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PERFORMANCE EVALUATION OF UNSIGNALIZED UNCONTROLLED INTERSECTION UNDER MIXED TRAFFIC CONDITIONS

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Abstract— The main goal of this study is to find the capacity of unsignalized intersection using conflict technique method and to compare the results with HCM(2000) procedure. Conflict technique is developed to overcome these shortcomings. Surveillance equipment is used to obtain the required data, such as traffic volume flow and speed. The speed of vehicle is used to calculate the capacity of vehicular movements for each conflict group. Result comparison is made between the conflict method, observed values and the HCM 2000. Pedestrians are not considered in this study, further study can be focused on pedestrian movements along with vehicle movements.

Key words: conflict method, conflict group , unsignalized intersections.

I. INTRODUCTION

Traffic conflicts between vehicular movements are created when two or more roads crossed each other. Such conflicts may cause delay and traffic congestion with the possibility of road accidents. Each intersection requires traffic control. It is regulated with stop signs, traffic lights, and roundabout. Traffic and transportation in developing countries are also very different to developed countries since traffic composition and level of road side activities are in contrast to developed countries. Traffic rules, for examples, like give way or lane discipline etc. are neglected in most cases. Drivers are more aggressive so that a gap acceptance behavior is rather uncommon. If there is any critical gap which is likely to be accepted, then this is small with about 2 seconds. In this view, vehicles contribute to variation in speed behavior ranging from slow vehicles to rather fast–moving cars. Typical for developing countries, is there is also a great number of activities occurring at the edge of the road, both on the roadway and shoulders and sidewalks. In comparison with cities in the West, these cities consume less transport energy. Characteristics of this urban centre are high density, mixed land use, short trip distances, and high share of walking and non–motorized transport. Traffic, thus, consists of many motorized two–wheelers, motorized three–wheelers, bicycles, non–motorized three–wheelers, cars, buses and pull carts. **Satish Chandra and Upendra Kumar (2003)** have proposed a concept to estimate the PCU factor for a mode in a mixed traffic environment utilizing area concept. This was attributed to the greater freedom of movement on wider roads and therefore a greater speed differential between a car and a vehicle type. **Ebrahim ,Zeina and Reza(2004)** proposed a simulation model for vehicular dynamics using probabilistic cellular automata and evaluated the delay experienced by the traffic for specified time intervals .**Chandra & Sinha (2001) And Chandra & Kumar (2003)** stated that the capacity on two–lane roads was influenced by directional split of traffic. HCM (1997) determined the capacity of a road segment based on basic capacity with various adjustment factors such as carriageway width, kerb and shoulders, median and directional split, side friction and city size. In such a case, it is very difficult to measure the capacity due to poor lane discipline which exists including a tendency to"cut corners" while drivers making right–turn which results in a blockage of other traffic movements.

II. DATA COLLECTION

The data for this study was collected manually at three T-leg intersections in the Hyderabad city. Each of the intersections was different from each other in traffic performance and geometric design. Several aspects including traffic flow, road environment, speed, geometric design of the intersections, roadside activities, and type of areas at the major and the minor roads were considered at the given intersections during field investigation. Each intersection was investigated during two expected peak hour periods - in the morning (06.30 – 07.30) am and in the afternoon (16.30 – 17.30) pm.

III. VEHICLE CLASSIFICATION

The study from Bang et al. (1995) has been carried out with the following seven vehicle classes and the criteria for vehicles were distinguished .In this study, the type of vehicles is given in five main classes (LT, MHV, LV, MC, UM) while each main class could consist of several other vehicles. Furthermore, those main classes are considered based on the speed performance corresponding to the static (width and lengths) and dynamic (speed) characteristics. Vehicle types were grouped as LT (Light Trucks), MHV (Medium Heavy Vehicles), LV (Light Vehicles), MC (Motorcycle) and UM (Un– Motorized). This grouping is mainly based on the dynamic characteristics of each type of vehicle, e.g. speed, which one performed slightly different with another.

Table 1 Vehicle Categories for Analysis

Vehicles	Category
Truck 3-axles	Light truck(LT)
Truck 2-axles	Medium heavy vehicle-truck (MHV1)
Minibus	Medium heavy vehicle-minibus(MHV2)
Car	Light vehicle(LV)
Motorcycle	Motorcycle(MC)
Bicycles	Unmotorized – bicycles (UM1)
Rickshaws	Unmotorized – Rickshaws (UM2)
Tricycles	Unmotorized – Tricycles (UM3)
Pushcart	Unmotorized – Pushcart (UM4)

IV. CONFLICT TECHNIQUE METHOD

The proposed analyses are based on interactions among streams in terms of speed and flow. Therefore, the parameters of each stream should be analyzed considering the effect of other streams. The scheme consisted of six streams (C–A, C–B, B–C, B–A, A–C, A–B) and six conflict points (1, 2, 3, 4, 5, 6). Furthermore, it is proposed to have six groups of conflicts (I, II, III, IV, V, and VI) which include all streams' conflicts and each group with its own subject stream, as shown in Figure 3.7 and Table 3.1. Since the study did not use any of the priority rules, six subject streams were defined for analysis. Each stream remains the subject stream of its conflict group and was included in the analysis to find maximum flow. In general, the conflict groups were defined as the subject streams which crossed conflict movement with other streams, e.g. subject stream C–A would only cross one conflict movement with stream B–A, but subject stream B–A would cross more than one stream (C–A, C–B and A– C).

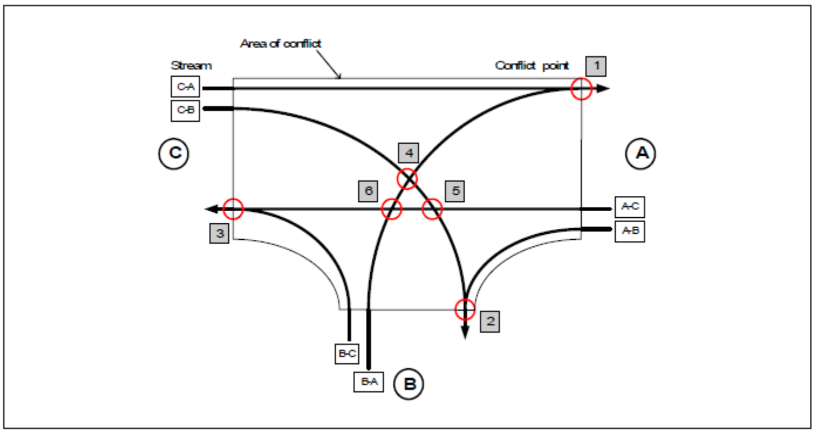

Figure 1 Scheme of conflict of traffic streams

Table 2 Interactions of Traffic Streams for Each Conflict Group

Group of Conflict	Subject Stream	Conflict Point	Streams Involved
I	C – A	1	C – A, B – A
II	C – B	2,4,5	C – B, B – A, A – C, A – B
III	B – C	3	B – C, A – C
IV	B – A	1,4,6	B – A, A – C, C – B, C – A
V	A – C	3,5,6	A – C, C – B, B – A, B – C
VI	A – B	2	A – B, C – B

For the present study, it is necessary to consider the traffic flow count for each of the six streams at intersections. Therefore, the scheme of three–leg unsignalized intersections was constructed for simplification and further analysis as it can be seen at Figure 3.1. Leg A and leg C were treated as the major roads because the traffic flows from these legs were larger than others without any implication to the priority rule. It was observed that the number of vehicles from legs C and A were higher than one from the leg B, thereby justifying leg A and leg C to be considered as majors road and leg B as minor road. Further analysis was made in this study based on observed data at three–leg signalized intersections. This type of intersections contains less conflict streams compared to four–leg unsignalized intersections. The study described the intersections which consist of six streams, six conflict points (I, II, III, IV, V, VI), and six groups of conflicts (C – A, C – B, B – C, B – A, A – C, A – B) (see also Table 3.1). Previously, it has been discussed that observation could only measure the average speed of each stream that by unusual measurement techniques only the average speed of each movement while crossing the intersection can be estimated. Therefore, the new empirically based method relies on the average speed of subject streams and the volume of each stream to determine the capacity as the maximum possible volume at the intersection. As an important parameter, speed and flow of each stream were measured and analyzed for all intersections. Each of them was observed on the basis of each group of conflict. Speed and flow descriptions of each conflict points.

The following coefficients are defined:

$f_1 = Q_{C\text{-}A}/Q_{B\text{-}A}$,

$f_2 = Q_{C\text{-}B}/Q_{A\text{-}B}$,

$f_3 = Q_{B\text{-}C}/Q_{A\text{-}C}$,

$f_4 = Q_{C\text{-}B}/Q_{B\text{-}A}$,

$f_5 = Q_{A\text{-}C}/Q_{C\text{-}B}$,

$f_6 = Q_{A\text{-}C}/Q_{B\text{-}A}$

Then for the each conflict the model is described by set of equations.

At the conflict point I,

$V_I = a_I - b_I.Q_{C\text{-}A} - C_I.Q_{B\text{-}A}$ ……………………………………………..…....(1)

$Q_{C\text{-}A}{}^{(1)}=\{[(a_1\text{-}v_1{}^{'})/(b_1+(c_1/f_1))],0\}_{MAX}$

$Q_{B\text{-}A}{}^{(1)}=\{[Q_{C\text{-}A}{}^{(1)}/F_1],0\}_{MAX}$

At the conflict point II ,

$V_{I\,I}= a_{II} - b_{II}.Q_{C\text{-}B} - c_{II}.Q_{A\text{-}B}$ ……………………………………...…...……..(2)

$Q_{C\text{-}B}{}^{(2)}=\{[(a_{II}\text{-}v_{1I}{}^{'})/(b_{II}+(c_{II}/f_2))],0\}_{MAX}$

$Q_{B\text{-}A}{}^{(2)}=\{[Q_{C\text{-}B}{}^{(2)}/F_2],0\}_{MAX}$

At the conflict point III ,

$V_{III} = a_{III} - b_{III}.Q_{B\text{-}C} - c_{III}.Q_{A\text{-}C}$ …………………………………………………....(3)

$Q_{B\text{-}C}{}^{(3)}=\{[(a_{III}\text{-}v_{III}{}^{'})/(b_{III}+(c_{III}/f_3))],0\}_{MAX}$

$Q_{A\text{-}C}{}^{(3)}=\{[Q_{B\text{-}C}{}^{(3)}/f_3],0\}_{MAX}$

At the conflict point IV ,

$V_{IV}= a_{IV} - b_{IV}.Q_{C\text{-}B} - c_{IV}.Q_{B\text{-}A}$ ……………………………………………………(4)

$Q_{C\text{-}A}{}^{(4)}=\{[(a_{IV}\text{-}v_{IV}{}^{'})/(b_{IV}+(c_{IV}/f_4))],0\}_{MAX}$

$Q_{B\text{-}A}{}^{(4)}=\{[Q_{C\text{-}B}{}^{(4)}/F_4],0\}_{MAX}$

At the conflict point V,

$V_V = a_V – b_V.Q_{C-B} – c_V.Q_{A-C}$ ……………………………………………..............(5)

$Q_{C-B}^{(5)}=\{[(a_V-v_V^{'})/(b_V+(c/f_5))],0\}_{MAX}$

$Q_{A-C}^{(5)}=\{[Q_{C-A}^{(5)}/f_5],0\}_{MAX}$

At the conflict point VI ,

$V_{VI} = a_{VI} - b_{VI}.Q_{B-A} - c_{VI}.Q_{A-C}$ …………………………………………………...(6)

$Q_{B-A}^{(6)}=\{[(a_{VI}-v_{VI}^{'})/(b_{VI}+(c_{VI}/f_6))],0\}_{MAX}$

$Q_{A-C}^{(6)}=\{[Q_{B-A}^{(6)}/f_6],0\}_{MAX}$

The considered speeds of each traffic streams are influenced by other from the method we have following equations

$V_{C-A} = a_{C-A} – b_{C-A}.Q_{C-A}- b_{B-A}.Q_{B-A}$

$V_{C-B} = a_{C-B} – b_{C-B}.Q_{C-B}- b_{B-A}.Q_{B-A-} b_{A-B}.Q_{C-B}- b_{A-C}.Q_{A-C}$

$V_{B-C} = a_{B-C} – b_{B-C}.Q_{B-C}- b_{A-C}.Q_{A-C}$

$V_{B-A} = a_{B-A} – b_{B-A}.Q_{B-A} – b_{A-C}.Q_{A-C –} b_{C-A}.Q_{C-A}- b_{C-B}.Q_{C-B}$

$V_{A-C} = a_{A-C} – b_{A-C}.Q_{A-C} – b_{C-B}.Q_{C-B –} b_{B-C}.Q_{B-C}- b_{B-A}.Q_{B-A}$

$V_{A-B} = a_{A-B} – b_{A-B}.Q_{A-B}- b_{C-B}.Q_{C-B}$

The following flow analysis were described as follows if streams' flow Q_{C-A} reaches its maximum flow at

$V_{C-A}^{'} = a_{C-A} – b_{C-A}.Q_{C-A}^{(1)} - b_{B-A}.[Q_{C-A}^{(1)}/f_1]$ ....(7)

the maximum flow of all streams are

$Q_{C-A}^{(1)} = \{[a_{C-A} - V_{C-A}^{'}/(b_{C-A}+(b_{B-A}/f_1))],0\}_{MAX}$

$Q_{B-A}^{(1)}= \{[Q_{C-A}^{(1)}/f_1],0\}_{MAX}$

$Q_{C-B}^{(1)}= \{[f_4 .Q_{B-A}^{(1)}],0\}_{MAX}$

$Q_{A-C}^{(1)}= \{[f_6 .Q_{B-A}^{(1)}],0\}_{MAX}$

$Q_{A-B}^{(1)}= \{[Q_{C-B}^{(1)}/f_2],0\}_{MAX}$

$Q_{B-C}^{(1)}= \{[f_3 .Q_{A-C}^{(1)}],0\}_{MAX}$

and the maximum flow of the intersection is

$Q_{int-MAXIMUM}^{(1)} = Q_{C-A}^{(1)}+ Q_{B-A}^{(1)} +Q_{C-B}^{(1)} +Q_{C-B}^{(1)} +Q_{A-B}^{(1)} +Q_{B-C}^{(1)}$.....................(8)

If streams' flow Q_{C-B} reaches its maximum flow at

$V_{C-B} = a_{C-B} – b_{C-B}.Q_{C-B}^{(2)}- b_{B-A}.(Q_{C-B}^{(2)}/f_{4)\ -}\ b_{A-B}.(f_{5.}\ QC_{-B}^{(2)}) - b_{A-B}.(Q_{C-B}^{(2)}/f_2)$

the maximum flow of all streams is

$Q_{C-B}^{(2)} = \{[a_{C-B} - V_{C-B}^{'}/(b_{C-B}+(b_{B-A}/f_4))],0\}_{MAX}$

$Q_{A-B}^{(2)}= \{[Q_{C-B}^{(2)}/f_2],0\}_{MAX}$

$Q_{A-C}^{(2)}= \{[f_5 .Q_{C-B}^{(2)}],0\}_{MAX}$

$Q_{B-A}^{(2)}= \{[Q_{C-B}^{(2)}/f_4],0\}_{MAX}$

$Q_{B-C}^{(2)}= \{[f_3 .Q_{A-C}^{(1)}],0\}_{MAX}$

$Q_{C-A}^{(1)}= \{[f_1 .Q_{B-A}^{(1)}],0\}_{MAX}$

and the maximum flow of the intersection is

$Q_{int-MAXIMUM}^{(2)} = Q_{C-A}^{(2)}+ Q_{B-A}^{(2)} +Q_{C-B}^{(2)} +Q_{C-B}^{(2)} +Q_{A-B}^{(2)} +Q_{B-C}^{(2)}$.....................(9)

If streams' flow Q_{B-} reaches its maximum flow at

$V_{B-C}^{'} = a_{B-C} – b_{B-C}.Q_{B-C}^{(4)}- b_{A-C}.[Q_{A-C}^{(4)}/f_3]$

$Q_{B-C}^{(3)} = \{[a_{C-B} – V_{B-C}^{'}/(b_{B-C}+(b_{A-C}/f_3))],0\}_{MAX}$

$Q_{A-C}^{(3)}= \{[Q_{B-C}^{(3)}/f_3],0\}_{MAX}$

$Q_{C-B}^{(3)}= \{[Q_{A-C}^{(3)}/f_5],0\}_{MAX}$

$Q_{A-B}^{(3)} = \{[\ Q_{C-B}^{(3)}/f_2],0\}_{MAX}$

$Q_{B-A}^{(3)} = \{[\ Q_{A-C}^{(3)}/f_6],0\}_{MAX}$

$Q_{C-A}^{(3)} = \{[\ f_1 .Q_{B-A}^{(3)}],0\}_{MAX}$

and the maximum flow of the intersection is

$Q_{int\text{-}MAXIMUM}^{(3)} = Q_{C-A}^{(3)} + Q_{B-A}^{(3)} + Q_{C-B}^{(3)} + Q_{C-B}^{(3)} + Q_{A-B}^{(3)} + Q_{B-C}^{(3)}$....................(10)

If streams' flow Q_{B-A} reaches its maximum flow at

$V_{B-A}' = a_{B-A} - b_{B-A}.Q_{B-A}^{(4)} - b_{C-A}.[f_1.Q_{B-A}^{(4)} - b_{C-B}.(f_4.Q_{B-A}^{(4)}) - b_{A-C}.(f_6 . Q_{C-B}^{(4)}$

the maximum flow of all streams is

$Q_{B-A}^{(4)} = \{[\ a_{B-A} - V_{B-A}'/(b_{B-A}+(\ b_{A-A}.f_4))],0\}_{MAX}$

$Q_{C-A}^{(4)} = \{[\ f_1 .Q_{B-A}^{(4)}],0\}_{MAX}$

$Q_{C-B}^{(4)} = \{[\ f_4 .Q_{B-A}^{(4)}],0\}_{MAX}$

$Q_{A-C}^{(4)} = \{[\ f_6 .Q_{B-A}^{(4)}],0\}_{MAX}$

$Q_{B-C}^{(4)} = \{[\ f_3 .Q_{A-C}^{(4)}],0\}_{MAX}$

$Q_{A-B}^{(4)} = \{[\ Q_{C-B}^{(4)}/f_2],0\}_{MAX}$

and the maximum flow of the intersection is

$Q_{int\text{-}MAXIMUM}^{(4)} = Q_{C-A}^{(4)} + Q_{B-A}^{(4)} + Q_{C-B}^{(4)} + Q_{C-B}^{(4)} + Q_{A-B}^{(4)} + Q_{B-C}^{(4)}$....................(11)

If streams' flow Q_{A-C} reaches its maximum flow at

$V_{A-C}^{(5)} = a_{A-C} - b_{A-C}.Q_{A-C}^{(5)} - b_{C-B}.(Q_{C-B}^{(5)}/f_5) - b_{B-A}.(Q_{A-C}^{(5)}/f_6) - b_{B-C}.(f_3.Q_{A-C}^{(5)})$

The maximum flow of all streams is

$Q_{A-}^{(5)} = \{[\ a_{A-C} - V_{A-C}'/(b_{A-C}+(\ b_{C-B}.f_6))],0\}_{MAX}$

$Q_{B-C}^{(5)} = \{[\ f_3 .Q_{A-C}^{(5)}],0\}_{MAX}$

$Q_{C-B}^{(5)} = \{[\ Q_{A-C}^{(5)}/f_5],0\}_{MAX}$

$Q_{B-A}^{(5)} = \{[\ Q_{A-C}^{(5)}/f_6],0\}_{MAX}$

$Q_{A-B}^{(5)} = \{[\ Q_{C-B}^{(5)}/f_2],0\}_{MAX}$

$Q_{B-A}^{(5)} = \{[\ f_1 .Q_{B-A}^{(5)}],0\}_{MAX}$

and the maximum flow of the intersection is

$Q_{int\text{-}MAXIMUM}^{(5)} = Q_{C-A}^{(5)} + Q_{B-A}^{(4)} + Q_{C-B}^{(5)} + Q_{C-B}^{(5)} + Q_{A-B}^{(5)} + Q_{B-C}^{(5)}$....................(12)

If streams' flow Q_{A-B} reaches its maximum flow at $V_{A-B}' = a_{A-B} - b_{A-B}.Q_{A-B}^{(6)} - b_{C-B}.(f_2.Q_{A-B}^{(6)}$

The maximum flow of all streams is

$Q_{A-B}^{(6)} = \{[\ a_{C-A} - V_{C-A}'/(b_{C-A}+(\ b_{B-A}/f_1))],0\}_{MAX}$

$Q_{C-B}^{(6)} = \{[\ 2_5 .Q_{A-B}^{(6)}],0\}_{MAX}$

$Q_{A-C}^{(6)} = \{[\ f_5 .Q_{C-B}^{(6)}],0\}_{MAX}$

$Q_{B-A}^{(6)} = \{[\ Q_{C-B}^{(1)}/f_4],0\}_{MAX}$

$Q_{C-A}^{(6)} = \{[\ f_1 .Q_{B-A}^{(6)}],0\}_{MAX}$

$Q_{B-C}^{(6)} = \{[\ f_3 .Q_{A-C}^{(6)}],0\}_{MAX}$

and the maximum flow of the intersection is

$Q_{int\text{-}MAXIMUM}^{(6)} = Q_{C-A}^{(6)} + Q_{B-A}^{(6)} + Q_{C-B}^{(6)} + Q_{C-B}^{(6)} + Q_{A-B}^{(6)} + Q_{B-C}^{(6)}$....................(13)

The total maximum flow of the intersection is the least maximum flow from all possible maximum flows, Qint-Maximum $C_{int} = \{Q_{int\text{-}MAXIMUM}^{(1)}, Q_{int\text{-}MAXIMUM}^{(2)}, Q_{int\text{-}MAXIMUM}^{(3)}\ Q_{int\text{-}MAXIMUM}^{(4)}\ Q_{int\text{-}MAXIMUM}^{(5)}\ Qint_{MAXIMUM}^{(6)})_{MIN}$…...(14)

In order to simplify the calculation and performance for data and results, a matrix for capacity analysis of the total intersection

Table 3 Maximum flow of intersection

Speed at the maximum flows subject stream	Maximum flows of subject stream	Q_{C-A}	Q_{C-B}	Q_{B-C}	Q_{B-A}	Q_{A-C}	Q_{A-B}	Total maximum flow at intersection
V_{C-A} ‘	$Q_{C-A}^{(1)}$	$Q_{C-A}^{(1)}$	$Q_{C-B}^{(1)}$	$Q_{B-C}^{(1)}$	$Q_{B-A}^{(1)}$	$Q_{A-C}^{(1)}$	$Q_{A-B}^{(1)}$	$C^{(1)}$
V_{C-B} ‘	$Q_{C-B}^{(2)}$	$Q_{C-A}^{(2)}$	$Q_{C-B}^{(2)}$	$Q_{B-C}^{(2)}$	$Q_{B-A}^{(2)}$	$Q_{A-C}^{(2)}$	$Q_{A-B}^{(2)}$	$C^{(2)}$
V_{B-C} ‘	$Q_{B-C}^{(3)}$	$Q_{C-A}^{(3)}$	$Q_{C-B}^{(3)}$	$Q_{B-C}^{(3)}$	$Q_{B-A}^{(3)}$	$Q_{A-C}^{(3)}$	$Q_{A-B}^{(3)}$	$C^{(3)}$
V_{B-A} ‘	$Q_{B-A}^{(4)}$	$Q_{C-A}^{(4)}$	$Q_{C-B}^{(4)}$	$Q_{B-C}^{(4)}$	$Q_{B-A}^{(4)}$	$Q_{A-C}^{(4)}$	$Q_{A-B}^{(4)}$	$C^{(4)}$
V_{A-C} ‘	$Q_{A-C}^{(5)}$	$Q_{C-A}^{(5)}$	$Q_{C-B}^{(5)}$	$Q_{B-C}^{(5)}$	$Q_{B-A}^{(5)}$	$Q_{A-C}^{(5)}$	$Q_{A-B}^{(5)}$	$C^{(5)}$
V_{A-B} ‘	$Q_{A-B}^{(6)}$	$Q_{C-A}^{(6)}$	$Q_{C-B}^{(6)}$	$Q_{B-C}^{(6)}$	$Q_{B-A}^{(6)}$	$Q_{A-C}^{(6)}$	$Q_{A-B}^{(6)}$	$C^{(6)}$
Maximum flow of intersection = $C^{(J)}$ MIN								

Each stream was observed related to its speed and flow at its own group of conflict. Theory of conflict was then adopted in analysis. It was assumed that each stream has reached its maximum flow, Qi j (stream i and alternative j) at the smallest speed, Vi'. When one stream reaches its maximum flow, e.g. $Q_{C-A\ (1)}$, $V_{C-A'}$ means that other streams would not meet their (real) maximum flow ($Q_{C-B\ (2)}$, $Q_{B-C(3)}$, $Q_{B-A(4)}$, $Q_{A-C\ (5)}$, $Q_{A-B\ (6)}$) and their (real) speed ($V_{C-B'}$, $V_{B-C'}$, $V_{B-A'}$, $V_{A-C'}$, $V_{A-B'}$). By using the value of maximum flow, e.g. $Q_{C-A\ (1)}$, the speed, $V_{C-A'}$ and the streams' speeds V_{C-B}, V_{B-C}, V_{B-A}, V_{A-C}, V_{A-B}, other streams' flow, $Q_{C-B\ (1)}$, $Q_{B-C\ (1)}$ $Q_{B-A\ (1)}$, $Q_{A-C\ (1)}$, $Q_{A-B\ (1)}$ can easily be calculated from the regression equations.

V. ANALYSIS

Analysis of the intersection by using the data measurement and the following calculation are done and from the field measurement we have

Q_{C-A} =639 pcu/h,

Q_{A-B} =350 pcu/h,

Q_{B-A} =272 pcu/h,

Q_{B-C} =222 pcu/h,

Q_{C-A} =570 pcu/h,

Q_{C-B} =170 pcu/h,

At conflict group I ;

$V_{C-A} = 34.52 - 0.32Q_{C-A} - 0.148Q_{B-A}$

The portion the flow

$f_1 = (Q_{B-A}/Q_{C-A})$

$Q_{B-A} = 0.477\ Q_{C-A}$

thus

$Q_{C-A}^{(1)} = \{[\ 34.521 - V_{C-A}\text{‘}/0.39],0\}_{MAX}$

$= 168$ PCU/h

$Q_{B-A}^{(1)} = \{[\ Q_{C-A}(1)/f1],0\}_{MAX}$

$= \{[168/0.4],0\}$

$= 356$ pcu/h

$Q_{C-B}^{(1)} = \{[\ f_4\ .Q_{B-A}^{(1)}],0\}_{MAX}$

$=\{[0.6 \times 356],0\}$

$= 220$ pcu/h

$Q_{A\text{-}C}^{(1)} = \{[\ f6\ .Q_{B\text{-}A}^{(1)}],0\}_{MAX}$

$= \{[0.426 \text{ x } 350],0\}_{Max}$

$= 160$ pcu/h

$Q_{A\text{-}B}^{(1)} = \{[\ Q_{C\text{-}B}^{(1)}\ /f_2],0\}_{MAX}$

$= \{[220/0.4],0\}_{Max}$

=456 pcu /h

$Q_{B\text{-}C}^{(1)} = \{[\ f3\ .Q_{A\text{-}C}^{(1)}]'0\}_{MAX}$

$= \{[0.263 \text{ x } 160],0\}_{Max}$

= 390 pcu/h

C(1) = 168+356+220+160+456+ 390 = 2735 pcu/h

At conflict group II;

VC-B = 18.18 - 0.211QC-B – 0.268QB-A -0.08AQA-C - 0.229QA-B

The portion the flow

$f_2= (Q_{C\text{-}B}/Q_{A\text{-}B})$

$Q_{A\text{-}B}=2.082\ Q_{C\text{-}B}$

$f3= (Q_{A\text{-}C}/Q_{C\text{-}B})$

$Q_{A\text{-}B}=3.80\ Q_{C\text{-}B}$

$f_4= (Q_{C\text{-}B}/Q_{B\text{-}A})$

$Q_{B\text{-}A}=1.6\ Q_{C\text{-}B}$

thus

$Q_{C\text{-}B}^{(2)} = \{[\ 18.189 - V_{C\text{-}B}\ '/1.44],0\}_{MAX}$

= 290 PCU/h

$Q_{A\text{-}B}^{(2)} = \{[\ Q\ _{C\text{-}B}^{(2)}/f2],0\}MAX$

$= \{[290/0.4],0\}$

= 456 pcu/h

$Q_{A\text{-}C}^{(2)} = \{[\ f_5\ .Q_{C\text{-}B}^{(2)}]'0\}MAX$

$=\{[2.8 \text{ x } 290],0\}$

= 832 pcu/h

$Q_{B\text{-}A}^{(2)} = \{[\ Q_{C\text{-}B}^{(2)}\ /f_4],0\}_{MAX}$

$= \{[290/\ 1.61],0\}_{Max}$

= 180 pcu/h

$Q_{B\text{-}C}^{(2)} = \{[\ f3.\ QA\text{-}C(2)],0\}_{MAX}$

$= \{[3.8 \text{ X } 832],0\}_{max}$

=316 pcu /h

$Q_{C\text{-}A}^{(2)} = \{[\ f_1\ .Q_{B\text{-}A}^{(2)}]'0\}_{MAX}$

$= \{[0.47 \text{ x } 180],0\}_{Max}$

= 284 pcu/h

C(2) = 290+456+832+180+316+284 = 2939 pcu/h

At conflict group III ;

$V_{B-C} = 18.88 - 0.288Q_{B-C} – 0.091Q_{A-C}(3)$

The portion the flow

$F_5= (Q_{B-C}/Q_{A-C})$

$Q_{A-C} = 2.8\ Q_{B-C}$

thus

$Q_{B-C}^{(3)} = \{[\ 18.808 – V_{B-C}\ '/0.54],0\}_{MAX}$

$= 344\ \ PCU/h$

$Q_{A-C}^{(3)} = \{[\ Q_{B-C}^{(1)}\ /f_3],0\}_{MAX}$

$= \{[344/0.26],0\}$

$=1\ 307\ pcu/h$

$Q_{C-B}^{(3)} = \{[\ QA-C(3)/f_5],0\}_{MAX}$

$=\{[\ 1307/0.34],0\}$

$= 791\ pcu/h$

$Q_{A-B}^{(3)} = \{[\ \ Q_{C-B}^{(3)}\ \ /f_2],0\}_{MAX}$

$= \{[791/2.042],0\}$

$= 379\ pcu/h$

$Q_{B-A}^{(3)}= \{[\ Q_{A-C}(3)/f_6],0\}_{MAX}$

$= \{[1307/0.4],0\}$

$=370\ pcu\ /h$

$Q_{C-A}^{(3)} = \{[\ f_1\ .Q_{B-A}^{(1)}],0\}_{MAX}$

$= \{[0.477\ x\ 370],0\}$

$= 176\ pcu/h$

$C^{(3)} = 344+1307+791+379+370+176 = 3369\ pcu/h$

At conflict group IV;

$V_{B-A} = 29.80 - 0.045Q_{C-A} – 0.014Q_{C-B} -0.157Q_{B-A} - 0.058Q_{A-C}$

The portion the flow

$F_1= (Q_{B-A}/Q_{C-A})$

$Q_{C-A}=2.082\ Q_{B-A}$

$F_4= (Q_{C-B}/Q_{B-A})$

$Q_{C-B}=0.61\ Q_{B-A}$

$F_6= (Q_{A-C}/Q_{B-A})$

$Q_{A-C}=2.634\ Q_{B-A}$

thus

$Q_{B-A}^{(4)} = \{[\ 29.802 – VB-A\ '/0.39],0\}_{MAX}$

$= 227\ PCU/h$

$Q_{C-A}^{(4)} = \{[\ f_1\ .Q_{B-A}^{(4)}\ ],0\}_{MAX}$

$= \{[0.47\ X\ 227],0\}$

$= 106\ pcu/h$

$Q_{C\text{-}B}^{(4)} = \{[\ f_4 .Q_{B\text{-}A}^{(4)}\ ],0\}_{MAX}$

$=\{[1.68 \text{ x } 227],0\}$

$= 1381$ pcu/h

$Q_{A\text{-}C}^{(4)} = \{[\ f_6.Q_{B\text{-}A}^{(4)}],0\}_{MAX}$

$= \{[0.42 \text{ x } 227],0\}$

$= 196$ pcu/h

$Q_{B\text{-}C}^{(4)} = \{[\ f_3.\ Q_{A\text{-}C}^{(2)}\ ]^{,}0\}_{MAX}$

$= \{[0.26 \text{ X } 196],0\}$

$=511$ pcu /h

$Q_{A\text{-}B}^{(4)} = \{[\ Q_{B\text{-}A}^{(2)} /f_2],0\}MAX$

$= \{[1381 /0.48],0\}$

$= 877$ pcu/h

C(4) = 227+106+1381+511+196+877 = 3301 pcu/h

At conflict group V;

$V_{A\text{-}C} = 31.65 - 0.061Q_{C\text{-}B} – 0.44Q_{B\text{-}C} -0.256Q_{B\text{-}A} - 0.311\ Q_{A\text{-}C}$

The portion the flow

$F_3= (Q_{A\text{-}C}/Q_{C\text{-}B})$

$Q_{C\text{-}B}=0.26\ Q_{A\text{-}C}$

$F_5= (Q_{B\text{-}C}/Q_{A\text{-}C})$

$Q_{B\text{-}C}=0.34\ Q_{A\text{-}C}$

$F_6= (Q_{A\text{-}C}/Q_{B\text{-}A})$

$Q_{B\text{-}A}=0.42\ Q_{A\text{-}C}$

thus

$Q_{A\text{-}C}^{(5)} = \{[\ 31.65 – V_{A\text{-}C}\ `/0.619],0\}_{MAX}$

$= 913$ PCU/h

$Q_{B\text{-}C}^{(5)} = \{[\ f_3 .Q_{A\text{-}C}^{(5)}\ ],0\}_{MAX}$

$= \{[0.26 \text{ X } 913],0\}$

$= 240$ pcu/h

$Q_{C\text{-}B}^{(5)} = \{[\ Q_{B\text{-}A}^{(4)}/f_5],0\}_{MAX}$

$=\{[913 / 0.348],0\}$

$= 623$ pcu/h

$Q_{B\text{-}A}^{(5)} = \{[\ Q_{B\text{-}A}(4)/f_6],0\}_{MAX}$

$= \{[913 /0.48],0\}max$

$= 214$ pcu/h

$Q_{A\text{-}B}^{(5)} = \{[\ \ Q_{C\text{-}B}^{(2)} /f_2],0\}_{MAX}$

$= \{[623/0.48\ ],0\}$

$=1298$ pcu /h

$Q_{C\text{-}A}^{(5)} = \{[\ Q_{B\text{-}A}^{(5)} \cdot f_1],0\}_{MAX}$

$= \{[214 \text{ X } 0.48],0\}max$

$= 198$ pcu/h

$C^{(5)}$ = 913+239+623+2141298+198= 3479 pcu/h

At conflict group VI;

$V_{B-A} = 29.80 - 0.045Q_{C-A} – 0.014Q_{C-B} -0.157Q_{B-A} - 0.058Q_{A-C}$

The portion the flow

$F_2= (Q_{C-B}/Q_{A-B})$

$QC\text{-}B=0.48\ Q_{A-B}$

thus

$Q_{A-B}^{(6)} = \{[\ 29.802 – V_{A-B}\ ‘/0.57],0\}_{MAX}$

$= 497$ PCU/h

$Q_{C-B}^{(6)} = \{[\ f_2\ .Q_{B-A}^{(6)}],0\}_{MAX}$

$= \{[0.48X\ 497],0\}$

$= 238$ pcu/h

$Q_{A-C}^{(6)}= \{[\ f_5\ .Q_{C-B}^{(6)}\ ],0\}_{MAX}$

$=\{[0.348\ x\ 240],0\}_{MAX}$

$= 183$ pcu/h

$Q_{B-A}^{(6)}= \{[\ Q_{C-B}^{(6)}\ /f_4],0\}_{MAX}$

$= \{[238/1.68],0\}_{Max}$

$= 1471$ pcu/h

$Q_{C-A}^{(6)} = \{[\ f_4.\ Q_{B-A}^{(6)}],0\}_{MAX}$

$= \{[0.47\ X\ 1471],0\}_{Max}$

$= 691$ pcu /h

$Q_{B-C}^{(6)}= \{[\ Q_{A-C}^{(6)}\cdot f3],0\}_{MAX}$

$= \{183\ x3.8],0\}_{Max}$

$= 695$ pcu/h

$C^{(6)} = 691+238+695+1471+183+497= 3777$ pcu/h.

Table 4 Maximum Flow at Goshamahal Intersection

Speed at the maximum flows subject stream	Maximum flows of subject stream	Q_{C-A}	Q_{C-B}	Q_{B-C}	Q_{A-A}	Q_{A-C}	Q_{A-B}	Maximum flow at intersection
VC-A'	$Q_{C-A(1)}$	166	354	218	150	456	390	2736
VC-B'	$Q_{C-B(2)}$	285	143	832	180	316	284	2940
VB-C'	$Q_{B-C(3)}$	176	792	370	316	1307	380	2668
VB-A'	$Q_{B-A(4)}$	106	1381	197	511	228	877	3370
VA-C'	$Q_{A-C(5)}$	199	623	239	214	1298	913	3479
VA-B'	$Q_{A-B(6)}$	691	238	695	1472	183	497	3777
Maximum flow at intersection								2736

Average speeds between 10 km/h and 15 km/h were used to predict the capacity of an intersection which is considered from observations of intersections, e.g. intersection-1, where its maximum flow was likely to be reached. There was a total number of 4577 vehicles per hour and various width of legs: 9.6 m, 6.5 m and 8.0 m, total average speed 15.6 km/h for motorized vehicles (11.3 km/h for cars) and 5.8 km/h for non–motorized vehicles.

VI. RESULTS

Three T–leg unsignalized intersections have been investigated and analyzed. They have various widths of legs (geometric design). Flows and composition (type of vehicles) would contributed to various traffic speeds. Types of vehicles were classified into nine (9) categories differing in static and dynamic characteristics. Motorcycles have the largest percentage of 70% – 88% and higher average mean speed than others. Each vehicle movement from each stream was observed by using manual count. Furthermore, speed and flow of each type of vehicle from each stream and total vehicles' occupancy were counted. A large number of vehicle types which differ in characteristics give impacts in traffic performance while they mixed. Therefore, this study has determined values for passenger car units (PCUs) based on performance of speed and projected rectangular area of vehicles. Results showed that each vehicle performed at different speeds. Also the same type of vehicle has also performed at different speed between streams' flow. The values have been used for further analysis of flows' stream in passenger car units (PCUs). Each of the movements at an intersection has been observed related to their speed and flow. By those two parameters, investigations have been made further at any correlation between conflict streams (six streams; C – A, C – B, B – C, B – A, A – C, A – B) as defined by group of conflicts (I, II, III, IV, V, VI). Results of the relation between parameters show that a suitable correlation between speed and flow of conflict groups could be developed even if there was only a small correlation at some groups. The volume of each movement is the most important parameter to calculate the maximum flow (capacity) based on the conflict streams. Maximum flows of each stream were found to correspond to the speed and flow of other streams at a group of conflict. There are six (6) alternatives of maximum flows at the intersection because the maximum flow of each stream has to be counted. Results of parameters related to maximum flow (capacity) and other parameters of traffic flow quality and performance, It can be concluded that the maximum flows were reached at the average speed of vehicles within the range of 11 km/h – 15 km/h which is appropriate for all intersections. This corresponds to the results from the manual.

VII. VALIDATION OF RESULTS

Validation is the process of checking the developed simulation model in terms of predicted traffic performance for road system against field measurements of traffic performance such as traffic volumes, travel times and average speeds. In the present study, the calibration and validation process was carried out by trial and error method. After carrying out many trials, the prediction error in volume and speed is reduced to satisfactory level. It has been observed from the comparison that the error in estimation of traffic volumes is less than 5 per cent across different vehicle types whereas the overall error in the estimation of traffic volume is almost zero which represents the accuracy of the developed model. The comparison of observed and estimated data of different vehicle speeds shows that the error in vehicular speeds is ranging from 1 per cent to 5 per cent for different vehicle types which represent, the developed model is reasonable accurate and showing the actual ground conditions. It can be inferred that the developed models are able to predict the vehicular movements (i.e. flow and speed) with reasonable degree of accuracy under heterogeneous traffic conditions. For unsignalized intersection. Based on the developed models, the evolution of speed - flow relationships is attempted. Using the same, capacity is estimated. From the Calculated data intersection capacity values obtained are: Goshamahal Intersection = 4209 pcu/h, Malakpet fire station Intersection = 4529 pcu/h, Yadgiri theatre Intersection = 3774 pcu/h

The calculated capacity values obtained from the HCM are: Goshamahal Intersection = 3250 pcu/h, Malakpet fire station Intersection = 3223 pcu/h, Yadgiri theatre Intersection = 3730 pcu/h, The developed values obtained from the model are: Goshamahal Intersection = 4577 pcu/h, Malakpet fire station Intersection = 3750pcu/h, Yadgiri theatre Intersection = 4274 pcu/h

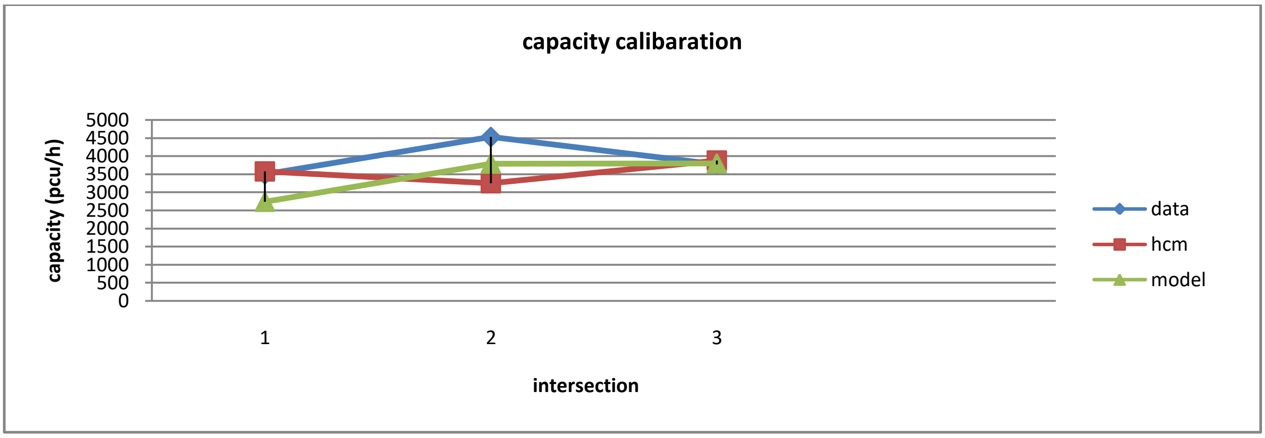

Figure 2 Capacity Calibrated Data- HCM- Model

Based on the capacity calculation, both methods are compared in the following graph in Figure 3. In order to give an overview of the capacity analysis, results from each intersections' data analysis and their average are performed. The type of data analysis means that each data resource (speed and flow) from each intersection was used to find a maximum flow.

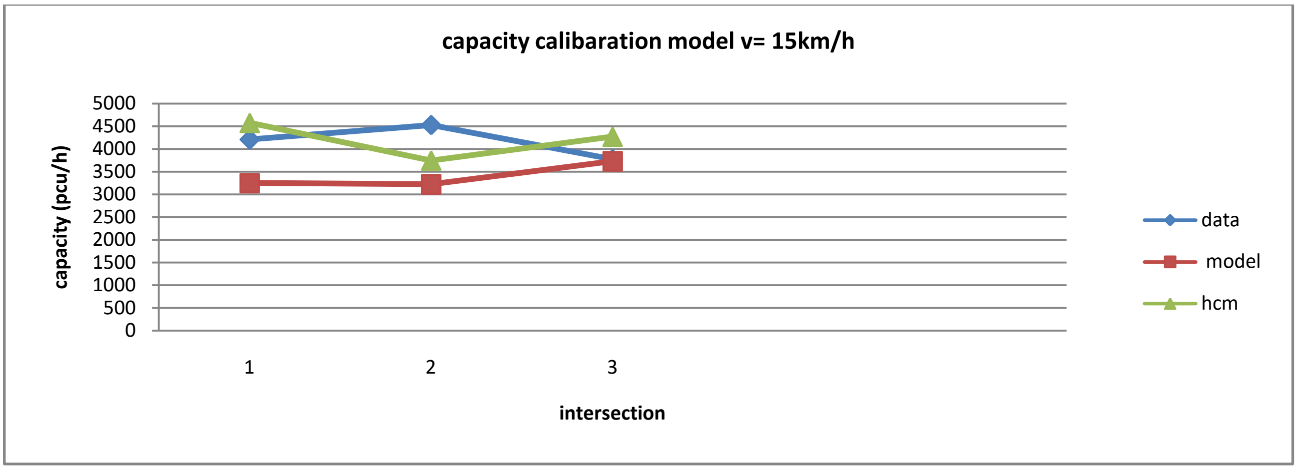

Figure 3 Capacity calibration model v= 15km/h

Results of maximum flows (capacity) at several intersections with various speed levels have been presented. The average speed of vehicles at the intersections has a significant impacton total (maximum) flow where small differences of speed would indicate large differences in maximum flow (mean difference = 575.70 pcu/h, s = 293.60). While the model was developed by the portion of streams' flow, it is then necessary to create a model which is suitable for total flow of the intersection, Q Total and average speed of the intersection, V. Based on data Figure 4 was plotted to show the relationship between speed and flow of unsignalized intersections. It can be concluded that the free–flow speed is found to be 16.863 km/h and the speed is decreasing by 1.50 km/h for every 1000 pcu/h.

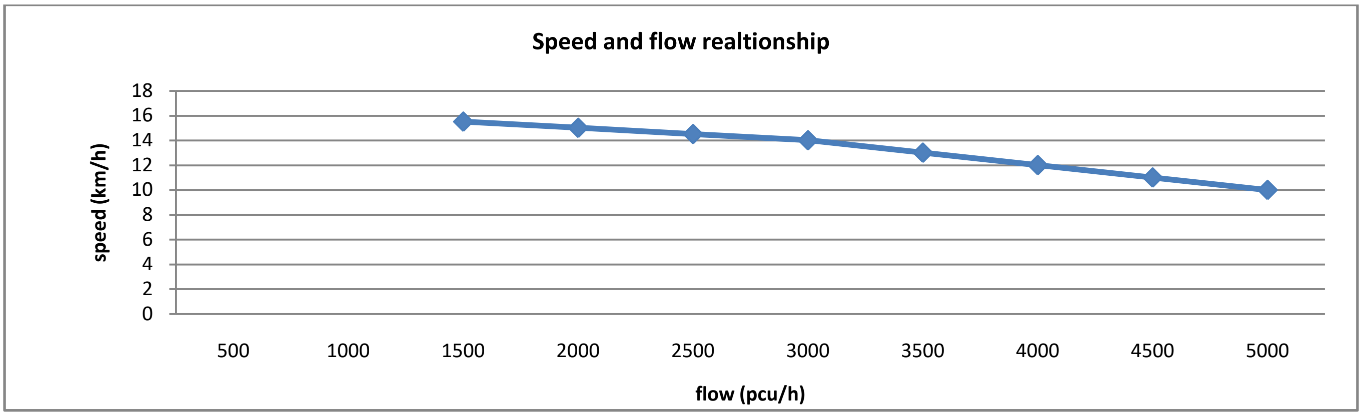

Figure 4 Relationship between speed and flow of intersections

VIII. CONCLUSIONS

From data recorded, relationships between the three parameters were developed, e.g. the speed and flow relationship and the flow and intersection occupancy relationship. The results showed that there was a good correlation between speeds – flow in each group of conflict.

1. The information like Volume, Flow, and Capacity of each sort of vehicle can be acquired from the field contemplate where with respect to hole acknowledgment models.

2. In light of the movement stream estimations, the most extreme stream of a stream, the aggregate limit of a crossing point can be computed.

3. By Comparing all the 3 T-intersections

a) The study area of goshamahal Junction has shown the Mixed traffic conditions.

b)The maximum number of vehicles in the peak hours is 2209 in the direction from minor Street to left side which is obtained in the evening hours.

c) The study area of malakpet fire station Junction has shown the Major Stream.

d) The maximum number of vehicles in the peak hours is 1896 in the direction from minor Street to right side which is obtained in the evening hours.

e) The study area of yadgiri theatre Junction has shown the Minor Stream.

f)The maximum number of vehicles in the peak hours is 1954 in the direction from Minor Street to right side in the morning hours and away from complex in the Major street in the evening hours.

IX. FURTHER STUDY

1. Pedestrians are not considered in this study, further study can be focused on pedestrian movements along with vehicle movements.
2. It was recommended to extend the study for more than two hours and the speed can be counted in order to achieve a better prediction.

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