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A Conspectus Study on: Relationship between Space Mean Speed and Actual Travel time on link between Signalized Intersections

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Abstract-*In signal co-ordination Time space diagram and Average speed of traffic stream will be considered. Average speed of traffic stream is obtained by spot speed study of mid block section. Spot speed study gives Space Mean Speed (S.M.S.) and this S.M.S. is considered for signal co-ordination. In fact Actual Travel Time of vehicle includes starting acceleration, interaction, deceleration and stopping to travel between two signalized intersections. Actual travel time is generally more than Travel Time obtained from S.M.S. hence, it is necessary to establish relationship between S.M.S. and Actual Travel Time so that it gives more accurate and realistic estimation of travel time. After obtaining actual travel time and travel time calculated from the observed S.M.S. by spot speed study the relationship between these two parameters will be obtained in this study. It involves spot speed study with an aim to develop various relationships between Traffic flow parameters (Space mean speed and actual travel time) under existing situations for study area. Study is limited to observed the travel time and space mean speed on the links between 3 intersection (4 arm signalized intersection) in Indian traffic condition. This study will helpful for designing coordinated signal on urban corridors. This relationship can be utilizing the same situation at other sites.*

Key words: *Time Space Diagram, Space Mean Speed, Actual Travel Time, Corridors, Signalized Intersection.*

I. INTRODUCTION

1.1 General

Transport sector plays a very significant role in improving the economic development of any country. Road transportation is the major component of the transport sector in India. India has one of the largest road networks in the world hovering around 3.4 million km at present. As per present estimate, total road network carries nearly 65% of freight and 85% of passenger traffic. Traffic on roads is growing at a rate of 7 to 10% per annum while the vehicle population growth is of the order of 12% per annum. Among them National Highways are the main arterial roads which run through the length and breadth of the country connecting ports, state capitals, industrial and tourist centers and neighboring countries. About 40% of total road traffic is carried by the National Highways which is only 2% of the total road network. These will clearly indicate the congestion of traffic and drop in Level of Service (LOS) on our road network. For achieving optimal utilization of the road network in the country, the knowledge of highway capacity is of paramount importance.

Traffic flow is the study of interactions between vehicles, drivers, and infrastructure (including highways, signal, and traffic control devices), with the aim of understanding and developing an optimal road network with efficient movement of traffic and minimal traffic congestion problem. Traffic streams are described by three variables: density (k), speed (v), and flow (q), measured respectively in vehicles per lane per km, km per hour, and vehicles per lane per hour. At the macroscopic level, these variables are defined under stationary conditions at each point in space and time, and are related by the identity $q = k \times v$. The heavy concentration of population in a few centres has resulted in the expansion of cities in density as well as area. With the increase in population and economic activities the travel demand has increased many folds. Study of the basic traffic flow characteristics like traffic volume is the pre-requisites for the effective planning, design, operation and management of roadway systems. Traffic in developing countries like India is heterogeneous in nature consisting of vehicles of different categories with widely varying dimensional andoperational characteristics. In Indian road traffic, the heterogeneity is of high degree withvehicles of widely varying static and dynamic characteristics. Under this condition, it becomes difficult to make the vehicles to follow traffic lane. The problem of measuring volume of such heterogeneous traffic has been addressed by

converting the different types of vehicles into equivalent passenger cars and expressing the volume in terms of Passenger Car Unit (PCU) per hour.

Traffic Flow depends upon the driver's movement and the interactions done by the vehicles in between two points. Traffic flow prediction by the driver's movement is more difficult to analyze. The basic parameters of traffic flow are speed, density and flow which are most essential to know before to understand the vehicle flow. With the above three parameters roadway facility can be designed, planned and operated.

The urban traffic congestion has become a global phenomenon. Rapid urbanization and industrialization have caused drastically growth of vehicles all over the world. But the problems like congestion, delay, energy consumption, environmental pollution, etc. still remain in question if the traffic signals are not coordinated. Coordination of signals is achieved when the flow of traffic on a given phase of movement at one intersection is accommodated by a "go" phase on its arrival at the next signalized intersection. It enhances progressive movement of traffic streams at some specific speed without enforced halts and reduced overall delay. It reduces the speed variations and provides smooth traffic operation, which increases capacity, decreases energy consumption and reduces air and noise pollution. Coordination of traffic signals on a road is one kind of traffic management measure.

For the coordination of traffic signals in a given urban road network, different software packages are available like, SCOOT, TRANSYT, DYNAMIT etc. These are working with the help of sensors. These are costly and may not be giving satisfactory results in Indian traffic conditions so this study is useful in the co-ordination of traffic signal in mixed traffic urban roads.

1.2 Population Growth

Current Population of India - India, with 1,210,000,000 (1.21 billion) people is the second most populous country in the world, while China is on the top with over 1,350,044,605 (1.35 billion) people. More than 50% of India's current population is below the age of 25 and over 65% below the age of 35. About 72.2% of the population lives in some 6,38,000 villages and the rest 27.8% in about 5,480 towns and urban agglomerations. India has the largest illiterate population in the world. The literacy rate of India as per 2011 Population Census is 65.38%, with male literacy rate at 75.96% and female at 54.28%. Kerala has the highest literacy rate at 90.86%, Mizoram (88.80%) is on the second position and Lakshadweep (86.66%) is on third (Sensus-2011).

1.3 Current scenario of traffic in India

Pattern of traffic is very heterogeneous on Indian roads. There are around 30 million vehicles in India, which are growing at a rapid rate of 15-17 % every year. The major 23 cities contribute 35% of the total motor vehicles in the country. In terms of numbers on road 2-wheelers dominate the scene with about 65% of share whereas in terms of share trips, buses cover the maximum passenger km of about 36% of total. Vehicular ownership is very low in our country with only 26 vehicles per thousands of population, which is very low compared to other countries and global average (148 vehicles per 1000 population) shown below in table 1.

In India work trips are the most important component of the traffic demand during peak hours of the day. Transport demand is likely to increase by about 2.5 times from 1991 to 2001 in large metros and other medium sized cities by about 3-3.5 times.

Table 1: A profile of top ten states with the highest population in the India

Table 2: Comparing Vehicle ownership

Sr. No.	State	Population in Crores
1	Uttar Pradesh	19.95
2	Maharashtra	11.23
3	Bihar	10.38
4	West Bengal	9.13
5	Andhra Pradesh	8.46
6	Madhya Pradesh	7.25
7	Tamil Nadu	7.21
8	Rajasthan	6.86
9	Karnataka	6.11
10	Gujarat	6.03

(Source- Census-2011)

Sr. No	Country	Vehicle ownership (Vehicles per 1000 Population)
1	India	26
2	France	533
3	Germany	546
4	Japan	623
5	Malaysia	315
6	Singapore	197

India's transportation system has a number of drawbacks, which causes problems of delays, safety, and pollution. Average number of road accidents per thousands of vehicles is around 23, which is one of the highest in the world. Non-motorized are involved in about 60-65% of the road accidents and share of pedestrians is also very high standing at about 40%.

As urbanization increases in the country, the number of vehicles in the metros likes Delhi, Chennai; Mumbai & Kolkata is increasing tremendously. In the increase of vehicular population, Ahmadabad is facing same kind of problems. In last two decades there is a steep increase in the various categories of vehicles in the Ahmadabad city. The vehicular population has grown by 11 times from the year 1980. The total numbers of vehicles are almost 12, 50,000 vehicles.

1.4 Problems in Indian road traffic condition

Followings are general problems found in present Indian road traffic condition.
- ➢ Traffic is not lane following;
- ➢ A vehicle entering the approach (upstream) on a particular lane need not maintain the same at the intersection;
- ➢ Uncontrolled side roads and on-street parking;
- ➢ High mix of traffic;
- ➢ Obtaining a correct measure of traffic count is highly complex;
- ➢ Data loss due to power failure;
- ➢ Network failure.

1.5 Necessity of signal

As the vehicular traffic increases day-by-day in the cities, it becomes necessary to signalize the intersections of arterial/sub-arterial streets to control and regulate the traffic. It is just not enough to install the signals on intersections to satisfy one or more warrants. By installing the signals and applying proper phase plans, there is considerable reduction in conflicting points, which ensures reasonable safety. So the main consideration should be given to reduce the delay to vehicles on the legs of intersection. The operation of traffic signal installation will be optimum when the delay to vehicles on each approach of intersection becomes minimum. There will be considerable reduction in delay to vehicles on the approaches of a road by coordinating the signal installations of a road. Generally, coordination of signals should be done to reduce the delay on major streets, should be examined carefully. If there is considerable increase in the delay to the vehicles of side streets, then the decision of applying coordination is not justifiable.

Signal coordination is a is a tool available in the hand of traffic engineers by means of which they control, regulate and manage the traffic in the signal system in such a way the most-productive and cost-effective use of the existing signal system can be made. A good knowledge of road user characteristics, vehicular characteristics, Traffic flow characteristics, and Highway and Environmental characteristics is necessary for traffic engineers to arrive at effective coordination.

Signal can be coordinated in several ways, but the three most common techniques are the simultaneous system, the alternate system and the progressive system. The type of regulations prevailing in the street system, i.e. one-way or two-way street system or mixed network, affects the planning of coordination. The single route 'green wave' concept can be extended to a whole network, using several signal plans, known as "Area Traffic Control", through computer programming and centralized control.

Traffic signals when properly designed, located and operated have the following advantages:

[1] They provide orderly movement of traffic and increase the traffic handling capacity of most of the intersections at grade.
[2] They reduce certain types of accidents, notably the right angled collisions.
[3] Pedestrian can cross the roads safely at the signalized intersection.
[4] Proper coordinated signal system provides reasonable speed along the major road traffic.
[5] Signals provide a chance to crossing traffic of minor road to cross the path of continuous flow of traffic stream at reasonable intervals of time.
[6] Automatic traffic signal may work out to be economical when compared to manual control.
[7] The quality of traffic flow is improved by forming compact platoons of vehicles, all the vehicles move at approximately at the same speed.

If they are not installed and designed not properly,
[1] The rear end collisions may increase.
[2] Excessive delay may be caused during off peak hours.
[3] Unwarranted signal installations tend to encourage the disobedience of the signal indications.
[4] Drivers may be induced to use less adequate and less safe routes to avoid delays at signals.
[5] Failures of the signal due to electric power failure or any other defect may cause confusion to the road user.

1.6 Problem Statement
In signal co-ordination Time space diagram and Average speed of traffic stream will be considered. Average speed of traffic stream is obtained by spot speed study of mid-block section. Spot speed study gives Space Mean Speed (S.M.S.) and this S.M.S. is considered for signal co-ordination.
In fact, Actual Travel Time of vehicle includes starting acceleration, interaction, deceleration and stopping to travel between two signalized intersections. Actual travel time is generally more than Travel Time obtained from S.M.S. hence, it is necessary to establish relationship between S.M.S. and Actual Travel Time so that it gives more accurate and realistic estimation of travel time. After obtaining actual travel time and travel time calculated from the observed S.M.S. by spot speed study the relationship between these two parameters will be obtained in this study.

1.7 Aim of the Study
Determination of relationship between Space Mean Speed (SMS) and actual travel time on a link between signalized intersections.

1.8 Objectives
[1] To measure the Space Mean Speed of vehicles in the mid-block of the link between signalized intersections.
[2] To enumerate the actual travel time of a particular vehicle.
[3] Develop a relation between the Travel time calculated by space mean speed and actual (observed) Travel time of vehicle between stop lines of two signalised intersections.

1.9 Scope of the Study
[1] It involves spot speed study with an aim to develop various relationships between Traffic flow parameters (Space mean speed and actual travel time) under existing situations for study area.
[2] Study is limited to observe the travel time and space mean speed on the links between 3 intersections (4 arm signalized intersection) in Indian traffic condition.
[3] This study will helpful for designing coordinated signal on urban corridors.
[4] This relationship can be utilised the same situation at other sites.
[5] This relationship can be utilised for trip assignment procedure.

II. REVIEW OF LITERATURE

2.1   General
In the previous chapter introduction of the study is carried out in which problem statement, Aim of study, scope of study and structure of report. In this chapter terminology related to study and previous research study related to this is analyzed.

Terminology related to traffic flow
2.2   Speed (v)
The speed of a vehicle is defined as the distance it travels per unit of time. In quantifying the traffic flow, the average speed of the traffic is the significant variable. The average speed, which is called the space mean speed, which can be found by averaging the individual speeds of all of the vehicles in the study area.

2.2.1   Spot speed
Spot speed is the instantaneous speed of a vehicle at a specified location. Spot speed can be used to design the geometry of road like horizontal and vertical curves, super elevation etc.

2.2.2   Running speed
Running speed is the average speed maintained over a particular course while the vehicle is moving and is found by dividing the length of the course by the time duration the vehicle was in motion.

2.2.3   Journey speed
Journey speed is the effective speed of the vehicle on a journey between two points and is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped time.

2.2.4   Time mean speed
Time mean speed is defined as the average speed of all the vehicles passing a point on a highway over some specified time period.

2.2.5   Space mean speed
Space mean speed is defined as the average speed of all the vehicles occupying a given section of a highway over some specified time period.

2.3   Volume
Volume is simply the number of vehicles that pass a given point on the roadway in a specified period of time. By counting the number of vehicles that pass a point on the roadway during a 15-minute period, you can arrive at the 15-minute volume.

2.3.1   Types of volume measurements
Since there is considerable variation in the volume of traffic, several types of measurements of volume are commonly adopted which will average these variations into a single volume count to be used in many design purposes.

1. **Average Annual Daily Traffic (AADT):**
   The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365.
2. **Average Annual Weekday Traffic (AAWT):**
   The average 24-hour traffic volume occurring on weekdays over a full year. It is computed by dividing the total weekday traffic volume for the year by 260.
3. **Average Daily Traffic (ADT):**
   An average 24-hour traffic volume at a given location for some period of time less than a year. It may be measured for six months, a season, a month, a week, or as littl1e as two days. An ADT is a valid number only for the period over which it was measured.
4. **Average Weekday Traffic (AWT):**
   An average 24-hour traffic volume occurring on weekdays for some period of time less than one year, such as for a month or a season.

2.4   Flow
There are practically two ways of counting the number of vehicles on a road. One is flow or volume, which is defined as the number of vehicles that pass a point on a highway or a given lane or direction of a highway during a specific time interval.

2.5   Density
Density is defined as the number of vehicles occupying a given length of highway or lane and is generally expressed as vehicles per km/mile.

2.6   Travel time
Travel time is defined as the time taken to complete a journey. As the speed increases, travel time required to reach the destination also decreases and vice versa. Thus travel time is inversely proportional to the speed.

2.7   Fundamental diagrams of traffic flow:
The relation between flow and density, density and speed, speed and flow, can be represented with the help of some curves. They are referred to as the fundamental diagrams of traffic flow. They will be explained in detail one by one below.

2.7.1   Flow-density curve
The flow and density varies with time and location. The relation between the density and the corresponding flow on a given stretch of road is referred to as one of the fundamental diagram of traffic flow. Some characteristics of an ideal flow-density relationship are listed below:

1. When the density is zero, flow will also be zero, since there are no vehicles on the road.
2. When the number of vehicles gradually increases the density as well as flow increases.
3. When more and more vehicles are added, it reaches a situation where vehicles can't move. This is referred to as the jam density or the maximum density. At jam density, flow will be zero because the vehicles are not moving.
4. There will be some density between zero density and jam density, when the flow is maximum.

The relationship is normally represented by a parabolic curve as shown in figure 1 the point O refers to the case with zero density and zero flow. The point B refers to the maximum flow and the corresponding density is k_{max}. The point C refers to the maximum density k_{jam} and the corresponding flow is zero. OA is the tangent drawn to the parabola at O, and the slope of the line OA gives the mean free flow speed, i.e. the speed with which a vehicle can travel when there is no flow.

It can also be noted that points D and E correspond to same flow but has two different densities. Further, the slope of the line OD gives the mean speed at density k1 and slope of the line OE will give mean speed at density k_2. Clearly the speed at density k_1 will be higher since there is less number of vehicles on the road.
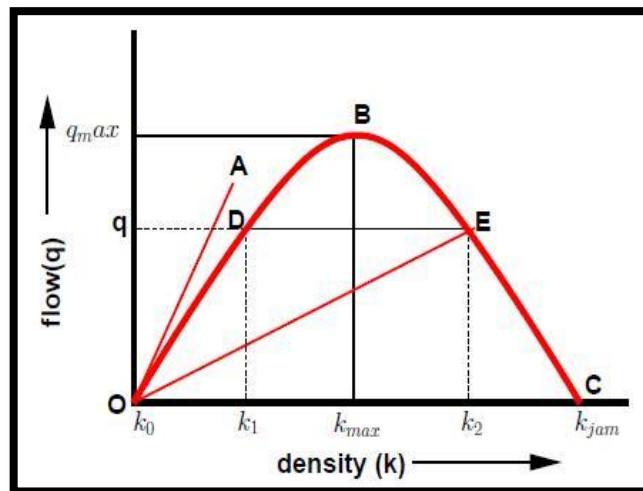
Figure 1: Relationship between Flow and Density
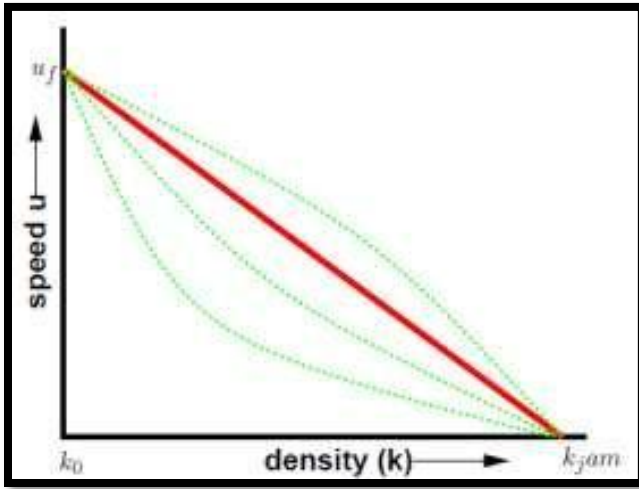
2.7.2   Speed-density diagram
Similar to the flow-density relationship, speed will be maximum, referred to as the free flow speed, and when the density is Maximum, the speed will be zero. The simplest assumption is that this variation of speed with density is linear as shown by the solid line in figure 2.
Corresponding to the zero density, vehicles will owe with their desire speed, or free flow speed. When the density is jam density, the speed of the vehicles becomes zero. It is also possible to have non-linear relationships as shown by the dotted lines.
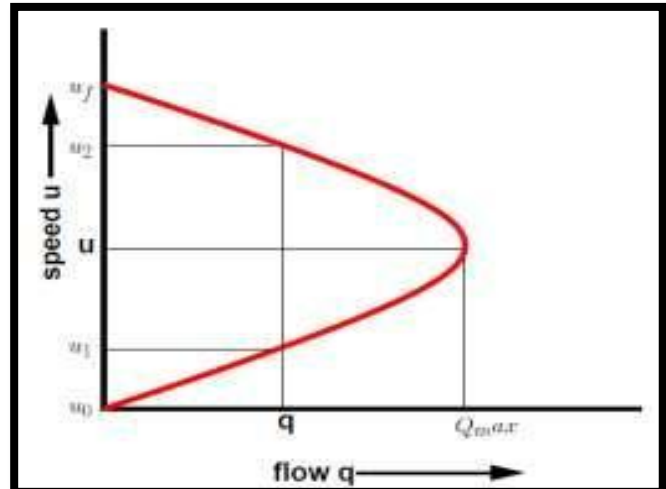
2.7.3   Speed-flow relation
Relationship between the speed and flow can be postulated as follows. The flow is zero either because there is no vehicle or

there are too many vehicles so that they cannot move. At maximum flow, the speed will be in between zero and free flow speed. This relationship is shown in figure 3. The maximum flow qmax occurs at speed u. It is possible to have two different speeds for a given flow.
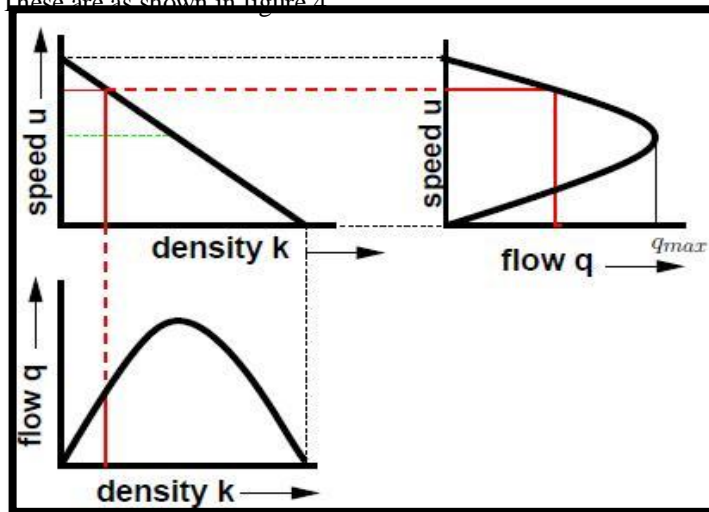

Figure 2: Relationship between Speed and density   **Figure 3: Relationship between Speed and Flow**

2.8   Combined diagram
The diagrams shown in the relationship between speed-flow, speed-density, and flow-density are called the fundamental diagrams of traffic flow. These are as shown in figure 4.


Figure 4: Combined Diagrams showing relationship of Speed-density, speed-flow and flow-density

2.9   Time-space diagram
The vehicle trajectory (often denoted as x_i (t)) of a vehicle (i) describes the position of the vehicle over time (t) along the roadway. The trajectory is the core variable in traffic flow theory which allows us to determine all relevant microscopic and macroscopic traffic flow quantities. Note that, for the sake of simplicity, the lateral component of the trajectory is not considered here.

To illustrate the versatility of trajectories, Figure 5 shows several vehicle trajectories. From the figure, it is easy to determine the distance headway S_i, and the time headway h_i, overtaking events (crossing trajectories), the speed $v_i = dx_i/dt$, the size of the acceleration (see top left where one vehicle accelerates to overtake another vehicle), the travel time TT_i and so forth.
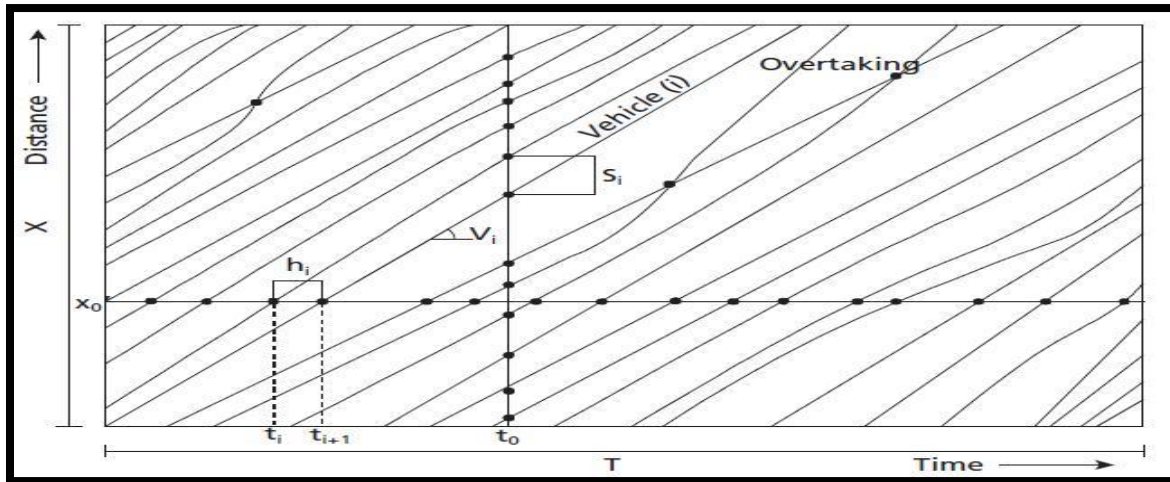
Figure 5: Time space diagram and vehicle Trajectories for different vehicles

2.10 Factors that influences on the traffic flow characteristics
2.10.1   Vehicular characteristics
The physical and mechanical characteristics of a vehicle that include, overall length, overall width, engine power, weight, acceleration, deceleration and braking and other manoeuvring characteristics.

2.10.2 Traffic stream characteristics
The various characteristics of the traffic stream that include,
- [1] Traffic volume to capacity ratio (V/C ratio);
- [2] traffic stream composition;
- [3] speed characteristics of the stream and
- [4] Distribution of transverse gap and longitudinal clearance of vehicles (gaps between the vehicles) at different speeds.

2.10.3   Roadway characteristics
The various characteristics of roadway that include,
- [1] horizontal and vertical alignment,
- [2] magnitude of grades and its length
- [3] roadway elements (e.g. mid-block, rotary, uncontrolled and signalized intersections),
- [4] pavement width,
- [5] pavement type and structural condition,
- [6] pavement surface condition and skid resistance, and
- [7] type of road (rural or urban)

Apart from the important variables listed earlier, the environmental, climatic, and traffic control conditions also influence the traffic flow characteristics.

2.11   Research papers
Patel et al., (2011) have studied and analyzed Goal of coordination is to get the greatest number of vehicles through the system with the fewest stops in a comfortable manner but the problems like congestion, delay, energy consumption, environmental pollution, etc. still remain in question if the traffic signals are not coordinated. Coordination of signals is achieved when the flow of traffic on a given phase of movement at one intersection is accommodated by a "go'' phase on its arrival at the next signalized intersection. It enhances progressive movement of traffic streams at some specific speed without enforced halts and reduced overall delay. It reduces the speed variations and provides smooth traffic operation, which increases capacity, decreases energy consumption and reduces air and noise pollution. In this paper, a methodology has been suggested for the pre timed signal coordination at network level by adopting different phase plans to reduce the vehicular delay.

Shah et al., (2013) have studied the signal coordination is perceived by many agencies as a beneficial improvement to the community or corridor under consideration. In this paper, a critical review and analysis of the previously developed

methodology for the pre-timed two- way signal coordination and coordination at network level has been presented. Coordination has been achieved by adopting different phase plans to reduce the vehicular delay. The study found that both the methodologies can reduce vehicular delay ranging from 30% to 60% for the assumed ideal conditions. Methodology of signal coordination should be upgraded based on Time- of- Day (TOD) intervals to suit for actual traffic conditions of road network such as, change in traffic flow, change in average journey time, change in geometrics, etc. The result obtained by both methodologies has been critically reviewed and novel approach of signal setting using disutility Index (DI), simulation software's, soft computing techniques and mathematical modelling is proposed.

Thakor et al., (2014) have studied and analyzed all the traffic parameters of the study road it is concluded that present urban road caters very heavy traffic and does not produce required level of service. The condition of existing road is also not good at some location which obstructs the speed of vehicles, so it should be improved. From the data collection and analysis, it is observed that existing road width is not sufficient to handle the traffic now and in future so widening is required as early as possible. Immediate attention is needed to improve the level of service on link road and reduction in road-accident. It is observed that the mean speed of overall traffic stream is 25 kmph which is less. This shows the reduction in level of service. Also, 15th percentile speed is 19 kmph which indicates the vehicle below this speed (i.e. cycles) obstruct the running traffic. From the speed flow data, the R^2 value are very low, which shows the data are very poor.

Patel and Kumpavat, (2014) have determined relationship between speed and flow is essential for arriving at the capacity of a road. The Principal objective of the study was to evaluate speed-flow relationships on NH-8 for different types of vehicles by developing separate speed-flow equations on NH-8. The following methods can be adopted for speed-flow analysis: Linear Method, Non-Linear Method. The composition of traffic clearly indicates the influence of city area on rural road. The highest and average speed of various types of vehicles are too high then city area because of the distance from CBD area.

Somanathan and Thamizh (2013) have studied the moving vehicles of heterogeneous traffic occupy any convenient lateral position on the road without any lane discipline, based on the availability of space. The interaction between moving vehicles under such traffic condition is highly complex in nature, which can be represented in terms of the amount of impedance caused to flow of traffic by a vehicle type in comparison with that of standard vehicle (passenger car). Passenger Car Unit (PCU) can be an appropriate measure to represent the relative impedance caused by a vehicle in heterogeneous traffic. This paper is concerned with the application micro-simulation technique to derive equivalency values (PCU factors) on a purely homogeneous (cars-only) traffic stream as well as on a heterogeneous traffic stream for different categories of road vehicles over a wide range of traffic flow and compositions on four-lane divided urban roads in India. The PCU values obtained for the different types of vehicles, for a wide range of traffic volume and composition, indicate that the PCU values of a vehicle type significantly changes with change in traffic volume and composition. They studied Traffic on Indian roads (both urban and inter-urban) consists of a variety of vehicles. These vehicles have widely different static and dynamic characteristics. The traffic is also very different from homogeneous traffic which primarily consists of motorized vehicles. The density method assumes motorized, four-wheeler traffic, i.e., homogeneous traffic, and does not include motorized three-wheelers, motorized two-wheelers, and non-motorized traffic often present on Indian highways. By modifying the density method to represent non-homogeneous traffic, which includes significant percentages of motorized, three-wheelers, motorized two-wheelers, and non-motorized traffic entities, one can derive more accurate passenger car units for Indian conditions.

Tiwari et al, (2007) have studied the modified density method recognizes the loose lane discipline characteristic of non-homogeneous traffic. Rural non-homogeneous traffic that includes large percentages of trucks, farm vehicles, tractors, three-wheelers, two-wheelers, bicycles, and animal drawn carts exhibits a wide variation in static and dynamic characteristics of traffic entities. Vehicles such as buses, trucks and cars with a possible maximum speed of over 100 km/h (62 mi/h) share the carriage way with tractors and bicycles with a possible maximum speed of 30 km/h (19 mi/h) and 15 km/h (9 mi/h), respectively. Often vehicles in this traffic mix do not use the delineated lanes. Traffic entities of similar speeds and size pre-segregate into the most-efficient and safest distribution possible across the pavement width.

Karthik and Raleogoankar have stated in their study that in order to achieve the comfort, safety and to organize the traffic flow in an organized manner, traffic signal timings play a vital role. Optimal signal timing is the most effective and economic method for mitigating vehicular delays in urban areas. In this paper, an in-deterministic way of signal optimization technique is proposed, which is suitable for the Indian road conditions. The road network of the study area was coded in the Micro simulation software called VISSIM with the existing signal timings and field delays were compared with the simulated delays for software validation. Sensitive analysis was carried out by varying the parameters in the software and cycle time was adjusted with the parameter contributing less amount of delay. The proposed model has given good results by reducing delays up to 29 %.

Patel and Patel (2012) have stated in their study that saturation Flow (SF) is a key parameter required in capacity analysis of signalized intersections. It is also an important parameter in design of signal timings. Well-established guidelines such as Highway Capacity Manual (HCM) are available for the estimation of SF in developed countries. Traffic characteristics and driver behaviour are significantly different in heterogeneous traffic of developing countries. Thus, it is unwise to follow the procedures adopted in developed countries. Another issue in heterogeneous traffic is about unit of expressing flow. In India, flow is expressed in Passenger Car Unit (PCU) in spite of its many limitations. In this study, we develop easy to use an alternate method to the use of saturation flow rate for capacity analysis of signalized intersections having heterogeneous traffic.

III. CONCLUSION

- Kadiya and Varia (2010) have suggested phase plan A and phase plan B and their suitability for the satisfactory coordination in odd and even phase differences between two 4 arm intersections. This strategy of pre-timed signal control can reduces about 30% travel time without any cost for sensors and software's. In the proposed phase plan B of Kadiya and Varia right and straight movement of the particular approach is separated which results in considerable delay in backward direction. In the proposed phase plan B of Kadiya and Varia right and straight movement of the particular approach is separated which results in considerable delay in backward direction.

- Patel et al. (2011) have presented a methodology to coordinate the signals in four- way direction on the busy urban corridor preparing time-space diagram in AutoCAD. She has developed three phase plan for better four-way signal coordination. Patel (2011) has calculated delay in AutoCAD and found that there may be considerable reduction in overall delay by four-way coordination.

- Shah et al., (2013) have found that the studies conducted by Kadiya & varia (2010) & Patel et al. (2011) have considered standard four arm intersections and logic for optimization of phase offset has not been developed. Both studies are only for evening peak period and real on site implementation or simulation of developed strategy was not performed to support their claim of travel time reduction.

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