Title	Intermediate Public Transport a Scenario and their Contribution to Urban Traffic Congestion in Indian Cities
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Citation	Environmental science, Hokkaido : journal of the Graduate School of Environmental Science, Hokkaido University, Sapporo, 8(2), 151-174
Issue Date	1986-03-15
Doc URL	http://hdl.handle.net/2115/37183
Type	bulletin (article)
File Information	8(2)_151-174.pdf

Environ. Sci. Hokkaido	8 (2)	151~174	Dec. 1985

Intermediate Public Transport a Scenario and their Contribution to Urban Traffic Congestion in Indian Cities

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Abstract

The public transport systems of the developing world is the combination of conventional forms like Buses and Rails and non conventional forms called the Intermediate Public Transport. To Indian conditions these forms of Intermediate Public Transport are Autorickshaws, Cyclerickshaws and Tongas. These forms of transport play a vitol role in the urban Public Transport cenario in view of various features existing in Developing World like, short supply of Mass transport facility, increasing transport demand, the inherited physical network pattern of the cities the socio-economic conditions etc.

The conventional traffic and transportation theories relate only to the modern transport vehicles and little was done to understand the behavioural characteristics of the Intermediate forms of transport vehicles. In this paper an attempt has been made to bringout the salient features of the Intermediate forms of Public Transport in terms of their role, importance, behaviour and their congestion effect in the urban traffic stream. Towards this direction, the case studies conducted by the author in Delhi the capital city of India are presented in this paper.

Key Words: Intermediate Public Transport, unorganised sector, Old quartars, Temporal flexibility, spatial flexibility, Uniform transport policy, Time lapse Photography, Greenberg's traffic model, Greenshield's linear Speed density model, Multi linear regression analysis and congestion effect.

1. Introduction:

The cities in the developing countries have exhibited a radically different character during the past few decades from those in the developed countries in terms of urban expansion and urban sprawl. The pace of socio-economic development being rather slow in the third world countries, the Urban magnate has been able to create and maintain an illusive image of higher employment potential and other socio-economic benefits. The one way migration resulting from this urban pull has only aggrevated the complexities of urban living. Interms of transportation demand, the peripheral expansion of the urban settlements and concentration of activities in the core ares have given rise to increased trip length and expensive commutation. On one hand, while the car ownership is seen increasing in the developing world it is apparent that the use of public transport also increasing. Any real increase in the income level of the people has the effect of revealing this demand. Unlike the situation in most countries of developed world; the urban public transport sector of the developing world is a growth industry. Furthermore it is an industry about which little is known because it comprises more than just the conventional buses and trains of developed cities. Urban transport is often greatly dependent on this sector as the conventional mass transport systems do not render service in commensurate with the growing transport demand. Many third world countries have their own unique forms of non conventional transport system which are mostly private operated and may not fall within the definition of the organized sector. This paper is intended to bringout the Intermediate Puplic Transport scenario in Indian cities in general and a case study carried out in Delhi, the capital city of India in 1979 on the Congestion effect of one of the forms of Intermediate Puplic Transport vehicles namely Autorickshaw in particular.

2. Intermediate Public Transport System Deffinition and Characteristics:

[a] *Definition*:

The Intermediate Public Transport system otherwise called as Para Transit is defined to be that form of public transport falling between the conventional buses and taxi transport systems. This is the most commenly recognised definition although there are many other forms of definitions offered to suit to the circumstances. Hence forth the Intermediate Public Transport shall be mentioned as I. P. T in short for convenience.

[b] *Characteristics*:

The schematic representation of the characteristics of I. P. T is as shown in Fig. 1.

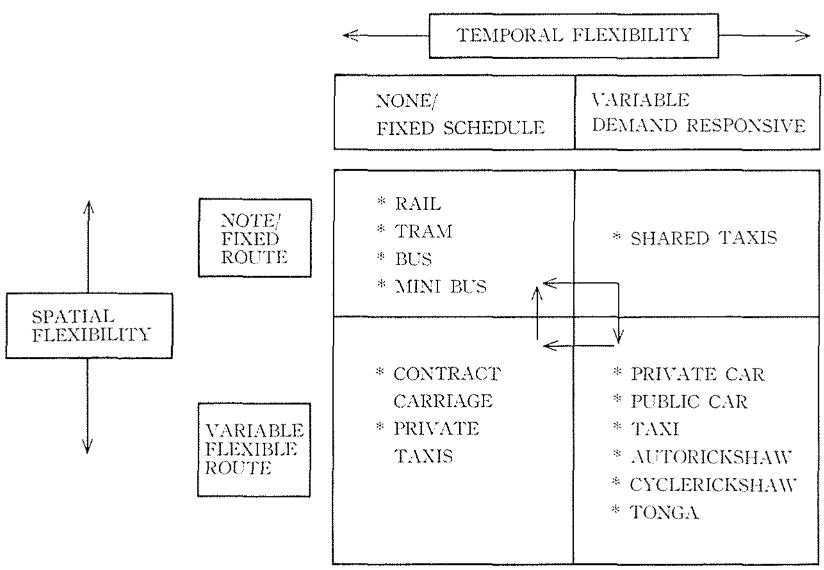

Figure 1. Space and Time Flexibility of Urban Transport Modes.

The characteristics of I. P. T are as follows :

i. I. P. T is between private and public transport.
ii. It is less flexible than individual private transport.
iii. Offshoot of private modes provide ride sharing in putting private vehicles to collective use.
iv. Offshoot of public modes become most demand responsive ie adjust their operation to cater to individual requirements.
v. Certain modes developed along with the city form using slow moving vehicles.

3. I. P. T in Indian Cities :

Besides the conventional forms of public transport systems like buses and trains all the cities of any description in India have inherited the I. P. T forms of public transport namely Autorickshaws, Cyclerickshaws, and animal drawn vehicles called Tongas. The growth in population as also that in number of vehicles have outpaced the planned growth of the cities. In many cases the transport network has remained practically static with marginal and adhoc improvements which have been proved to be highly inadequate to combat the growing needs of modern transportation. A clear gap has therefore been left between the aspiration of the people seeking more economic safe and efficient transportation systems on one hand and the supply of such facilities on the other. To fill in the gap there has been a mushroom growth of these forms of I. P. T vehicles. While the general growth rate of other vehicles was only 7 to 8%, the growth rate of Autorickshaws and Cyclerickshaws, the important forms of I. P. T was 11 to 12%. The general discription of these two forms of I. P. T are as follows.

i. *Cycle Rickshaws* : —

It is basically a slow moving triwheeled vehicle, similar to the wheels of a bicycle, operated by human energy. The seating capacity of the vehicle is two and often used for light goods transport also. This form of I. P. T is predominantly used in many cities particularly in areas where the road network pattern is narrow and not conducive for the modern motorised transport. The trip length of these I. P. T vehicles is also very short. More recently motorised forms of cyclerickshaws are also seen in a few cities. However the stability of the vehicle at higher speed, safety etc are yet to be taken stock of. In general the operation of this form of I. P. T is mostly localized or confined to a small area of operation.

ii. *Autocrickshaws* : —

This form of I. P. T is also triwheeled however power driven. It can be compared to a small three wheeled car with a seating capacity of three. The vehicle has a peculiar shape with wind screen glass in the front alone and the rest of the body of the vehicle is completly covered, with openings for the passengers to get in and getout of the vehicle. The design of the body is such that there is no rear wind screen as found in cars to facilitate rear view also. This vehicle is considered to be a fast moving vehicle with a maximum economic speed of 45 kmph and these vehicles operate in whole of city. The trip length of these vehicles is also more, comparable to buses or trains. The most predominantly used form of I. P. T is the Autorickshaw.

4. Role of I. P. T in Urban Public Transport:

A study carried out in cities like Delhi and surrounding towns on the objective assessment of the role of I. P. T in urban public transport during 1978 by the author revealed the following:

(1) The supply of mass public transport in satisfying the ever increasing transport demand is in short supply and not commensurate with the pace of developments and therefore the I. P. T vehicles fill up the gap.

(2) The various activities in the cities and the travel characteristics of the people revealed that there is latent demand for usage of I. P. T as the mass transport facility, however efficient it may be, can not satisfy all the travel demand with their fixed time and route operation system.

(3) While a homogeneous and efficient public transport for a city is the objective of any public transport planning exercise, considering the socio-economic pattern of the city, it is desirable not to replace one mode by another. Therefore the existance of I. P. T in cities and towns is inevitable.

(4) The city of any description in India has grown around a core area, the old quarters of the city with narrow road network pattern not conductve for motorised transport vehicles operation, for uniform transport facility massive redevelopment schemes are necessary. Since any redevelopment scheme will involve huge financial investment, the continuence of I. P. T service is essential.

(5) The greatest advantage of I. P. T lies in its more personalised form of public transport providing door to door service. The travel characteristics of the people indicate that for many trips like, social trips, recreation trips health service trips and business trips the I. P. T is prefered.

(6) More often luggage carrying facility in mass public transport facilities is either not possible or difficult, therefore I. P. T is prefered for such purposes by the people.

(7) The flexible route and time operation of I. P. T is another major advantage for its high demand and it provides a wide variety of choice in availing the most suitable form of transport to suit to the need, nature and purpose of the journey and purse of the traveller.

(8) Wider income disparity prevailing in India is not conducive for an uniform transport policy and regimentation in favour of particular mode of transport may rather deter development than promoting it.

(9) The I. P. T is an industry by itself. It provides a vast employment potential in various spheres of its existance, therefore in a situation where promotion of gainfull employment is of pramount importance, there is large scope in

the sector of I. P. T.

5. Need for the Study:

Having assessed the role of I. P. T that it can play in the overall urban public transport if not in the present form, perhaps in a more organised manner, an attempt was made towards identifying the behavioural characteristics of Autorickshaws and their congestion effect in the urban traffic stream towards effecting a better transportation planning and traffic control. The need for the study was felt in view of the following;

The objective of a transportation facility is to accommodate a quantity of demand with an acceptable quality of service. This quality is apparent to the user in terms of his freedom to follow a path and speed of his choice, the ease and the physical and mental comfort of his operation. Although not directly of these factors, the driver is affected also by the degree of hazard to which he is subject, the probablity of failure to meet his transportation objectives and the total cost of the service. An acceptable quality of service to accommodate a quantity of traffic depends on the capacity of road network, that is, the capacity of open road sections and of road intersections is a measure of its ability to accommodate traffic. Obviously this ability depends greatly on the physical features of the roadway itself. Yet there are other factors not directly related to roadway features that are of major importance in determining capacity of highways. Many of these factors relate to variations in the traffic demand and the interactions of the vehicles in the traffic stream. If all the vehicles in traffic stream were identical in performance, determination of capacity would have been a simple matter. However, composition of traffic on road network is seldom homogeneous in nature and the traffic stream consists of vehicles of different performance characteristics, determination of capacity becomes a complex task. The hetrogenity of traffic stream in developing countries is especially large compared to the developed countries. In the United states for instance the average traffic composition of flow with regard to motor vehicles only shows that the majority of motor vehicles on the road are commercial vehicles. In urban areas traffic flow composition consists of large variety of fast and slow moving vehicles like, Cars, Scooters Motorcycles, Autorickshaws, Buses, and Trucks Cyclerickshaws and animal drawn Vehicles.

Vehicles of different types require different amounts of road space because of variations in size and performance. Hence Autorickshaws basiclly a power drawn vehicle differs in size [comparatively smaller] and performance in the urban traffic stream. Though there is a general agreement on the role of Autorickshaw it can play in the overall urban transport facility the wide spread contentions are:

(1) The number of Autorickshaws in the traffic stream cause congestion.

(2) The smaller Autorickshaws introduce greater accident hazard on urban roads because of reduced visibility from within and greater difficulty by other drivers in seeing the vehicles or seeing through it to other vehicles in the stream.

(3) Another school of thought is that small vehicles are safe or safer because of greater maneouverability and because other drivers can see over them to other vehicles in the traffic stream.

However there were no studies undertaken to identify the behavioural characteristics of Autorickshaws, whether they cause congestion to the urban traffic flow or not, so as to arrive at a rationale for traffic management, control and regulatory measures in order to ensure better level of service of the urban transportation facility.

6. Objectives of the Study:

(1) To compile and review all the available literature on Traffic Flow Theory and its applicability to Indian traffic condition.
(2) To study the concept of level of service and its relationship with land use and the operational characteristics of all the vehicles in general and Autorickshaws in particular.
(3) Delineation of areas in Delhi urban area having distinct landuse, road network, traffic characteristics and accident analysis and identification of level of service of each zone.
(4) To undertake case study for practical application of one or more methods identified from literature study to determine the behavioural characteristics of Autorickshaws in the traffic stream and the congestion effect of Autorickshaws on the traffic and interpretation of study results to different levels of service.

Though the case study conducted at Delhi was to cover many objectives, it is felt sufficient to elaborate the analysis carried out to identify the behavioural characteristics of Autorickshaws and their congestion effect in the traffic stream alone for the purpose of this paper.

7. Case Study I:

[A]. *Behavioural Characteristics of Autorichshaws*: —

The Study methodology is as shown in Fig. 2 and the study location and analysis grid are shown in Fig. 3.

[a]. *General*: —

It has long been recognized that the composition of the traffic stream, ie proportion of cars, buses, trucks Autorickshaws etc is a major factor in determining the total number of vehicles which can be transported through a section of roadway. Different types of vehicles exhibit widely different behaviour in traffic. Such a variation in behaviour can materially affect the character of the traffic stream as a whole.

On a normal multilane facility the effect of difference in operating behaviour of vehicles is minimised so long as sufficient freedom exists for drivers to change lanes. However, at facilities where lane changing is not permitted,

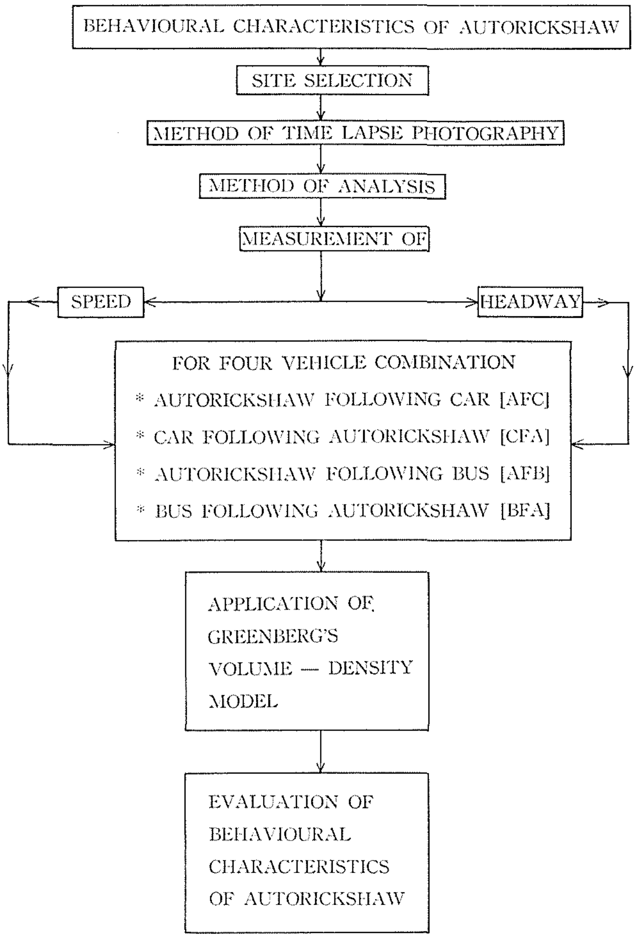

Figure 2. Study Methodology Flow Chart.

traffic will tend to be governed by those vehicles which are least able to respond to change in traffic speed and volume. Consequently, it is important that as much as possible be understood about the behaviour of each type of vehicle in relation to all types occuring in the traffic stream. Towards this end the present study is undertaken to study the behavioural characteristics of Autorickshaws in relation to buses and cars as there is heavy demand from these vehicles for road space utilization in urban Delhi roads.

[b]. *Physical Situation* : —

To study the behavioural characteristics of Autorickshaws in relation to buses and cars on a stretch of road, where there is heavy flow, composition of all vehicles, less traffic interruptions like pedestrian crossings, bus stops and other traffic control measures and finally having a suitable vantage point [a tall building] to fix the camera and take phtographs, a four lane divided carriageway named I. P. Marg was selected. The I. P. Marg is a major artery connecting

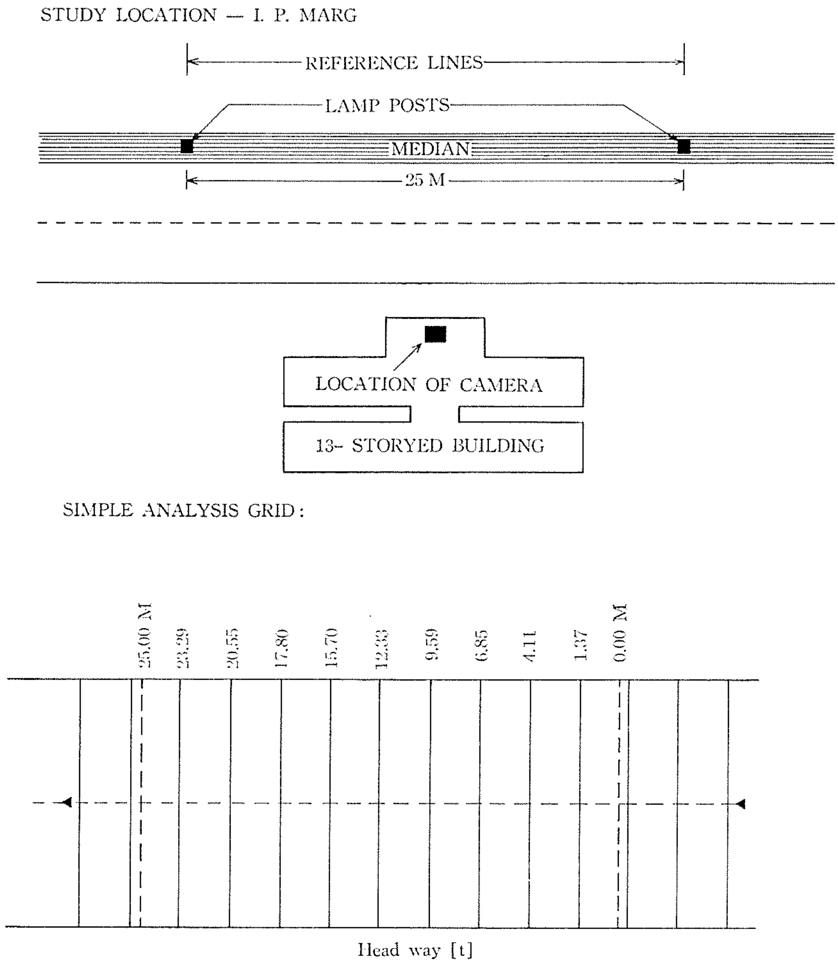

Figure 3. Study location and Simple analysis grid.

work centres bearing heavy volume of traffic during peak hour. The details of the site conditions are shown in Fig. 3.

[c]. *Experimental Procedure*: —

To identify the behavioural characteristics of Autorickshaws in relation to buses and cars, it was necessary to know, for each vehicle its headway time and velocity or the speed. The instrument used in collecting the necessary data was a Time lapse photography camera.

[d]. *Time Lapse Photography*: —

Off all the availble methods and instruments, time lapse photography has been proved to be the best suited for headway time measurements and prediction of behavioural characteristics of vehicles as Time lapse photography exhibits the field situation as it is and provides a permanent record of the data on headway, speed, density and volume.

For the purposes of the study, a 16 mm cine camera was used. The camera was set up at a vantage point on the terrace of a thirteen story building facing the I. P. Marg. The camera was set up perpendicular to the flow of traffic. The Fig. 3 explains the position of the camera and other relevant details. The lamp posts on the central median acted as reference points. The time interval between each frame was maintained at one second. Photographs were taken of the traffic in the morning and evening peak hours for 35 minutes. During the process of photographing a blank frame was shot at every 15 seconds interval so as to have a number of sets for analytical purposes which will give the required results. About 30 such sets were prepared using film editing equipment.

[e]. *Method of Analysis* : —

To obtain data on Headway Time and speed of individual vehicles a suitable scale was constructed on transparent medium and fixed on the editing screen. The scale was so constructed to represent the exact field conditions. From the number of photographs in which an individual vehicle has occured over the section is identified and the speed of that individual vehicle was calculated as follows ;

$$V=\frac{d}{n}\times t\times 3.6 \text{ Kmph}$$

Where V—Speed of the vehicle in kmph

d—the displacement of a vehicle in metres

n—Number of frames (photographs) in which the vehicle has crossed the distance between the reference marks.

t—the speed of the camera ie. one frame per second.

The Time Headway has been measured using the lamp posts as reference mark. The time interval between the two successive vehicles just crossing the reference mark has been calculated. The typical scale constructed for the purpose of analysis is shown in the Fig. 3.

The Head way Time was calculated as follows ; "time interval between the fronts of the vehicle crossing a particular reference line when following one another [measured in terms of no of frames] or

Headway Time t=spacing in [M]

[f]. *Analysis* : —

For the purpose of the study, Four kinds of vehicle relationships were examined ;

1) AUTORICKSHAW FOLLOWING CAR [AFC]
2) CAR FOLLOWING AUTORICKSHAW [CFA]
3) BUS FOLLOWING AUTORICKSHAW [BFA]
4) AUTORICKSHAW FOLLOWING BUS [AFB]

Each of the pertinant data subsets were further segmented in to 5 kmph class intervals. Mean Headway Times were calculated for every increment of each of the four sets. Tables 1 to 4 given below illustrate the mean Headway Time and sample size by velocity class for each type of traffic. The plot of mean Headway Time [HWT] versus speed for the four traffic types mentioned above is shown in Fig. 4. After considering the general shape of the HWT speed data in Fig. 4 it seemed possible to fit smooth curves to the data. Upon

Table 1. Autorickshaw Following car [AFC]

Speed in kmph	Mean Headway secs	Sample size	Estimated Volume V.P.H
15–20	2.65	3	1358
20–25	2.40	5	1500
25–30	2.30	8	1565
30–35	2.45	16	1469
35–40	2.50	11	1440
40–45	2.60	4	1384
45–50	2.90	2	1241
50–55	—	—	—
55–60	—	—	—

Table 2. Car Following Autorickshaw [CFA]

Speed in kmph	Mean Headway secs	Sample size	Estimated Volume V.P.H
15–20	3.45	5	1043
20–25	3.41	2	1055
25–30	3.38	7	1065
30–35	3.40	11	1058
35–40	3.70	9	972
40–45	3.90	4	923
45–50	4.20	3	857
50–55	—	—	—
55–60	—	—	—

Table 3. Autorickshaw Following bus [AFB]

Speed in kmph	Mean Headway secs	Sample size	Estimated Volume V.P.H
15–20	3.00	1	1200
20–25	2.85	2	1263
25–30	2.27	7	1333
30–35	2.80	6	1285
35–40	2.92	3	1232
40–45	3.01	2	1196
45–50	3.20	3	1125
50–55	—	—	—
55–60	—	—	—

Table 4. Bus Following Autorickshaw [BFA]

Speed in kmph	Mean Headway secs	Sample size	Estimated Volume V.P.H
15–20	3.40	2	1058
20–25	3.10	5	1161
25–30	2.90	7	1241
30–35	2.58	11	1395
35–40	2.95	9	1220
40–45	3.16	4	1139
45–50	3.24	2	1111
50–55	—	—	—
55–60	—	—	—

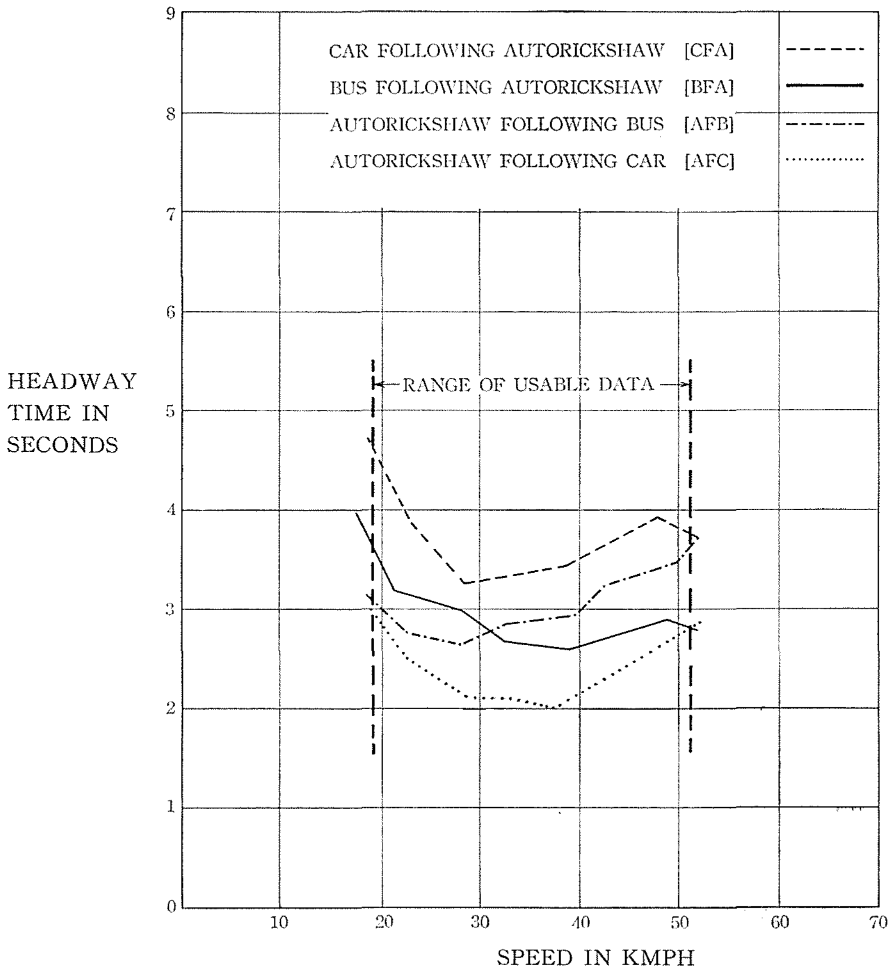

Figure 4. Head way Time Versus Speed for Four Combinations of Lead and Following Vehicles.

consideration a variation of the theoretical model proposed by Greenberg appeared to be a likely possiblity. Greenberg held that flow was related to concentration in the form of;

$$q = ck \ln \frac{[k_j]}{[k]}$$

where q is flow, c is critical velocity and k and k_j are densities. This results in the familiar $q-k$ curve which rises from zero flow at zero density to some point of maximum flow and then falls off as density builds up untill the point of jam density $[k_j]$ where flow is again zero.

Since flow can be expressed as $\frac{3600}{\mathrm{HWT}}$ it can be seen that maximum flow is equivalent to minimum HWT. In addition as velocity decreases due to the extra time required for the vehicle to clear its own length past the point. As velocity approaches zero, HWT approaches infinity. But as HWT approaches infinity flow approaches zero which fits the lower limit of Greenberg's model.

Rewriting Greenberg's equation to relate HWT to velocity it becomes;

$$t = \frac{1000}{k_j u} u/c$$

Where

t—HWT in seconds
u—velocity in kmph
c—Velocity [in kmph] at minimum HWT
k_j—Jam density in Veh/km.

The equation was fitted to the HWT — Velocity relationship for each of the four traffic types.

[g]. *Interpretation of Curves*: —

The fit of curves for the traffic type "Autorickshaw Following Car [AFC] and Car Following Autorickshaw [CFA]" are shown in Fig. 5.

The lower curve indicates the relationship of Autorickshaw following Cars while the upper curve also indicates the same relationship ie Car following Autorickshaw. This is the homogeneous flow conaition, a condition more possible to achive when all the vehicles are of same type. The AFC curve has minimum velocity of 25 km and HWT of 2.30 seconds. This represents a point of maximum flow of 1565 VPH. The curve CFA has its minimum velocity of 27.8 kmph and HWT of 3.38 seconds at a maximum flow rate of 1065 VPH. The two curves exhibit a considerable degree of similarity with a 2.8 kmph difference in speed at maximum flow.

The HWT offset between the two curves is quite constant within the normal range of operating speeds going from a difference of one second at 18 kmph to 1.6 seconds at 48 kmph.

The similarity in behaviour of these two types of traffic is most desirable as

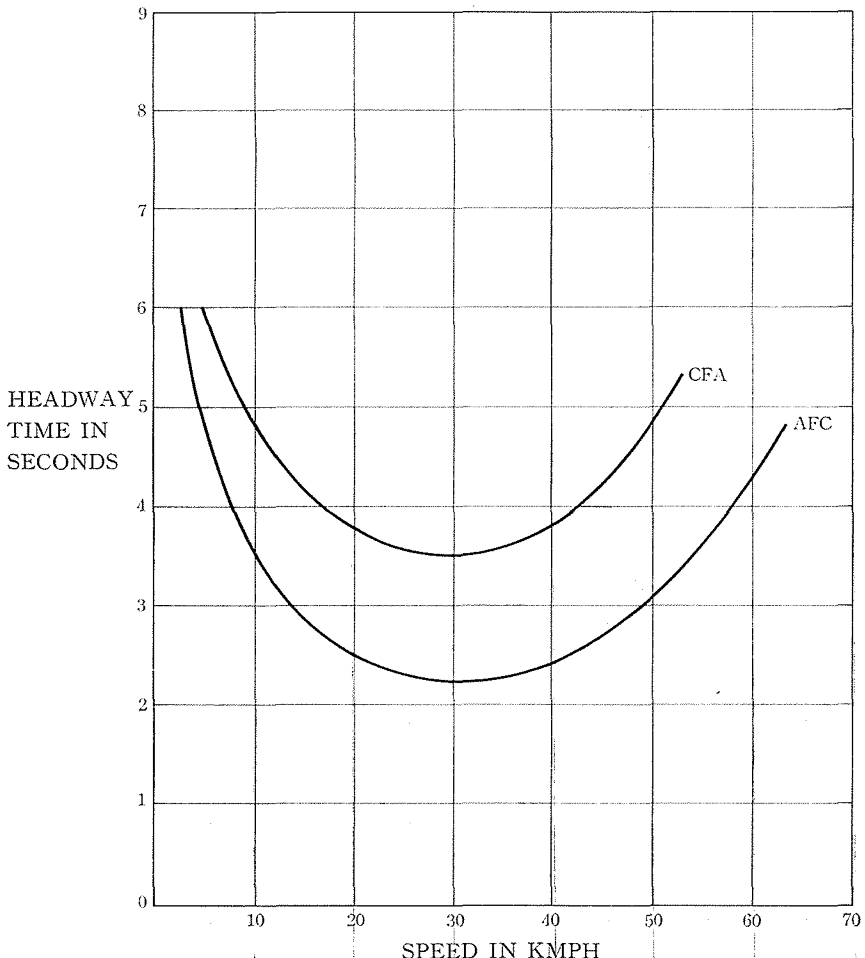

Figure 5. Fit of curves to Headway- Time Speed data for CFA & AFC.

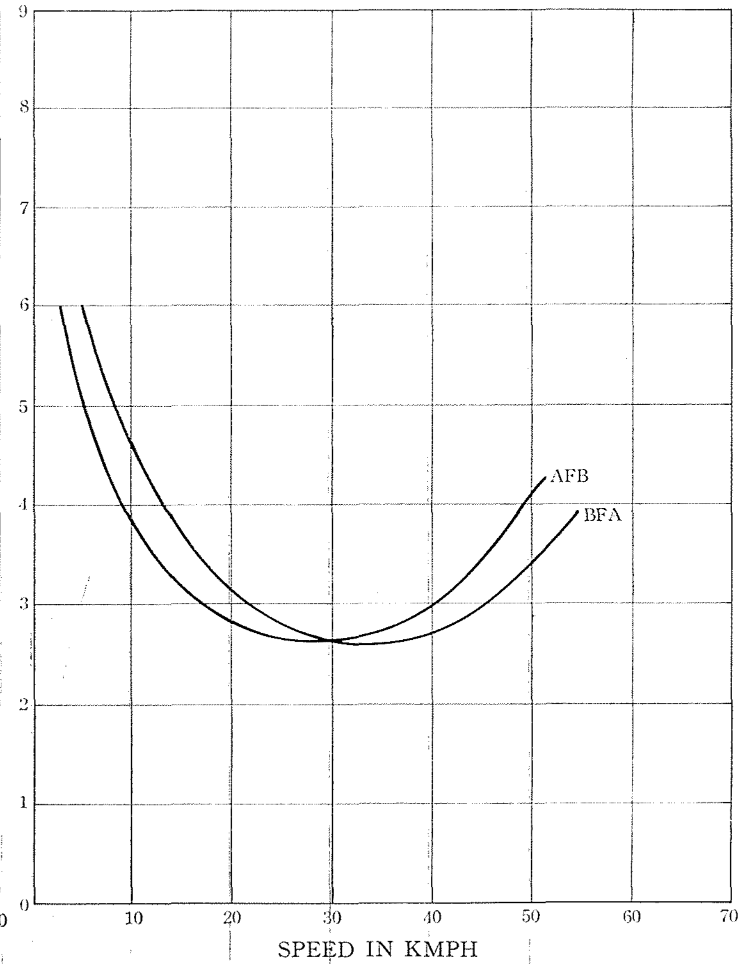

Figure 6. Fit of curves to Headway- Time Speed data for BFA & AFB.

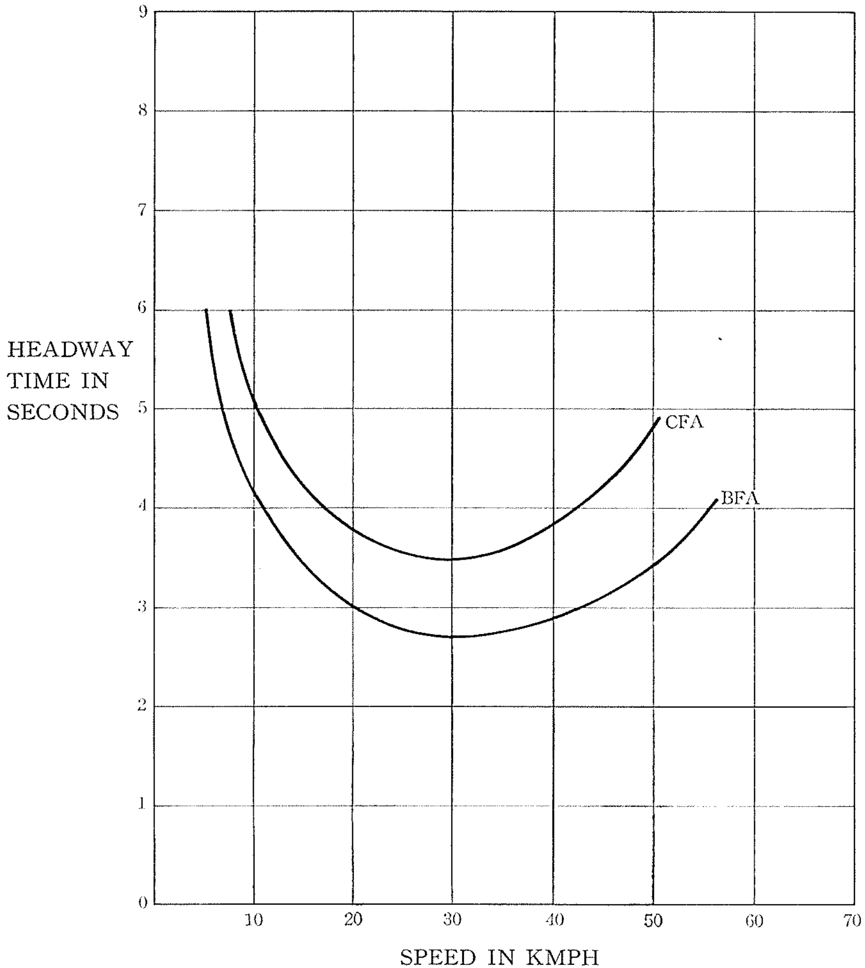

Figure 7. Headway Time Versus Speed with Autorickshaw As Lead Vehicle.

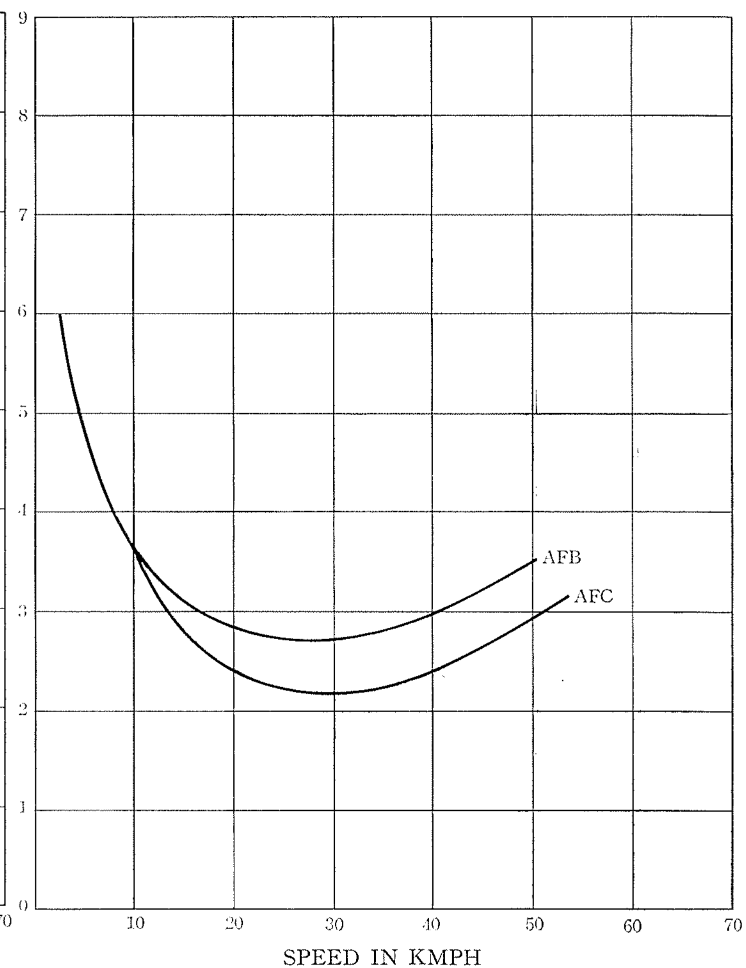

Figure 8. Head way Time Versus Speed with Lead Vehicle As Bus and Car.

it indicates that control procedures which attempt to optimize traffic flow in terms of speed could be equally effective with either type of traffic.

The fit of curves for the traffic type "Autorickshaw Following Bus [AFB] and Bus Following Autorickshaw [BFA]" is shown in Fig. 6.

The AFB and BFA curves exhibit the non homogeneous conditions wherein the minimum time Headway is 2.7 seconds with a velocity of 26 kmph and flow rate of 1333 veh/hr. For BFA the minimum Time Headway is 2.58 seconds with a velocity of 35 kmph and flow rate of 1395. Thus the non homogeneous flow exhibit definite similarity in maximum flow rate but at materially different velocity. This is quite opposite to the homogeneous flow experience.

The difference in optimum speed of AFB and BFA poses a setback in traffic control measures. If for example, speed is held at 26 kmph to optimise AFB, then the BFA segment will be operating at a less than optimum flow rate and vice versa. Hence a stream of large number of Buses and Autorickshaws can not be optimised at any one speed. However, a more possible velocity may be 30 kmph, but BFA would be required to operate at a sub-optimum velocity which might create unstable flow conditions.

The fit of curves for the traffic type "Car Following Autorickshaw and Bus Following Autorickshaw" is as shown in Fig. 7.

The fit of curves indicates that when Car follows Autorickshaws, Car maintains a larger space behind Autorickshaw. This may be because car drivers could not visualize the traffic ahead through the Autorickshaw as the body of the Autorickshaws are completely covered.

On the contrary when bus follows Autorickshaws Bus maintains a smaller spacing as the bus drivers could visualize traffic ahead over Autorickshaws,

The fit of curves for the traffic type "Autorickshaw Following Car and Autorickshaw Following Bus" is as shown in Fig. 8.

The fit of curves indicates a situation that when Autorickshaws follow Cars they maintain a smaller spacing behind the Car as the visibility through the Car is more clear than through the Autorickshaws when the Cars follow them. At the same time when the Autorickshaws follow the Buses they maintain a larger space as the size of the Buses prevents the driver of Autorickshaw to visualize the traffic ahead.

8. Case Study II:

Speed Density Relationship of Autorickshaws in Relation to Buses and Cars:

[a]. *General*: —

Congestion is the impedence of one vehicle on the other causing delay. In a situation like Delhi traffic which is heterogeneous in character, the impedence and consequent congestion is more. Hence the higher the heterogeneity the more the congestion. Since Autorickshaws have been increasing in number and forms considerable percentage composition of traffic, to find out the effect of Autorickshaws on the speed of other vehicles registration plate method of observation for speed, density, volume and composition was adopted.

Development of Speed- Density Relationship for Buses Cars and Autorickshaws

[b]. *Backround Study*: —

If traffic is sufficiently light, then the drivers of Buses, Cars and Autorickshaws have the freedom to do as they wish within certain limitations (i. e. Speed limits if the drivers are law abiding, or certainly the technological limits of the vehicles). Only occasionally will each driver slow down because of presence of other vehicles. As traffic increases to more moderate level, encounters with other slow moving vehicles are more numerous. It is still not difficult to pass the slower moving vehicles and hence the driver's average speed is not appreciably less than the desired speed.

However in heavy traffic, changing lanes become difficult and consequently the average speed of Buses, Cars and Autorickshaws get affected.

On the basis of these observations it is justified to use a simplifying assumption that at any point along the road, the velocity of a vehicle depends on the density of traffic.

Therefore;

$$V = v\,[k] \qquad (1)$$

Richards in the mid 1950's proposed this type of mathematical model of traffic flow. If there are no other vehicles on the road [corresponding to very low traffic densities] then the vehicles would travel at the maximum speed.

Therefore;

$$V\,[0] = V_{\max} \qquad (2)$$

$V_{\max}$ is sometimes referred to as the "mean free speed". However as the density increases, velocity would continue to diminish and at certain density, the vehicles would stand-still. This maximum density is known as jam density.

$$\text{ie}, V\,[K_{\max}] = 0 \qquad (3)$$

The relationship between the vehicle speed and traffic density corresponding to values in between those given by equations (1) and (3) may or may not be a linear relationship. However it may be assumed to be linear.

[c]. *Study Methodology*: —

The Study Flow chart shown in Fig. 9 explains the various steps followed for the purposes of the study;

[d]. *Data Collection*: —

Study Location;

To find out the different values of densities and the corresponding values

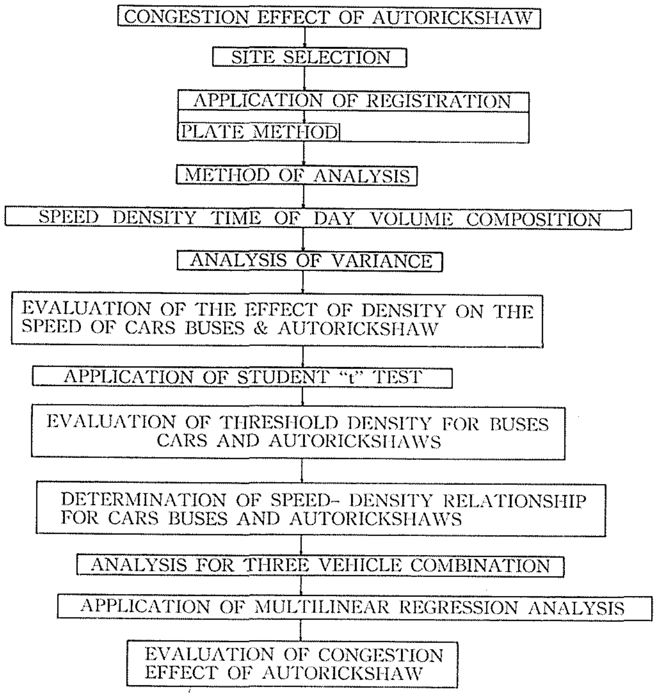

Figure 9. Study Flow Chart.

of Volume, Spot speed and Composition, a study location with heavy flow of traffic with considerable composition of Autorickshaws was selected on a Four lane road called ALIPUR ROAD in Delhi in such a way that the proper collection of data is ensured. The following were the criteria set for the data collection

(1) Observers were located and data recorded in such a manner that the measurement did not attract the notice of the drivers.
(2) Accumulation of onlookers or anything unusual at the study location was avoided.
(3) Lines marked with the chalk on the road were made inconsipicuous to the approaching drivers.
(4) The study location were also away from the traffic control points [eg. bus stop, intersections or right or left turn etc.] so that speed is not affected due to their presence.

While the data relating to spot speed, classified volume count and density were collected using the conventional methods, the data relating to the Jam density was collected at intersections as follows; "for the purpose of the data collection the length of the road near the Traffic signal was marked lengthwise at an interval of one metre. The jamming condition was considered to exist at red light of Traffic signal. At red light, both the number of different categories of vehicles and the length of the road occupied by these were noted. Fifteen observations were taken for jam density calculations.

[e]. *Data Analysis* : —

The data collected were analysed and Spot speed, Classified volume count, Density and Jam density were calculated. 34 data sets were established for detailed analysis as indicated below ;

(1) Spot speed, Space mean speed for various density values were established.

(2) The mean speed and their standard deviation for buses cars and autorickshaws were established.

(3) Two possible and measurable sources of variation for the speed of buses and cars were identified as,

a. the time of the day and

b. the traffic density.

To determine whether part of the variablity of the speed could be attributed to the identified sources namely the time of the day and the density of traffic an analysis of variance was performed on the data collected.

c. To determine the effect of the time of the day and the Traffic Density on the speed of Buses, Cars and Autorickshaw it was found that the number of observations were not the same from one cell to the other, the method of weighted squares was made use of.

d. The threshold density for Buses Cars and Autorickshaws was determined using the 'Student '*t*' test.

[f]. *Interpretation of the Analysis* : —

The speed density relationship determined for Buses Cars and Autorickshaws with respect to the type of the day and the traffic density are as shown in Figs. 10 to 12.

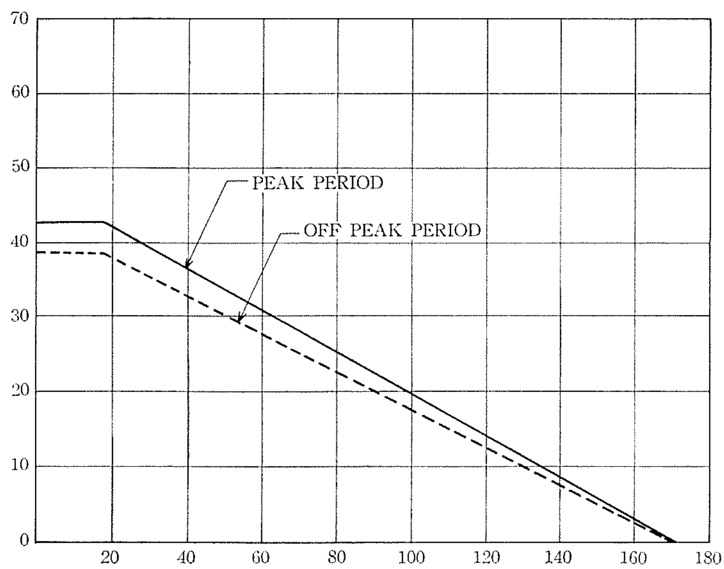

Figure 10. Speed Density Relationship for Autorickshaws.

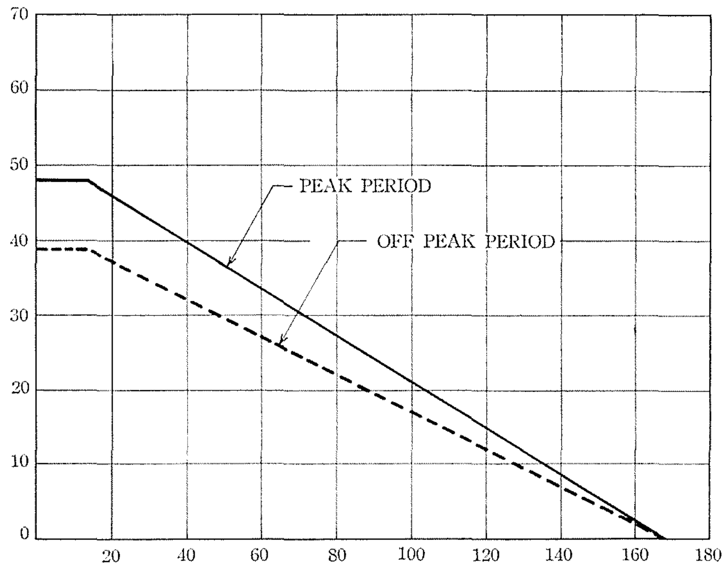

Figure 11. Speed Density Relationship for Buses.

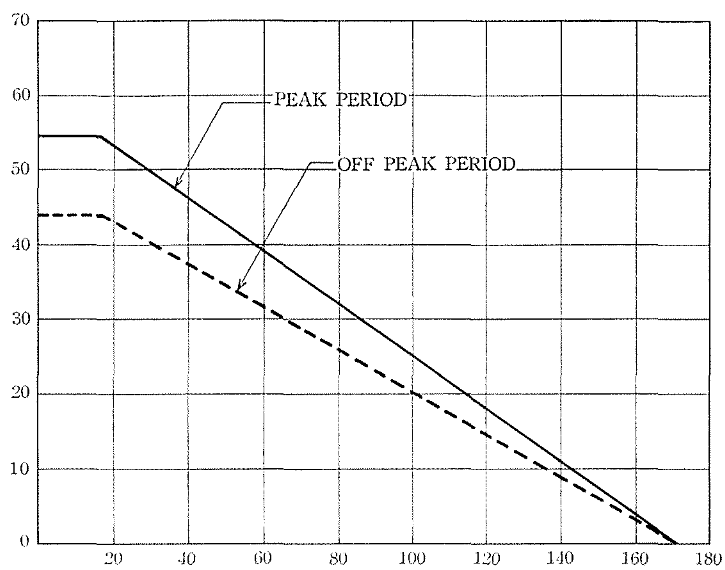

Figure 12. Speed Density Relationship for Cars.

(1) The Speed "V", Density "K" relationship for Autorickshaw using the GREENSHIELD'S Linear Speed Density model for Peak and Off peak periods as shown in Fig. 10 are as follows;

PEAK PERIOD:

$$V = [48.16 - 0.291\, k]$$

for $k \geqslant 17$

OFF PEAK PERIOD :

$$V = [43.89 - 0.256\ k]$$
for $k \geqslant 17$

Where ;

V = MEAN SPEED OF AUTORICKSHAW
k = DENSITY [VEH/KM/LANE]

Thershold Density for Autorickshaws during,

PEAK PERIOD :
17 [VEH/KM/LANE]

OFF PEAK PERIOD :
17 [VEH/KM/LANE]

The maximum mean speed of Autorickshaws, during

PEAK PERIOD is 42.98 KMPH,
OFF PEAK PERIOD is 39.54 KMPH.

(2) The Speed "V" Density "K" relationship for Buses using GREENSHIELD'S Linear Speed Density Model for Peak and Off Peak period as shown in Fig. 11 are as follows ;

PEAK PERIOD :

$$V = [51.40 - 0.308]$$
for $k \geqslant 4$

OFF PEAK PERIOD :

$$V = [41.35 - 0.246]$$
for $k \geqslant 14$

Where ;

V = Mean Speed of Buses [KMPH]
k = Density [VEN/KM/LANE]

The Threshold Density for Buses during,

PEAK PERIOD is 14 [VEH/KM/LANE]
OFF PEAK PERIOD is 14 [VEH/KM/LANE]

The maximum mean speed of Buses during,

PEAK PERIOD is 47.40 KMPH,
OFF PEAK PERIOD is 37.80 KMPH

(3) The Speed "V" Density "k" relationship for Cars using GREENSHIELD'S Linear Speed Density Model for Peak and Off peak period as shown in

Fig. 12 are as follows;

PEAK PERIOD:

$$V=[60.05-0.357\,k]$$
$$\text{for } k \geqslant 17$$

OFF PEAK PERIOD:

$$V=[46.80-0.276\,k]$$
$$\text{for } k \geqslant 14$$

Where;

V = Mean Speed of Cars [KMPH]
k = Density [VEH/KM/LANE]

The Threshold Density for Cars during

PEAK PERIOD is 17 [VEH/KM/LANE]
OFF PEAK PERIOD is 14 [VEH/KM/LANE]

The Maximum Mean Speed of Cars during

PEAK PERIOD is 53.95 KMPH,
OFF PEAK PERIOD is 42.88 KMPH.

[g]. *Findings of the Study*: —

(1) For higher values of density the rate of reduction in the speed of Autorickshaw is very small and more for cars and Buses.

(2) For every increase in density value of 10/veh/lane the rate of reduction in speed for,

BUSES 3.10 kmph,
CARS 3.60 kmph,
AUTORICKSHAW 2.20 kmph.

9. Congestion Effect of Autorickshaws:

[a]. *Genral*: —

Out of the well known mathematical expressions, regression analysis is the best and easy method of quantifying the effect of the one or more independent variables on the depedent variable.

Taking advantage of the method of regression analysis the collected data was grouped for Peak and Off peak periods. The grouped data provided the informations on Space mean speed, Density Values at different percentage mix of Autorickshaws as well as Buses.

[b]. *Multi Linear Regression Analysis*: —

The basic form of equation is;

$$Y = a + bx + cz$$

Where

Y—Dependent variable

x and z—Independent variables

a, b & c —Regression coefficients or constants

The form of the equation relating to the study is as follows. ;

$Y =$ The space mean speed of traffic in kmph

x—Loading rate Veh/km/lane

z—Percentage of Autorickshaws or buses.

a, b & c—constants.

The computed regression equation for peak and offpeak periods at various percentage composition of Autorickshaws is as follows,

FOR PEAK PERIOD :

$$Y = 48.59 - 0.23x + 1.57z \qquad (1)$$

FOR OFF PEAK PERIOD :

$$Y = 69.28 - 3.35x + 19.42z \qquad (2)$$

Where

Y—Traffic flow speed in kmph

x—Load for a Traffic Lane in TEN minutes
[as Vehicles, Variable between 54 & 131].

z—Percentage mix of Autorickshaws [variable Between 0.1 to 0.25].

The equations in (1) & (2) above indicate that when the percentage mix of Autorickshaw increases the speed increases rather decreasing the traffic flow speed and do not contribute to congestion of traffic as has been believed.

On the contrary when the traffic speed was analysed at various percentage mix of Buses, a different set of regression equations was formed which are given as follows ;

FOR PEAK PERIOD :

$$Y = 47.58 - 0.067x - 1.75z \qquad (3)$$

FOR OFF PEAK PERIOD :

$$Y = 69.0 - 2.65x - 8.64z \qquad (4)$$

The equations (3) and (4) above clearly indicate that the traffic flow speed is reduced when the percentage mix of Buses increases. The regression coefficients when correlated showed a high degree of correlation at 97 percent.

[c]. *Conclusions of the Study* : —

(1) The Autorickshaws do not contribute to the traffic congestion.

(2) The increase in the number of buses in the traffic stream adversely affected the flow speed.

10. Recommendations of the Study

(1) The speed density mathematical model and regression analysis have clearly established that Autorickshaws do not impede other vehicles and cause congestion. Hence the introduction of more number of Autorickshaws into the traffic stream on arterial and radial roads of New Delhi will not affect the level of service of the transportation facilities.

(2) The Headway speed analysis and regression analysis have shown that buses impede the other vehicles in the traffic stream and cause congestion. Hence there is a need to seggregate buses on to seperate lane on all arterial and radial roads which converge towards the city centre to maintain better level of service.

(3) Since the Autorickshaws have a maximum economic speed of 45 Kmph, on major Highways [Ring Road] at the periphery of Delhi Urban Area the Autorickshaws become a slow moving vehicle as the speed maintained on the Highway is more than 60 kmph. Therefore the Autorickshaws should be seggregated on to seperate lane on major Highways.

(4) The Headway analysis has clearly shown that the present structural design of the body of Autorickshaws is a visual intrusion for the car drivers and that optimisation of flow level suffers. Hence there is a need for improvement in the structural design of the body of Autorickshaws.

(5) Out of the two mathods; the registration plate method and Time lapse photography method, the later mathod holds much promise for use on extensive scale for better understanding of traffic flow phenomenon and arriving at a rationale for traffic and transportation planning and design on sound practical and economic grounds.

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(Received 26 Aug. 1985)