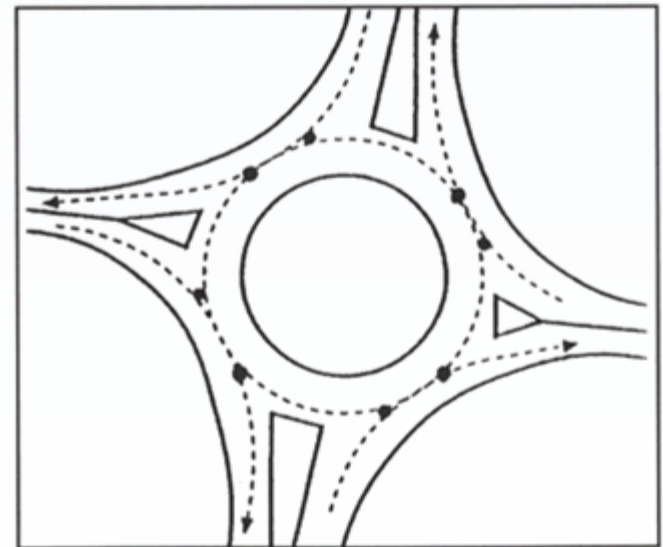
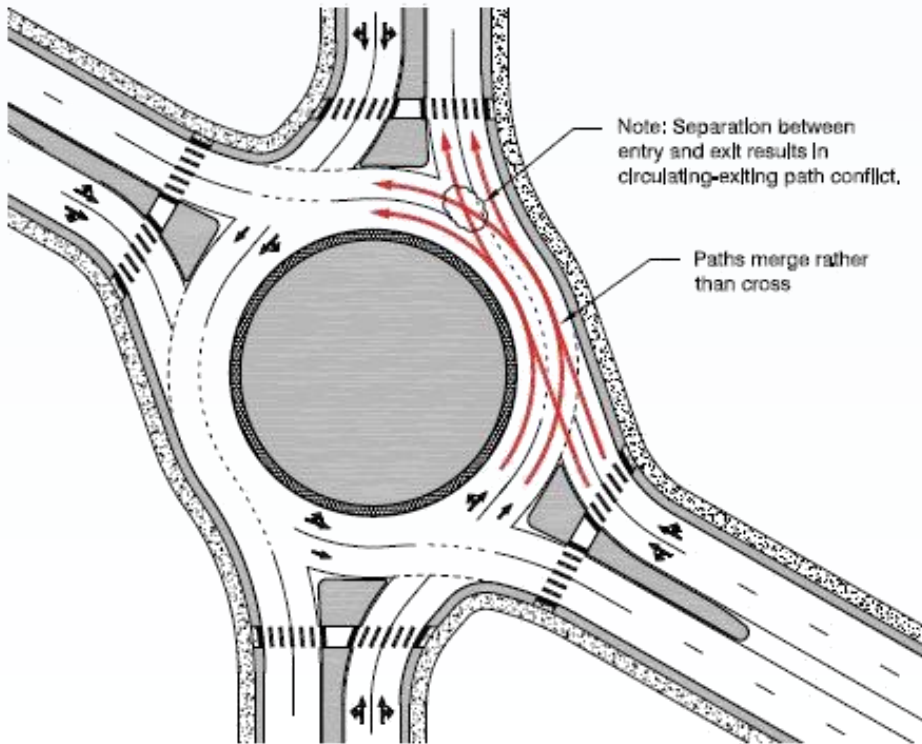
- normally ride to the right of traffic.
 - In-lane left turn
 - Dutch left turn



Alternatives:



- Diverging
- Merging
- Crossing



Roundabout Intersection

● = Conflict Point

Figure 2

Countermeasures:



HIERARCHY OF INTERSECTION CONTROL

Level I

- Basic rules of the road only (no signalization)

Level II

- Direct assignment of Right of Way (stop/yield signs)

Level III

- Full traffic signalization (traffic lights)

The appropriate level of control is determined based on which and how many conflicts a driver faces

- In cases where it is not feasible for the driver to perceive and avoid conflicts, traffic controls are imposed to provide assistance

Two factors influence the driver's ability to avoid conflicts:

- Driver must be able to recognize the potential conflict (vehicle or pedestrian) in time so as to avoid collision
 - I.e. stopping sight distance
- Volumes on the roadway should provide enough opportunities to maneuver safely
- Involves demand and conflict intensity

For example:

- A rural road intersection has very little likelihood of too many conflicts simultaneously occurring
- At the junction between two urban arterials the situation is different and requires the highest level of signalization

How do we determine when and what level of traffic control is necessary?

LEVEL I CONTROL

Basic rules of the road apply in cases where no traffic controls or signals are assigned:

- These are spelled out in detail in the state/provincial traffic laws
- **Priority to the right** of the **Vienna Convention on Road Traffic**
 - At intersections, the driver on the left has to yield to the driver on the right (if there is a possibility of a collision)
 - Mostly observed in Europe
- Level 1 control is exceedingly rare in North America

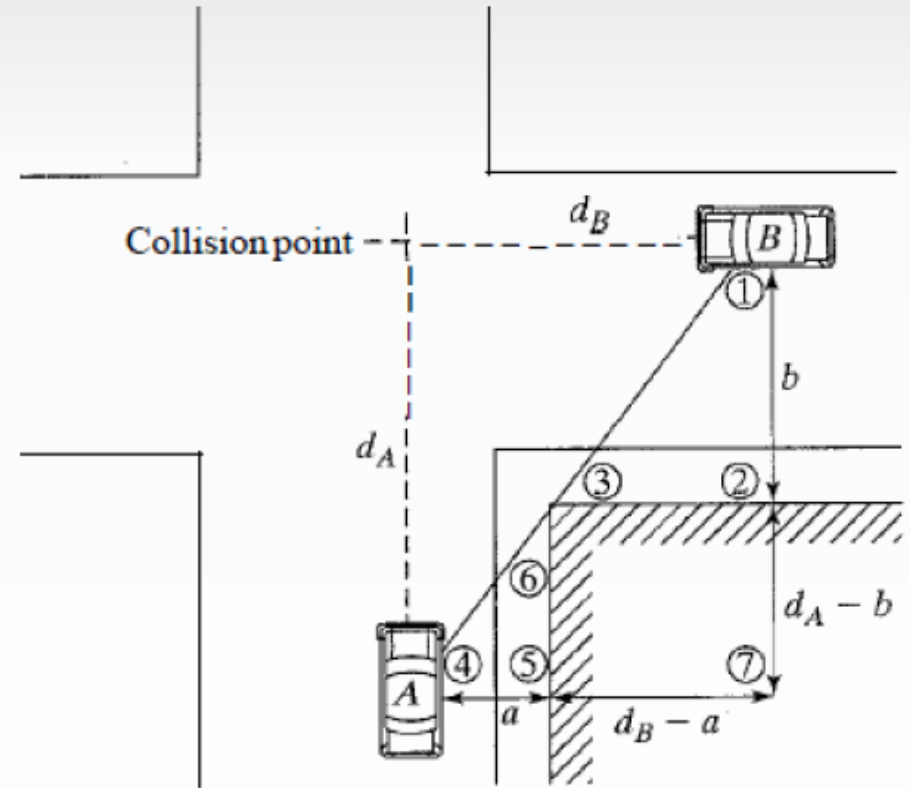
Basic rules of the road apply:

- In practice, in North America, through vehicles have right of way over turning vehicles
- Pedestrians have priority over all other conflicting movements, followed by cyclists
- Everything else being equal, first-come-first-serve is in effect
- Intentions are confirmed through **eye-contact**

Reliance on driver etiquette and traffic enforcement

The design should ensure that no two vehicles on two approaches collide with each other.

- The triangle $\Delta 147$ should be large enough that collision does not occur
- $\Delta 123$, $\Delta 456$, and $\Delta 147$ are similar triangles..



we need to compute the SSD for d_a and d_b to check that drivers can stop in time.

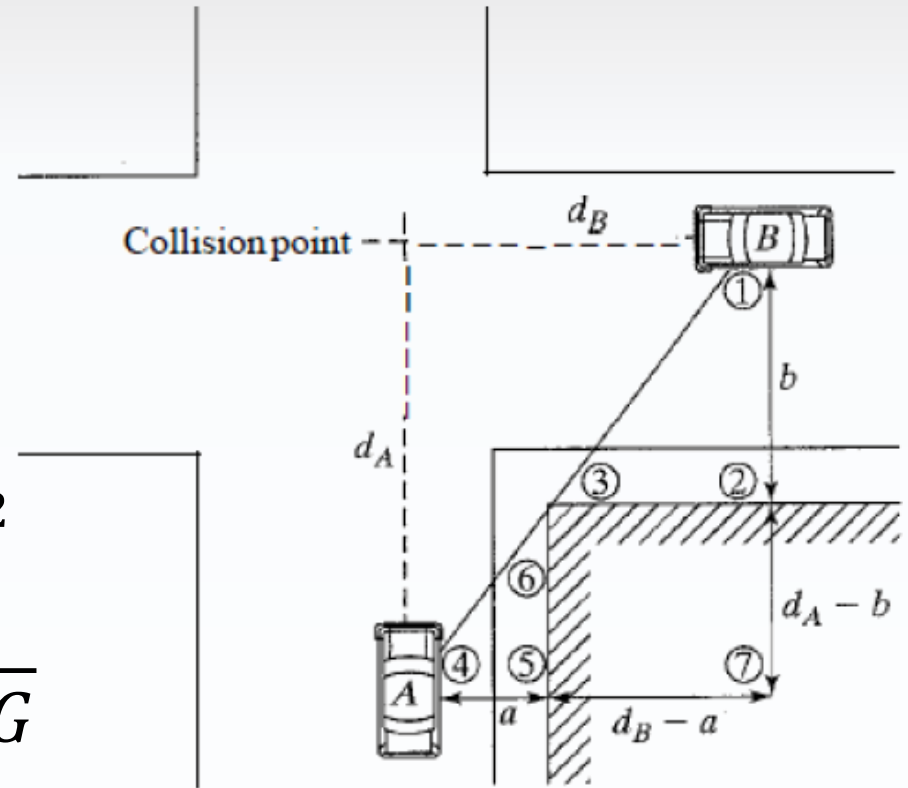
$$\frac{b}{d_B - a} = \frac{d_A - b}{a}$$

$$d_B = \frac{a d_A}{d_A - b}$$

Take reaction time as 2.5 seconds and use 85% percentile speed on the roadway for this computation.

$$d_{SSD} = \frac{5}{18} v t + \frac{\left(\frac{5}{18} v\right)^2}{19.6F \pm G}$$

• $t = 2.5$ and $F = 0.348$



$$\frac{b}{d_B - a} = \frac{d_A - b}{a}$$

$$d_B = \frac{a d_A}{d_A - b}$$

LEVEL II CONTROL

In cases where sight triangles do not work we consider there is a need to add an additional level of control with stop/yield sign

- There might be some conditions where even when the sight triangles provide safety we implement Level II control (based on volume and complexity of the conflicts)
- Manual of Uniform Traffic Control Devices (available online) provides “guidance” on installation of these controls
- In addition to the principle of first-in-first-out, the same rules of driving etiquette still apply in determining movement priority

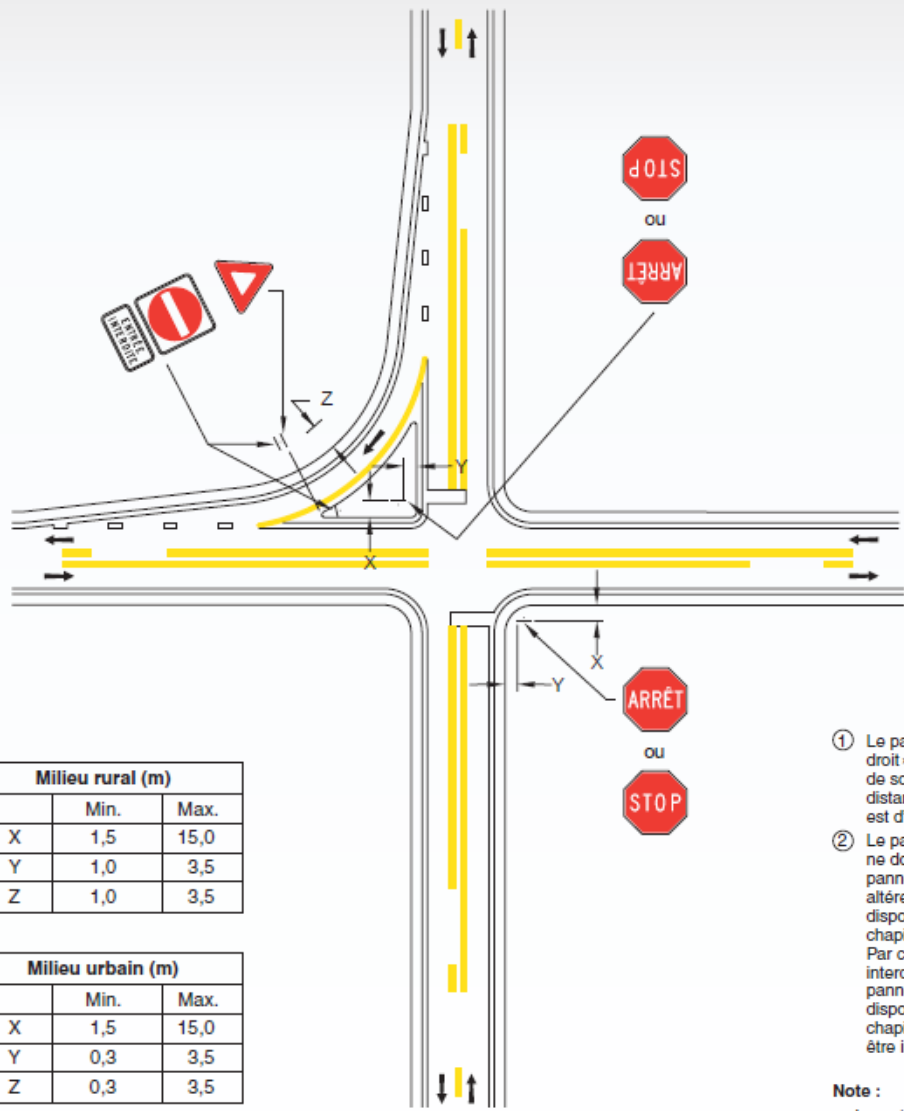
Factors:

- Vehicular, bicycle and pedestrian volumes on all approaches
- Number and angle of approaches
- Approach speeds
- Sight distance available on each approach
- Accident history

N.B.: Most first-world jurisdictions skip Level I entirely and put, as a minimum, stop signs on all minor streets because:

- stop signs are cheaper than engineering studies
- and as an added safety measure at the expense of very marginal convenience
- in these cases sight-triangles are still important



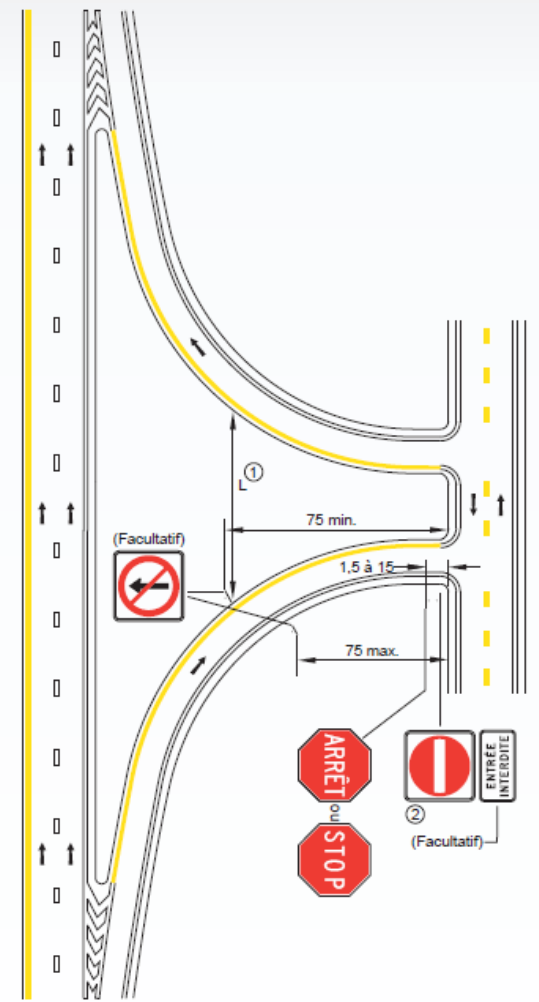


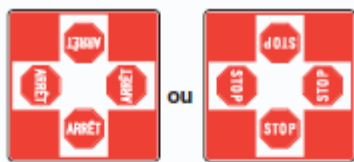
Milieu rural (m)		
	Min.	Max.
X	1,5	15,0
Y	1,0	3,5
Z	1,0	3,5

Milieu urbain (m)		
	Min.	Max.
X	1,5	15,0
Y	0,3	3,5
Z	0,3	3,5

- ① Le panneau « Interdiction d'aller tout droit » du côté gauche de la bretelle de sortie peut être installé lorsque la distance « L » entre les deux bretelles est d'au moins 12 mètres.
- ② Le panneau « Entrée interdite » ne doit pas être installé au dos du panneau « Arrêt » pour ne pas en altérer la forme, conformément aux dispositions de la section 1.7 du chapitre 1 des présentes normes. Par conséquent, le panneau « Entrée interdite » peut être installé sous le panneau « Arrêt » en respectant les dispositions de la section 1.13.3.1 du chapitre 1 des présentes normes ou être installé sur son propre support.

Note :
 – les cotes sont en mètres.





ou

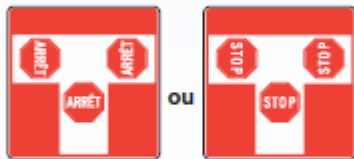
P-10-P-1



ou



D-40-3



ou

P-10-P-2



ou



D-40-4



ou

P-10-P-3



ou



D-40-5



D-10-1

That's all for today!