

Estimation of Capacity at Uncontrolled Intersections with and without Speed Breakers

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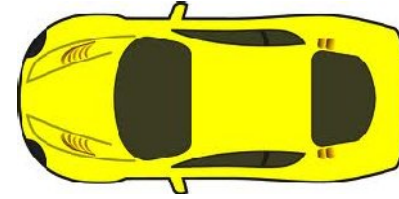
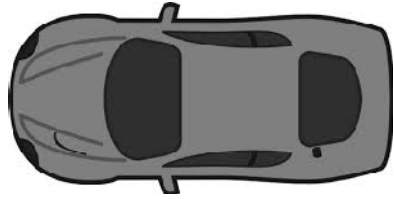
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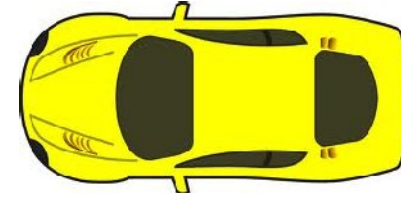
Introduction

- ❑ Unsignalised Intersection becomes major part of the Indian Roads. Various Methods have been developed to make capacity estimations for these intersections For eg Occupancy Time Method, Additive Conflict Flow method, etc.
- ❑ To evaluate Level of Service (LOS) of urban intersections, it is inevitable to consider also the non-motorized traffic, as on one hand these road users influence the motorized traffic and on the other hand pedestrians and bicyclists suffer delay caused by motorized traffic.

Gap


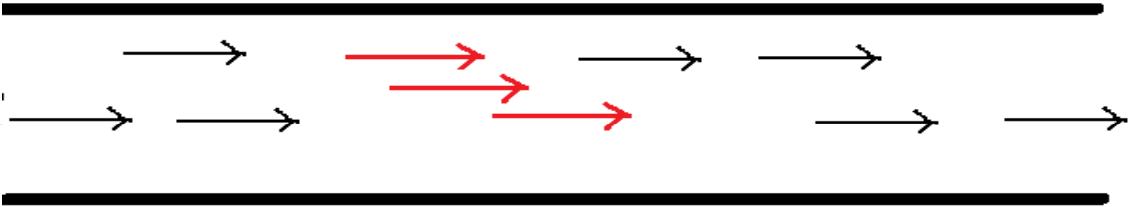
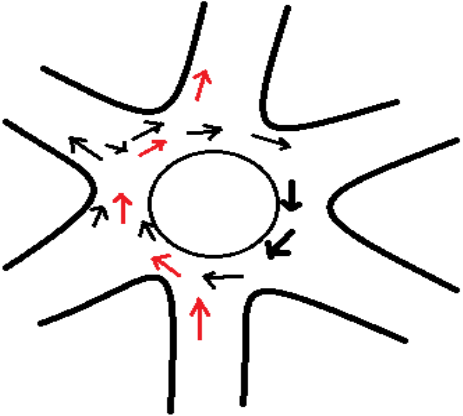


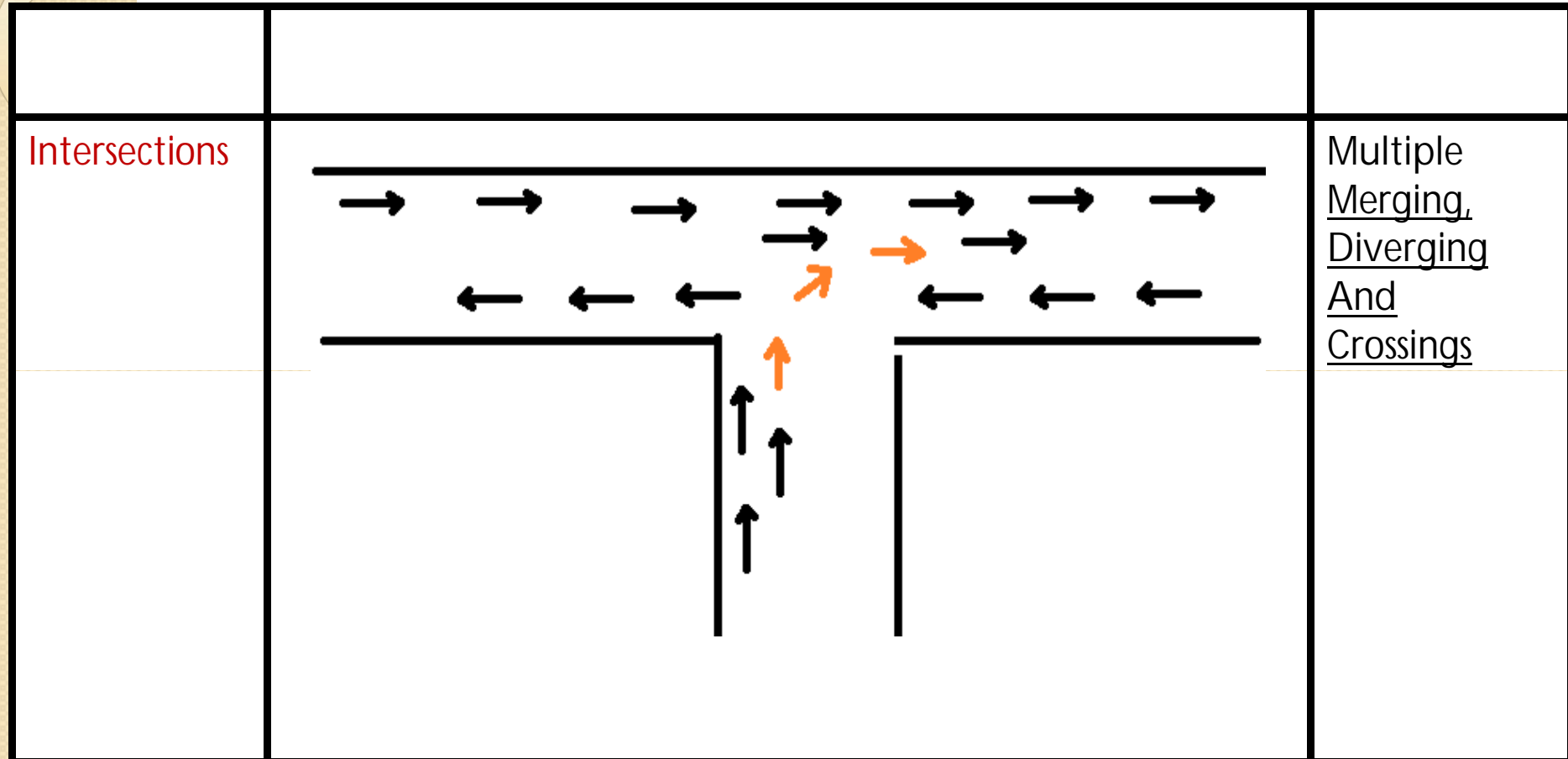
Lag



Gap Acceptance Theory

- ❑ When a driver makes a maneuver he looks for a gap which he thinks is sufficient to make a maneuver.
- ❑ If available gap is sufficient, he accepts it. If not, he rejects it and wait for the next acceptable gap.
- ❑ Therefore, gap acceptance theory can be applied where maneuverability is possible.
 - Un-signalized intersections
 - Roundabouts
 - Overtaking maneuver
 - U-turn

<p>U - Turn</p>		<p>Stopping followed by Merging</p>
<p>Overtaking</p>		<p><u>Diverging</u> followed by <u>Merging</u></p>
<p>Roundabout</p>		<p>Multiple <u>Merging</u>, <u>Diverging</u> And <u>Weaving</u></p>



This paper considers the case of Unsignalled Intersections 'with' and 'without' Speed Breakers

Literature Review

Approaches / Methods for Capacity Estimation of Unsignalised Intersections

Probabilistic Approach

Gap Acceptance Theory
Siegloch 1973, US HCM
2000, US HCM 2010

Deterministic Approach

Empirical Regression Analysis

(Kimber & Coombe 1980, Kyte et.al.
1991, Indonesia HCM 1993)

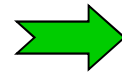
Conflict Matrix Method

(Prasetijo 2005, Brilon & Miltner 2005) 8

At unsignalized intersections as well as roundabouts

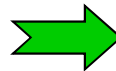
Critical gap is an engineering concept generally used for determination of capacity of individual movements at unsignalised intersections.

Greenshields (1934)



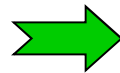
The gap accepted by 50% of the drivers

Raff & Hart
(1950)



The lag for which the number of accepted lags shorter than it is equal to the number of rejected lags longer than it.

HCM (2010)



minimum length of time interval that allows intersection entry to one minor stream vehicle.

Critical Gap Estimation Methods

- ❑ *Raff (1950)*
- ❑ *Lag (e.g., Solberg and Oppenlander 1966)*
- ❑ *Siegloch (1973)*
- ❑ *Harders (1976)*
- ❑ *Hewitt (1983)*
- ❑ *MLE (e.g., Troutbeck, 1992)*
- ❑ *Logit Model (e.g., Cassidy, 1995)*
- ❑ *Clearing Behavior (e.g., Ashalata & Chandra, S. 2011)*

Method	Data Requirements	Suitability
Modified Raff	Gap Data (accepted and rejected gaps)	❖ Under saturated conditions
Harders Method	Gap Data Only(accepted & total number gaps)	❖ Under saturated conditions
Logit	Gap Data (accepted and rejected gaps)	❖ Under saturated conditions

Method	Data Requirements	Suitability
Maximum Likelihood Method	Largest rejected & accepted gap in pair	<ul style="list-style-type: none"> ❖ Minor stream traffic is light ❖ Yield trivial solution if all drivers accept 1st gap offered without rejecting any gap
Clearing Behavior	Accepted Gap & Clearing Time	❖ Heterogeneous Traffic Conditions
Method deployed in Indo-HCM (2017)	Accepted Gap & Occupancy Time	❖ Heterogeneous Traffic Conditions

Major Studies on Unsignalised Intersections (1966 - 2014)

Heterogeneous

Author(s), Year	Factors affecting gap acceptance behavior
Sinha and Torniak (1971)	<u>major street speed</u> , type of manoeuvre and presence of <u>opposing traffic</u> and <u>vehicle type</u>
Katti (1982)	Critical gap differs mode among different modes based on <u>vehicle size</u> Smaller critical gap for smaller vehicles Percentage of slow moving modes in total traffic
Chakroborty and Kikuchi (1990)	The decision of a driver is rarely consistent, used fuzzy logic
Golias and Kanellaidis (1990)	Critical lag equals A times critical gaps is reasonable.

Author(s), Year	Highlights
Pant and Balakrishnan (1994)	type of control, the turning movements in both the major and the minor directions, size of gap, service time, stop type, vehicle speed, <u>queue in the minor direction</u> , and existence of vehicles in the opposing approach.
Shinar and Compton (2004)	characterized “aggressive driving”, as <ol style="list-style-type: none"><li data-bbox="913 1050 1265 1118">1. <u>honking</u>,<li data-bbox="913 1129 2018 1267">2. <u>cutting across one or more lanes in front of other vehicles</u>,<li data-bbox="913 1278 1749 1347">3. <u>passing on the shoulders</u>

Author(s), Year	Factors affecting gap acceptance behavior
Kaysi and Abbany (2007)	<p>probability of “forcing” decreases with increase in opposing traffic speed</p> <p>age, car performance, and average speed on the major road are the major determinants of aggressive behavior</p> <p>the total waiting time of the driver while waiting for an acceptable gap is of little significance</p>
Guo and Lin (2011)	exponential model of rejected gap proportion is more often practical than the linear model

Author(s), Year	Factors affecting gap acceptance behavior
Ashalata. and Chandra(2011)	<p>CG calculated using <u>clearing behavior</u> of vehicles in conjunction with gap acceptance data</p> <p>the under mixed traffic, where lane discipline is not strictly observed, gap acceptance is more a function of <u>forced gaps</u> created by the minor street vehicles</p>
Abhishek et al. (2014)	<p>Time gap at exit line is always larger than the time gap at entry line</p> <p>Gap should be measure at in front of the median of minor road</p>

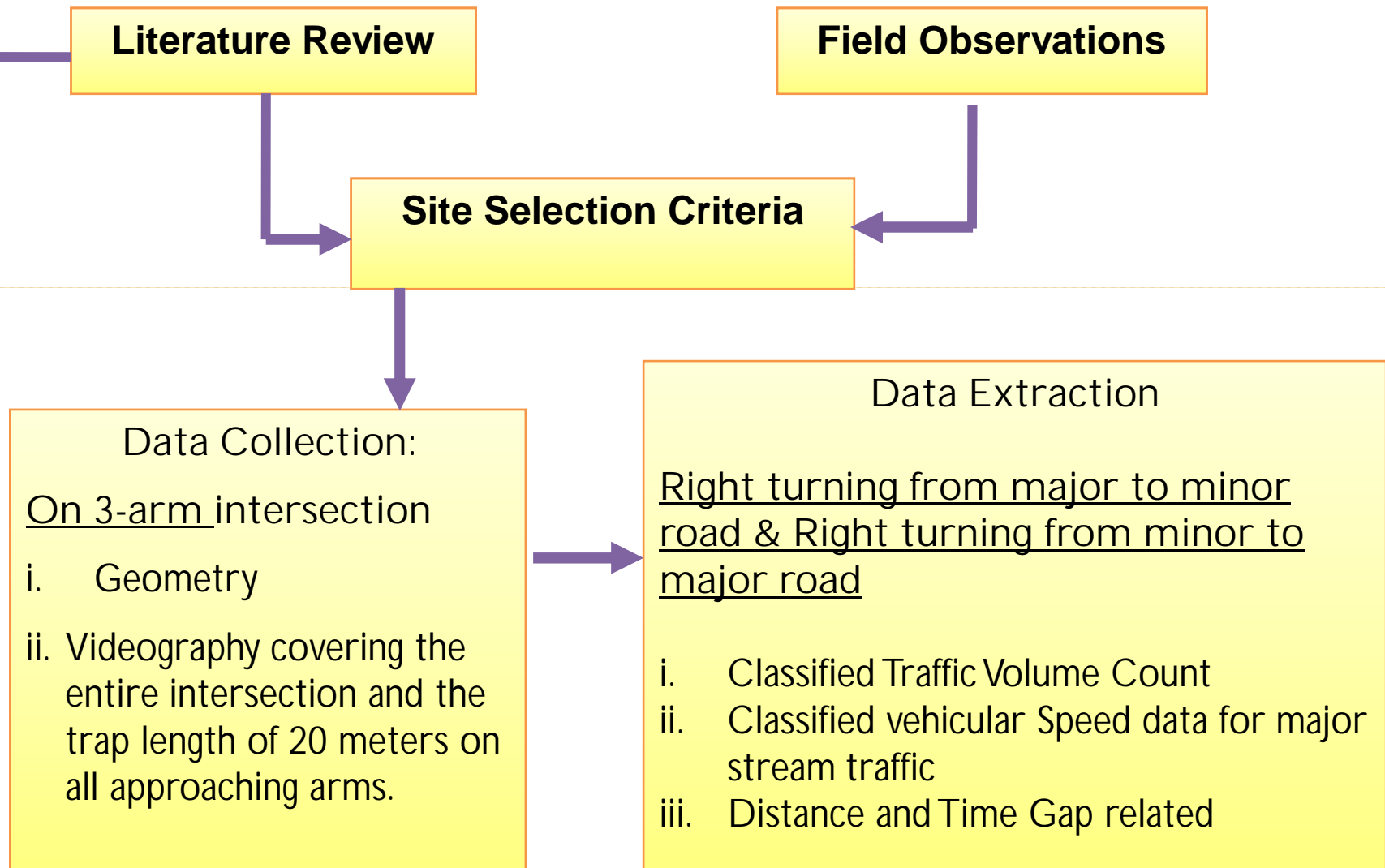
Need of study

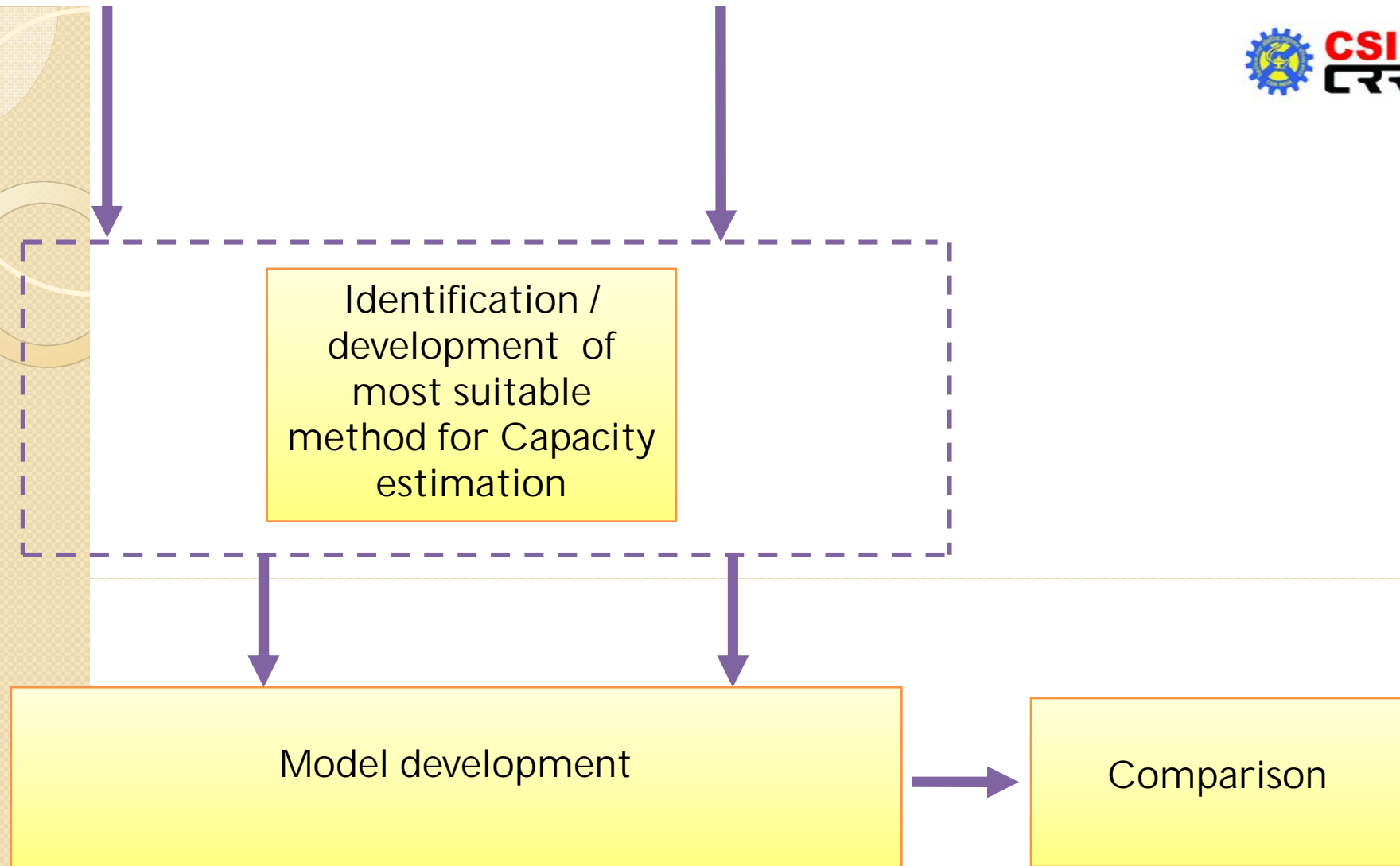
- ❑ *A model is proposed to be developed considering all for mixed traffic*
- ❑ *Studies on significance of distance gap and time gap for Indian scenario is very difficult.*

Objectives of the Study

- ❑ Calculation of capacity of un-signalized intersection using Occupancy Time Method and Conflict Matrix Method.
- ❑ Comparison of results using the two methods and determining the method which suits Indian road Conditions.
- ❑ Calculation of capacity of un-signalized intersection with and without speed breakers.

Methodology





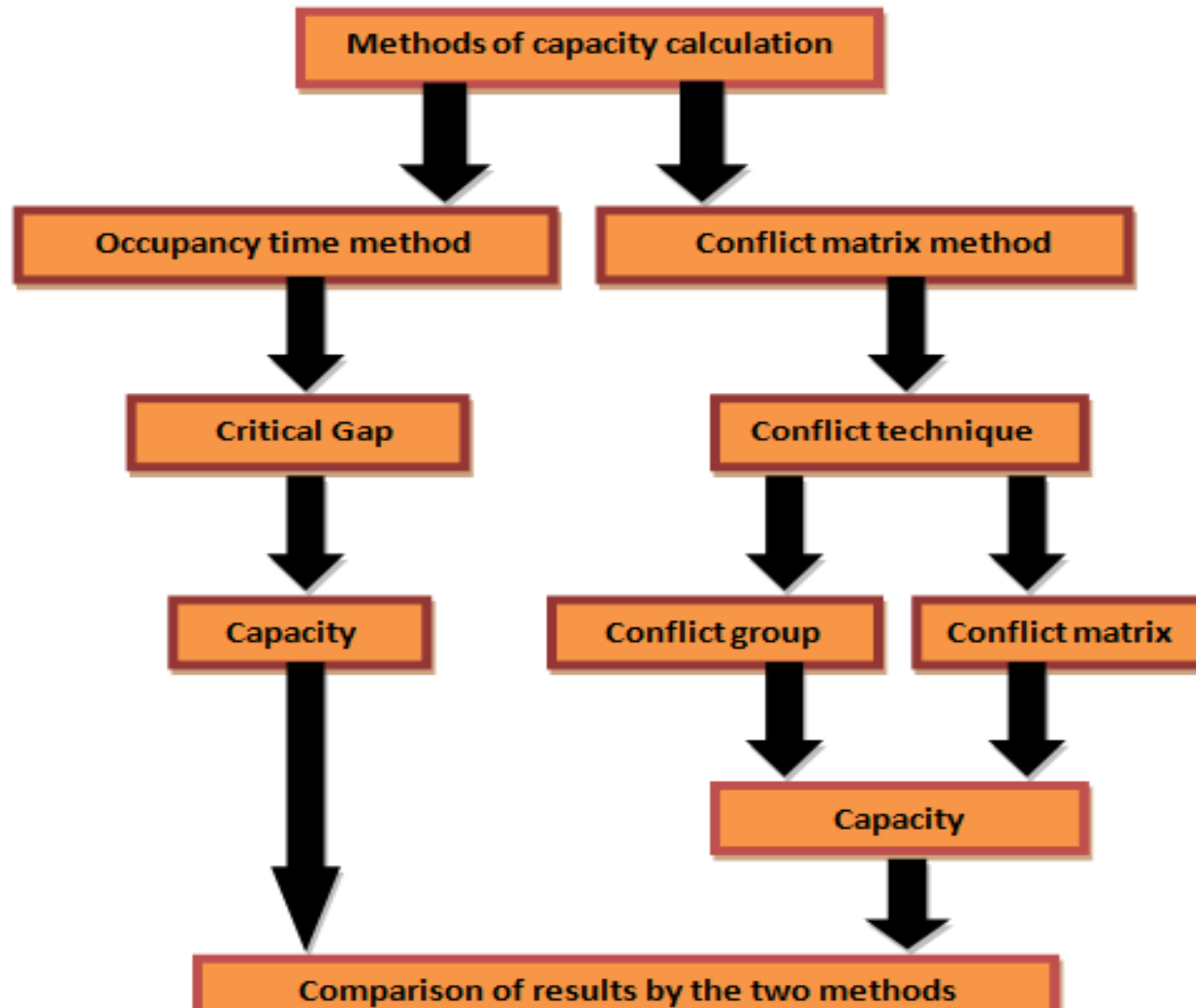
Study Area



Three arm Intersection at Faridabad

Video Data collected on a typical working day for peak hour.

Sr. No	Number & Name of the Intersecting Arm	Width of Intersecting arms (in meter)	Median (if any) width on all intersecting arms (in meter)	Landuse activities (if any) within 100 m on all arms
1				
	Towards NHAI	9	2 meter	No Landuse Activities
	Towards Airport	9	2 meter	No Landuse Activities
	Toward AIFF	9	1 meter	No Landuse Activities



Methodology deployed in INDO-HCM, (2017) using OTM

Step 1: Input data: Geometry data and Traffic Data

Step 2: Convert Traffic Volume into PCU's

Step 3: Calculate Conflicting Traffic Flow

Step 4: Determine Critical Gap

Step 5: Calculate Capacity of a Non- Priority Movement

Step 6: Level of Service

Capacity (C_x) for any movement at an uncontrolled intersection can be computed according to the gap acceptance model given in equation below.

Capacity of a movement can be deduced from the estimated values of critical gap, follow-up time and conflicting flow rates.

$$C_x = a \times V_{cx} \frac{e^{-V_{cx}(t_{cx}-b)/3600}}{1 - e^{-V_{cx}t_{fx}/3600}}$$

Where; C_x - Capacity of movement 'x' in PCU/hour

V_{cx} - Conflicting flow rates corresponding to movement 'x' in PCU/hour

t_{cx} - Critical gap for standard passenger car for movement 'x'

t_{fx} - follow up time for movement 'x'

'a' and 'b' - adjustment factors based on intersection geometry.

Critical gap for movement 2 using OTM

Vehicle Class	Small Car	Big Car	Two Wheeler	Overall Gap
Critical Gap (seconds)	6.1	5.3	3.9	6.0

Critical gap for movement 6 using OTM

Vehicle Class	Small Car	Big Car	Two Wheeler	Overall Gap
Critical Gap (seconds)	5.0	6.7	4.3	5.7

The Conflict Matrix Method

- ❑ *This is a new method which does not depend on critical gap calculation in order to make capacity estimation.*
- ❑ *Also different conflicting movements are given different values on the basis of priority.*
- ❑ *Pedestrians and cyclists are also considered in priority assignment.*

Traffic movements and priorities

- ❑ *Turning vehicles leaving the intersection have to give way to the pedestrians.*
- ❑ *Vehicles entering the intersection have the right of way over the pedestrians.*
- ❑ *Through traffic has the right of way over the pedestrians.*
- ❑ *Pedestrians on zebra crossing have right over all vehicular movements.*

Assignment of priorities

- *If one movement interferes with another one, the cell of the matrix contains a value A_{ij} .*
- *If $A_{ij} = 1$, then movement 'i' has priority over subject movement 'j'.*
- *If however $A_{ij} = 0$, then movement 'i' has to give way to 'j'.*

Traffic movements

- ❑ *Movement 1 -- major through*
- ❑ *Movement 2 -- major right*
- ❑ *Movement 3 -- major through*
- ❑ *Movement 4 -- major left*
- ❑ *Movement 5 -- minor left*
- ❑ *Movement 6 -- minor right*

Conflict Matrix

A_{ij}	1	2	3	4	5	6
1						1
2			0	0		1
3		1			1	1
4		1				
5			0			
6	0	0	0			

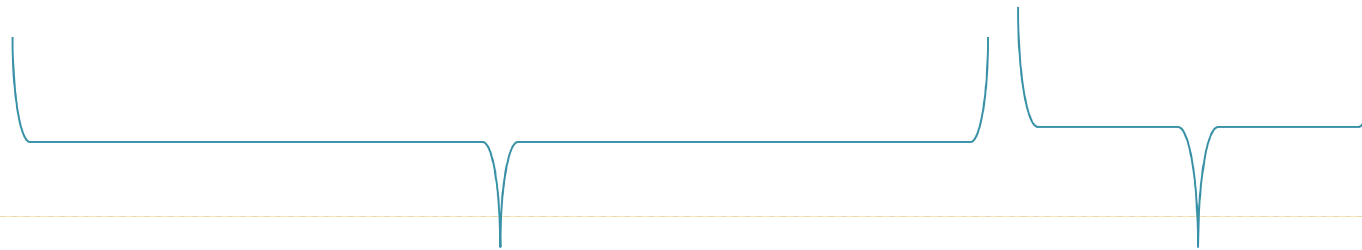
Conflict Groups

CONFLICT GROUP (K)	MOVEMENTS
A	1 and 6
B	2,3 and 6
C	3 and 5
D	2 and 4

Capacity Calculations

$$C_j = \frac{3600}{t_{s,j}} \left[\prod_k \left(1 - \frac{1}{3600} \sum_{i=D_k} (A_{i,j} \cdot q_i \cdot t_{s,i}) \right) \right] \cdot e^{-1/3600 \sum (A_{ij} Q_i T_{a,i})}$$

(HCM, 2010)



$$C_{max,j} \quad p_o$$

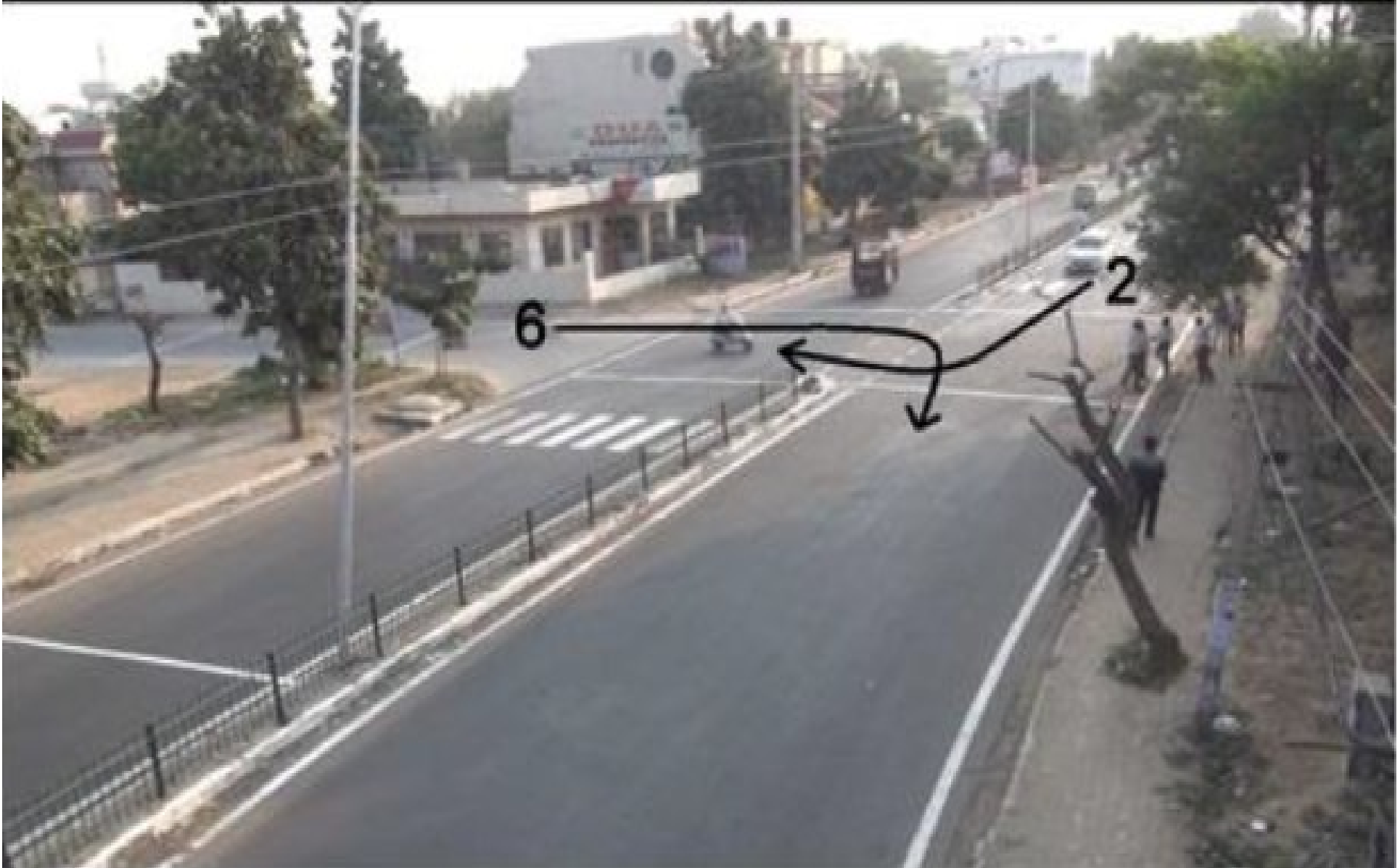
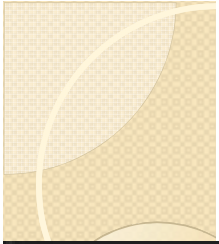
- Where $C_{max,j}$ is the capacity for minor movement without interference from other traffic movements and p_o is the probability that the conflict area is not blocked.

Results using CMM

Movements	Flow Value (vehicle per hour)	Occupancy Time (seconds)	Block Time (seconds)	Capacity
1-1	900	2	2	1800
1-2	280	3	0	430
3-3	2000	1.5	2	2400
3-4	600	1	0	1200
5-5	500	1	0	1100
5-6	250	3	0	290

Comparison

CAPACITY	Using OTM (PCUs/hour)	Using CMM (pcu/hour)	Field Observations (pcu/hour)
Movement 2	450	430	445
Movement 6	315	290	305



Comparison of Critical Gap values of Intersection 'with' or 'without' Speed Breakers from Minor to Major Approach

CRITICAL GAP (Seconds)	With Speed Breaker (pcu/hour)	Without Speed Breaker (pcu/hour)
	5.2	5.0

Comparison of capacity values of Intersection 'with' and 'without' Speed Breakers from Minor to Major Approach

CAPACITY	With Speed Breaker (PCUs/hour)	Without Speed Breaker (pcu/hour)
	340	397

Conclusion



- Though both the methods yielded almost similar capacity values, it was felt prudent to employ either of the two methods which has yielded conflicting turning flows nearer to the field observation for further analysis on the non-base section with Speed Breaker. In this regard, it is quite evident that **Occupancy Time Method yielded more reliable results** as the error in prediction is ranging between 1.1 to 3.3 % for the two conflicting movements.
- Moreover, the study has revealed that the presence of Speed breaker on the minor approach of an intersection increases the critical gap values by about 4 % with corresponding reduction in capacity to the tune of 13 % which amounted to a reduction of about 60 PCUs per hour due to the presence of Speed Breaker.

Comparison of the two methods for Critical Gap

Occupancy Time Method	Conflict Matrix Method
Critical Gap Calculation for capacity estimation	No critical Gap Calculation required.
No specific priorities assigned to different conflicting movements.	Proper matrix is made according to the assigned priorities.
Considers only the time duration for which the vehicle physically occupies the critical area.	In addition to the occupancy time , it also considers the time duration for which the major stream vehicle is blocking the conflict area in advance of its arrival.
Limited focus on driver behavior.	More focus on driver behavior.

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