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Effect of heavy vehicles on traffic stream speed on two lane two way undivided highway

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Abstract

The effect of heavy vehicles on highway traffic stream is significant as they are moving with slow speeds. This effect becomes more severe when there is no separate lane provided for the heavy vehicles, particularly on two-lane two-way undivided highway where considerable proportion of heavy vehicles are moving. Estimation of average traffic stream speed for the varying percentage of heavy vehicles is necessary to evaluate the level of service of the given highway section. This study is aimed to determine the effect of heavy vehicles on traffic stream speed of the selected two-lane two-way undivided highway section of Modasa-Bayad-Pankhiya road of Gujarat state, India. The major truck flow between Mumbai-Delhi is passing through this section. The continuous flow of heavy trucks and other vehicles slows down the average speed of traffic stream. The observed speed-flow-density relationship reveals that only density or only percentage of heavy vehicles has not a significant effect on speed variation. But, it is found that the combined effect of density and heavy vehicle fraction, termed as 'Heavy vehicle factor' has a good linear relationship with traffic speed.

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1. Introduction

Road network provides the integrated network which facilitates trade, transport, social integration and economic development. It is used for the smooth conveyance of both people and goods. Transportation by road has the advantage over other means of transport because of its easy accessibility, the flexibility of operations, door to door service and reliability. Consequently, passenger and freight movement in India over the years have increasingly shifted towards

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roads in comparison with other means of transport. There is also rapid increase in the number of commercial freight vehicles over the past decades that have raised the mixed flow traffic operation over the various types of roads. On the Indian roads, generally two wheelers, three wheelers, car, bus, truck, light commercial vehicles, bicycle, non-motorized vehicles are moving without lane discipline. Overall traffic flow on rural roads is largely affected by the presence of heavy vehicles like trucks and buses. Traffic speed reduces effectively with increased proportion of heavy vehicles. When the heavy vehicles move in platoon, they drastically affect the following vehicles, increasing their operational delay and lower down the level of service of road section.

1.1. Aim and objective of the study

Considering the above discussion, this study is aimed to determine the effect of heavy vehicles on traffic speed on two-lane two-way undivided rural highway. For this purpose it is required to select the highway stretch having mixed traffic flow with substantial proportion of heavy vehicles. Then it is interesting to know whether traffic speed varies with density, or with percentage of heavy vehicles, or with any other parameter. Therefore, on the selected highway section, determination of average traffic stream speed and density for the different percentage of heavy vehicles is intended.

1.2. Review of past studies

Some of the studies regarding impact of heavy vehicles on traffic flow parameters are briefly discussed here.

Pokulwar et al. (2016) have carried out detailed study regarding the impact of heavy vehicles, in which they evaluated speed and travel time of affected and unaffected vehicles at selected 100 m patch on Hingna road at Nagpur, India. They noted decline in the speed of the affected vehicles due to presence of heavy vehicles as compared to that of unaffected vehicles. They adopted the vehicle conversion model and lane changing model to find out the impact on traffic parameters. They assessed the impact by comparing changes in behaviour at different percentage of heavy vehicles.

Kaisy and Jung (2005) have investigated the effect of heavy vehicles during congestion using passenger car equivalent. They have on field data from varied situation of which one was located on level terrain and other was on 1 km long 3% upgrade near Toronto, Canada. Simulation model INTRODUCTION is used to analyse the data and determined the passenger car equivalent (PCE) for different situations. They interpreted that effect of heavy vehicles increases with increase in percentage of heavy vehicle and grade percentage.

Semeida (2017) has shown impact of both percentage of heavy vehicles and horizontal curvature on capacity of road on Egyptian road network. Various geometric features such as lane width, median width and radius of curve were taken and capacity is found out with respect to these features along with respective percentage of heavy vehicles. Study included the concept of the capacity loss that occurred due to combination of geometric features and percentage of heavy vehicles. Capacity loss clearly indicates the effect of geometry of road and heavy vehicles on traffic parameters.

Kong et al. (2016) have carried out the analysis of the impacts of trucks on traffic flow based on cellular autonomous (CA) model which considered both the performance difference between passenger cars and trucks as well as behavioral change in passenger cars under the influence of trucks. For preliminary study questionnaire survey was carried out among the drivers to assess the impact of truck and their behavioural change under the influence of trucks. CA model showed that there was significant impact of trucks and indicate that impact increased with increase in percentage of trucks. Comparison charts were provided with help of CA model for car following car condition and car following truck condition which showed the amount of change occurred due to presence of truck and same study was carried out for different percentage of trucks and it was found that higher percentage of trucks results in higher impact. It was also found that impact increased significantly in situation of congestion and speed of passenger cars was found to have inverse relationship with truck percentage.

Roy et al. (2017) have assessed the effect of mixed traffic on two lane roads in India. Roads were divided in 3 different categories in which category 1 included the intercity roads where motorist used to have higher speeds. Category 2 included the routes to major intercity roads where motorist used to have moderate speeds and category 3 roads included the roads of moderately developed areas. 500 m strip was marked on selected road and data is collected

through videography. Vehicles are divided in six different categories as trucks, non-motorized vehicles (NMV), car, bus, 3 wheelers and 2 wheelers. It was found that density reduced where more heterogeneity of traffic was present and speed profile of vehicles reduced where percentage of heavy vehicles was more. Category 1 roads have least impact as it have less percentage of heavy vehicles (slow moving). Category 2 and category 3 roads have more impact on speed profile as well as other traffic parameters.

2. Methodology

Looking at the objective of the study and reviewed literature, a methodology is proposed to determine the relationship of average speed of traffic stream with density and heavy vehicle percentage.

2.1. Average speed of traffic stream

On the selected highway stretch, on the different locations 1 km length sections can be chosen where continuous flow available for the same road width, without any junction or external disturbance. On the entry and exit points for both the directions, license plate number of vehicles can be detected by videography. By knowing the entry and exit time of same vehicle, average travel time can be determined. From the known distance and travel time, space mean speed of vehicles can be calculated for the chosen suitable time intervals.

2.2. Traffic density

As mentioned in 2.1, the difference of cumulative arrivals and cumulative departures for the every time interval on both the directions can give the number of vehicles existing in the selected section of 1 km. This density can be expressed in veh/km or pcu/km. The continuous videography on entry and exit points can make it possible.

2.3. Heavy vehicle percentage

From the videography at both entry and exit points, percentage of heavy vehicles like bus, truck (single axle, double axle, multi axle) and trailers can be identified out of all vehicles, for the chosen time interval.

For the total survey time, the required relationship of average speed of traffic stream with density and heavy vehicle percentage can be obtained by plotting above parameters for the chosen time interval points. The flow chart of the proposed methodology is shown in figure 1.

3. Study area and data collection

For the proposed study two-lane two-way undivided highway Modasa to Pankhiya via Bayad road of Gujarat, India (51 km length) is selected. This stretch is a part of State Highway (SH) 59, Nadiad-Mahudha-Kathlal-Kapadwanj-Bayad-Modasa-Raigadh road (127.2 km length). Modasa is one of the main centres of education and commercial activities in North Gujarat. It is the district head quarter of Aravalli district. It is located at latitude 23° 27’ N and longitude 73° 18’ E. Pankhiya is one junction on SH 59 and it is the place at which commercial transport vehicles (trucks) joins the traffic mix. It is located between Bayad and Kapadwanj, at latitude 23° 10’ N and longitude 73° 09’ E. Map of selected route is shown in figure 2.

51 Km stretch between Modasa to Pankhiya is a main road joining Kheda District and Aravalli District. This particular stretch is selected because mixed traffic with heavy vehicles, particularly commercial transport vehicles travelling between Mumbai and Delhi are plying on this section. On an average 9.6 m width of road including shoulder width is available throughout the length except at the locations of narrow culverts. The required data are collected at below mentioned 6 locations (for a length of 1 km on each location) of the selected route.

- Kolikhad
- Rahiyol
- Vatrak
- Bayad
- Dipak Tea Stall at border of Bayad
- Borol

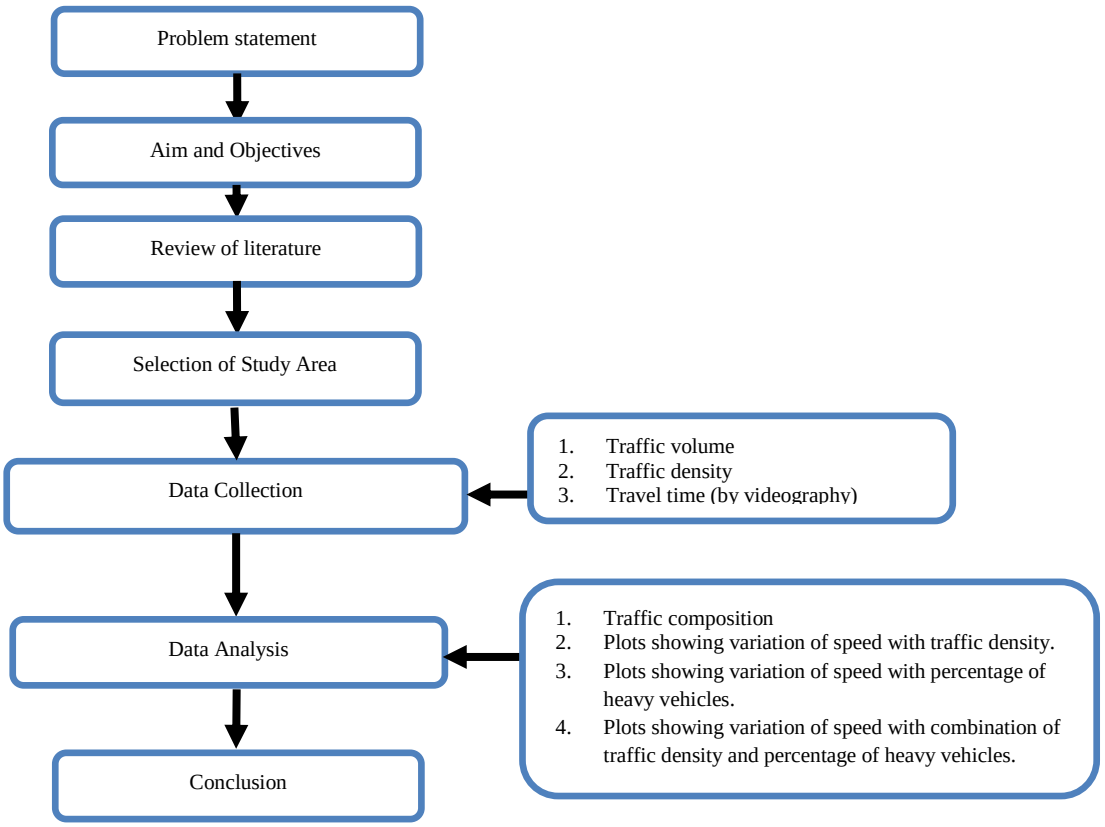

Fig. 1. Methodology flow chart

As mentioned in section2, the data regarding average speed of traffic stream, density and percentage of heavy vehicles have been collected for every 2 minute interval of 1 hour duration by videography at entry and exit points of the selected all six locations. These data have been analysed afterward by video display.

4. Data analysis and results

The composition of traffic flow observed on all selected locations reveal that overall percentage of heavy vehicles ranges 20% to 30% out of all vehicles. A typical pie chart of classified traffic volume for the Kolikhad location is shown in figure 3. The passenger car unit (pcu) values of different vehicles are adopted as per IRC: 64-1990, and shown in Table 1. A typical plot between average speed of traffic stream (kmph) and traffic density (pcu/km) is shown in figure 4 for the analysed data of the Kolikhad location. It reveals that scattered points do not give good linear relationship (coefficient of determination R^2 is 0.438). A similar type of relationship is observed for all other locations.

The other observed parameter, i.e. percentage of heavy vehicles is related with average speed of traffic stream. It's typical plot for the location of Kolikhad is shown in figure 5. This plot also reveals that there is not a good linear relationship (coefficient of determination R^2 is 0.398) between average speed of traffic stream and heavy vehicle (HV) fraction. A similar type of relationship is observed for all other locations.

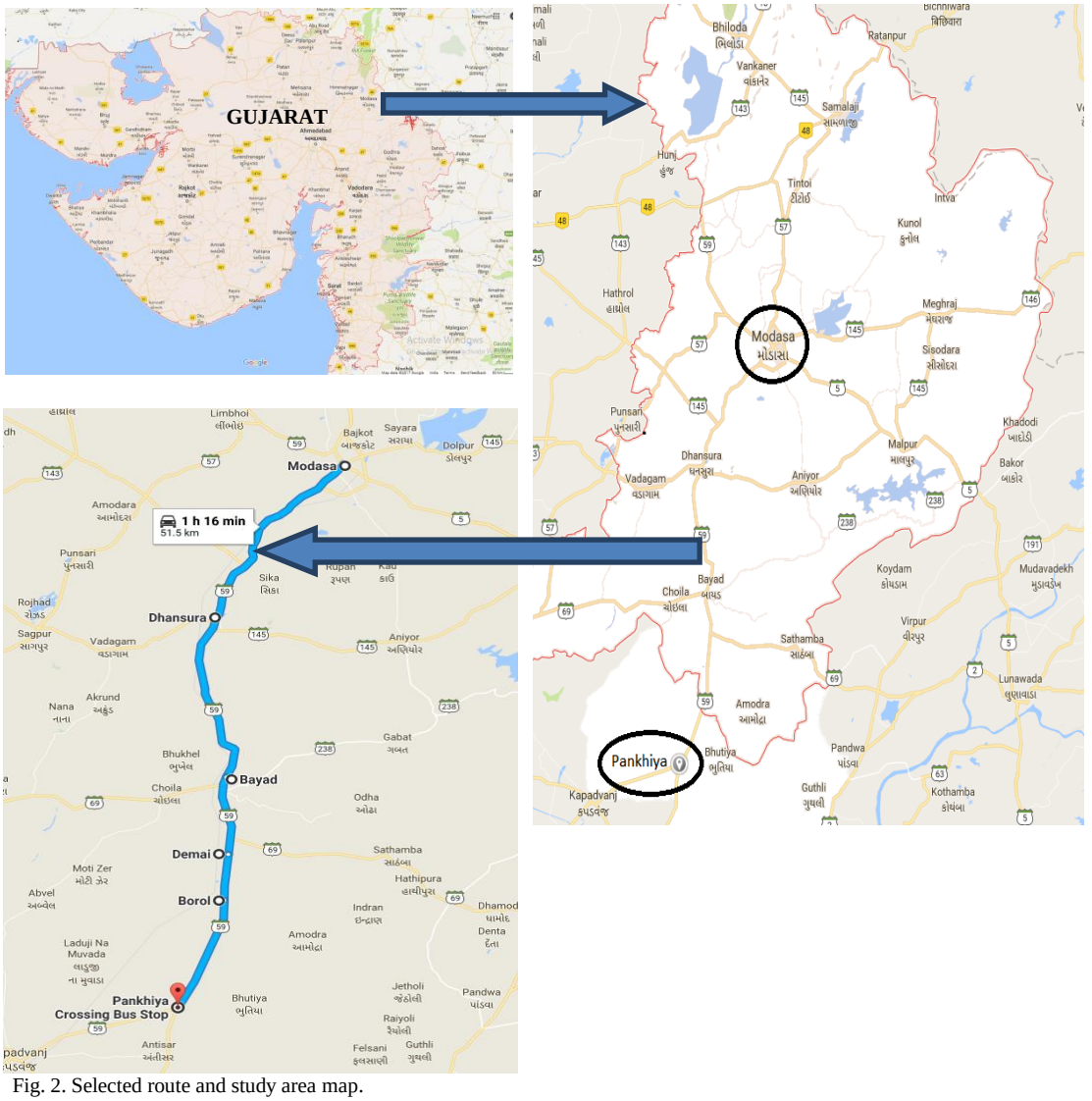

Fig. 2. Selected route and study area map.

These observations unveiled that sometimes traffic flow have higher density but having less HV fraction, speed is not that much affected. So, it can be inferred that traffic density alone does not affect the speed very much. Also, when HV fraction is more than 0.5 (traffic having more than 50 % of HVs) but traffic density being very low, the speed of other vehicles not affected that much as that would have been if traffic density would also be more. So, it can be concluded that density and HV fraction have combined effect on traffic speed rather than individual effect. Therefore, a combined factor termed as 'Heavy vehicle factor' (HV factor) is introduced in this study. HV factor is defined as the product of traffic density in pcu/km and HV fraction (i.e. number of HV/ total vehicles). So,

$$\text{HV factor} = \text{traffic density} * \text{HV fraction} \quad (1)$$

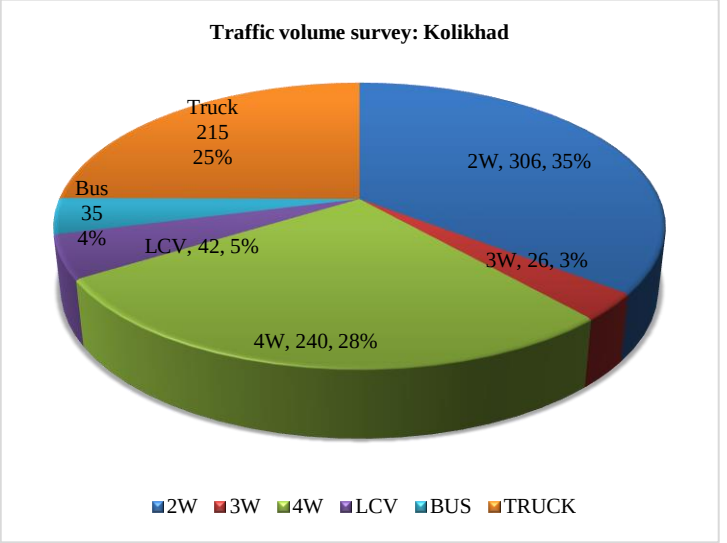

Fig. 3. Classified traffic volume at Kolikhad.

Table 1: Adopted PCU values (IRC: 64-1990)

Type of vehicle	PCU value
Two wheeler (2W)	0.5
Three wheeler (3W)	1.0
Car (4W)	1.0
Light commercial vehicle (LCV)	1.5
Bus	3.0
Truck	3.0

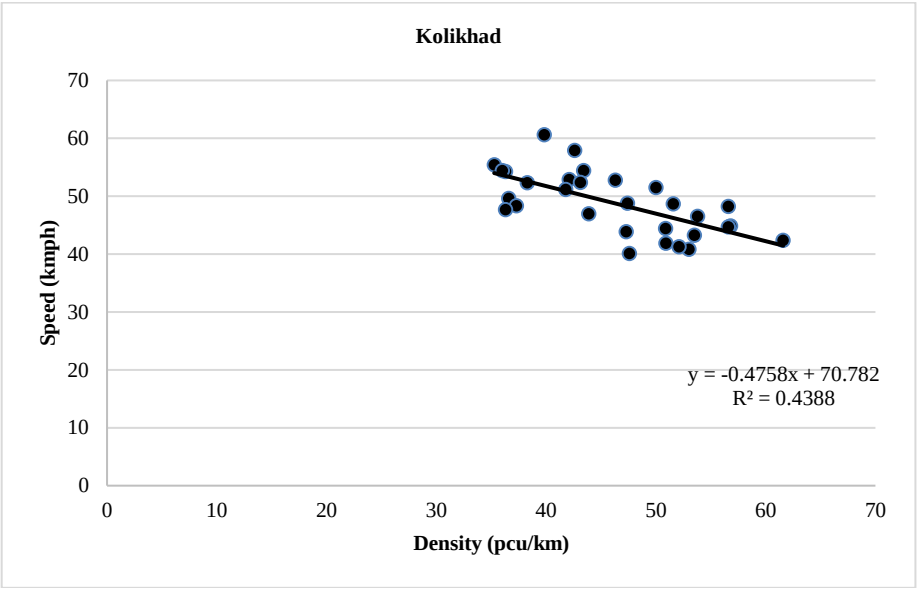

Fig. 4. Plot of average speed of traffic stream versus traffic density at Kolikhad.

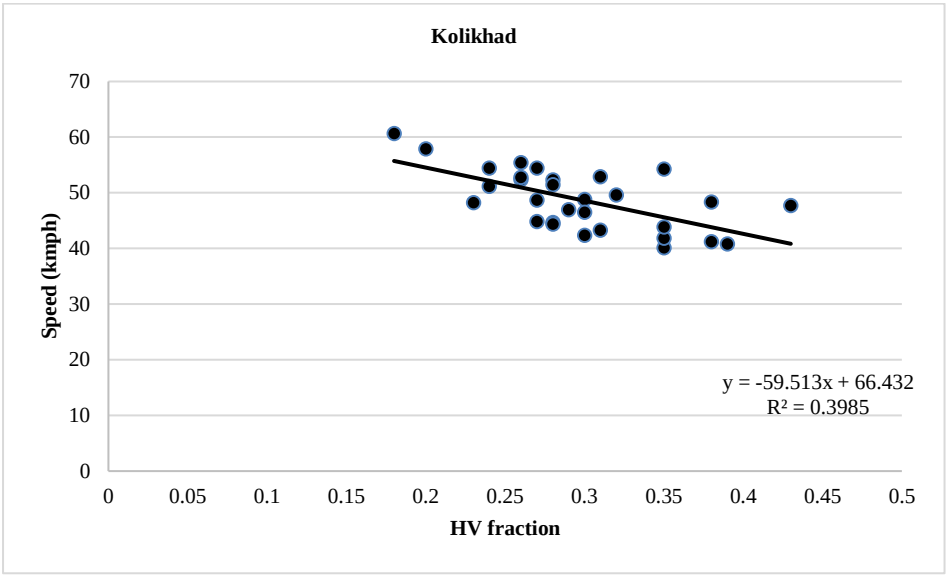

Fig. 5. Plot of average speed of traffic stream versus HV fraction at Kolikhad.

For the all selected locations, a relationship of average speed of traffic stream with HV factor is developed as per equation 1 and plotted. A typical plot for the Kolikhad location is presented in figure 6.

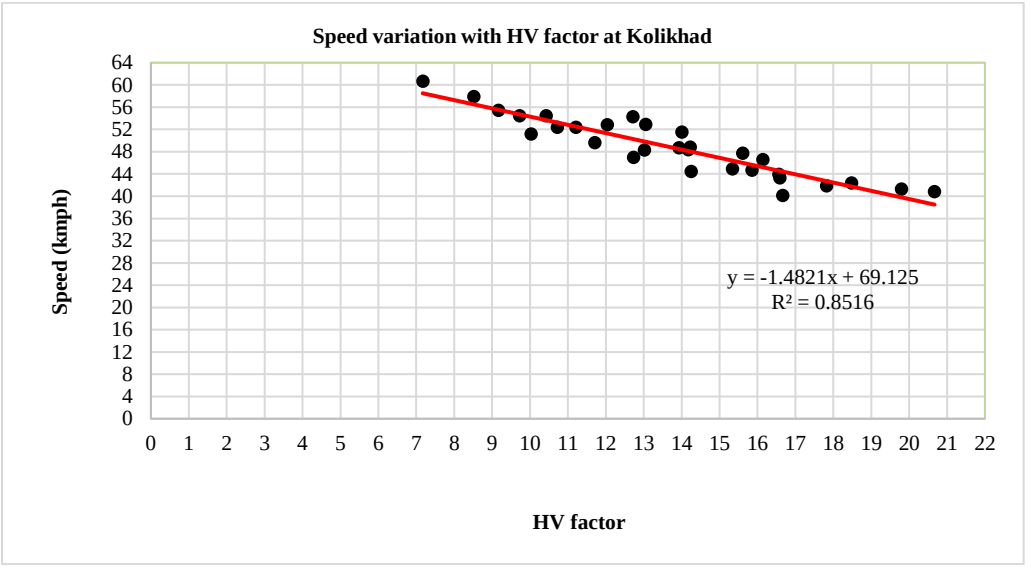

Fig. 6. Plot of average speed of traffic stream versus HV factor at Kolikhad.

Similar types of plots are developed for other locations and it is found that R^2 value is improved considerably. Their relationship equations and R^2 values are listed in table 2. Variable ‘x’ is HV factor and ‘y’ is average speed of traffic stream in kmph.

Table 2. Relationship between average speed of traffic stream and HV factor

Sr. No.	Location	Equation	R^2 value
1	Kolikhad	y = -1.482x + 69.12	0.851
2	Rahiyol	y = -1.736x + 73.42	0.888
3	Vatrak	y = -1.185x + 60.19	0.888
4	Bayad	y = -1.184x + 65.13	0.875
5	Dipak tea stall	y = -0.9196x + 53.988	0.8844
6	Borol	y = -1.823x + 76.32	0.894

5. Conclusions

Following conclusions are derived from this study:

- Overall proportion of heavy vehicles is found 20% to 30% on the selected locations of two-lane two-way undivided highway.
- Average speed of traffic stream (kmph) versus density (pcu/km) relationship gives R^2 value in range of 0.2 to 0.5 on the selected locations.
- Average speed of traffic stream (kmph) versus HV fraction relationship gives R^2 value in range of 0.01 to 0.4 on the selected locations.
- The proposed 'Heavy vehicle factor' is a multiplication of traffic density (pcu/km) and HV fraction (No. of HV/Total vehicles) gives profound results to estimate the average speed of traffic stream. Average speed of traffic stream (kmph) versus HV factor relationship gives R^2 value in range of 0.85 to 0.9 on the selected locations. It implies that suggested HV factor predicts more accurately the average speed of traffic stream.
- Value of HV factor ranges from 5 to 25 in the observations carried out at different selected locations.
- Average speed of traffic stream varies inversely with the HV factor, i.e. speed decreases as increase in HV factor. The rate of reduction in speed is about 0.9 to 1.8 times the HV factor.
- Free flow speed obtained from the developed equations ranges from 53 kmph to76 kmph for the selected locations.
- HV factor itself depends on both density and HV fraction and would give maximum value where both have higher values.
- Sometimes higher value of HV fraction may not lead to decrease in speed if density at that point is on lower side and thus HV factor is less and so impact on speed reduction would be less.
- The videography is found very effective for traffic data collection. In this study, classified traffic volume count, travel time and traffic density are observed accurately using videography on entry and exit points of selected location stretches.

References

IRC: 64 -1990. Guidelines for capacity of roads in rural areas (First revision). The Indian Roads Congress, New Delhi, pp. 10.

Kaisy, A., Jung, Y., 2005. Examining the effect of heavy vehicles during congestion using passenger car equivalents. Department of Civil Engineering, Montana State University.

Kong, D., Guo, X., Yang, B., Wu, D., 2016. Analyzing the Impact of Trucks on Traffic Flow Based on an Improved Cellular Automaton Model. Discrete dynamics in nature and society, volume 2016, Hindawi Publishing Corporation.

Pokulwar, S., Dabhelkar, K., Khode, B., 2016. Heavy vehicles impact on traffic flow on urban roads. IJSTE Volume 2, Issue 8, February 2016.

Roy, N., Roy, R., Talukdar, H., Saha, P., 2017. Effect of Mixed Traffic on Capacity of Two-Lane Roads: Case Study on Indian Highways, Procedia Engineering 187 (2017), 53-58.

Semeida, A., 2016. Impact of horizontal curves and percentage of heavy vehicles on right lane capacity at multi-lane highways. Promet-traffic and transportation. Volume 29, No 3, 2017, 299-309.