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EVALUATION OF FOLLOWING HEADWAY BEHAVIOUR IN MIXED TRAFFIC CONDITIONS IN NORTH-EAST INDIA

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Abstract

Purpose: Both a lack of understanding of the issues of following headway behaviour of the driver and a lack of sufficient data in different traffic conditions have been major reasons to attempt this research study. This paper attempts to address the hypotheses of the effects of the lead vehicle on following headway by measuring following headway in as wide a variety of conditions as possible on roads.

Design/methodology/approach: The study has been carried out from real-world data collected through video and instrumented vehicle using Video VBox. The hypothesis has been examined in detail.

Findings: Results provide an overview of the impact of this study in particular, on driver-following under (i) The level of traffic flow that affects driver behaviour in terms of time headway (ii) Driver following behaviour in terms of time headway varies with road characteristics (iii) Driver following behaviour is affected by the type of lead vehicle. (iv) Drivers are inconsistent in their choice of headway.

Research limitations/implications: The research conducted in this study is related to the typical north-east region of India where traffic flow is relative low and of a different mix, so further research should carried out in different parts of India to generalise the problem.

Practical implications: The study contributes to an understanding of how lead vehicles might influence gap maintenance behaviour in mixed traffic

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conditions. The results will help in the reduction of accidents and increase safety policies for drivers.
Originality/value: Under mixed traffic conditions, following the lead vehicle affects the safety of drivers and accounting for such behaviour remains unknown. The study enables simulation modeller and intelligent transport systems (ITS) to design and operate many in-vehicle systems for smooth traffic processes.

Keywords: Following headway driver behaviour, Mixed traffic, India, Headway and gap maintenance

Paper type: Research paper

INTRODUCTION

The "time headway" or "headway" is "the time, in seconds, between two successive vehicles as they pass a point on the roadway, measured from the same common feature of both vehicles" (Highway Capacity Manual, 2000). This parameter is one of the fundamental microscopic traffic flow characteristics. These characteristics are of great importance for planning, analysing, designing and operating roadway systems (Jakimavicius and Burinskiene, 2009; Mesarec and Lep, 2009). Therefore, it must be analyzed as accuratly as possible based on the real behaviour of drivers (Kerner, 2009). Traffic engineers and planners should be well aware of the real behaviour of drivers in choosing the desired headways. In fact, they should be able to predict the driver's behaviours while facing the headways in order to have better planning and traffic management through different conditions. This is because time headways and their distributions affect different flow parameters, including capacity, level of service and safety (Arasan and Koshy, 2003). Precise modelling and analysis of vehicle headway distribution helps traffic engineers to maximize roadway capacity and minimize vehicle delays (Zhang *et al.*, 2007).

Headway distributions are also needed to run digital simulations through modelling multilane traffic in driving simulators (Zwahlen *et al.*, 2007). Moreover, with headway analysis it is possible to get information from the causes of accidents and the ways of increasing the road safety. It should be pointed out that in most capacity modelling, the safety headway requirement is not taken into account during the model calibration and parameter estimation. This may partly explain why some problems are often experienced on roadways carrying less traffic than the perceived capacity (Yi *et al.*, 2004).

Brackstone *et al.* (2009) observed that drivers follow more closely behind trucks/van than cars. Postans and Wilson (1983) found that a frequency of headway of less than half a second varies by vehicle types. However, they were unable to quantify the magnitude of the variation of headway. Evans and Rothery (1976) found that different size of lead cars had no effect on following distance, while Parker (1996) measured individual headway for a population of drivers passing through a road work section (approximately 25 meters in each case) and found no difference between cars following cars as opposed to cars following trucks in the 60–70 km/hr speed band, and a small difference in the 20–30 km/hr speed band (with cars being followed at approximately 12 meters and trucks at 10 meters). Sayer *et al.* (2003) analysed the differential behaviour between cars and light trucks. They also supported the finding that light trucks would follow 6–7 meters closer than normal cars because truck drivers are less likely to misjudge any situations. Truck braking frequency and magnitude may be perceived as lower, hence the leading car driver views them as a safer and more predictable vehicle to be behind. The authors also suggested that drivers following a truck may have a reduction in driving workload, as there is now only one vehicle on which to concentrate, which results in a reduction in glance distributions. This gives the driver a greater degree of preparedness for deceleration, in turn encouraging an unconscious reduction in headway.

In Surat city, Katti *et al.* (1985) found through their study on arterials that for volumes ranging from 500 to 1000 vehicles/hour, negative exponential distribution was suitable for representing headways between vehicles. Mukherjee *et al.* (1988) evaluated the suitability of negative and shifted negative exponential distributions to generate vehicles approaching roads at the intersections in Calcutta, India.

The suitability of theoretical distributions was judged by using the chi-square test. It was found that the shifted negative exponential distribution gave a close fit for the observed headways. It was suggested that a comparison of theoretical headway distributions along with the observed distributions could be made based on cumulative frequencies. However, in all such studies conducted in India and abroad, very little has been done to understand the effect of type of lead vehicle on headway. All these studies are limited to consideration of the relationships between immediately following vehicles such as cars only.

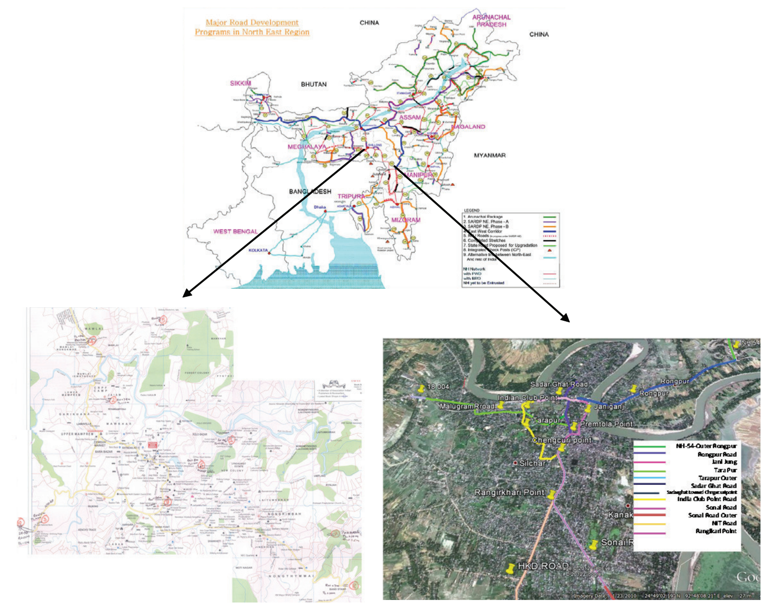
This paper gives special attention to region-specific needs in vehicle-following behaviour. It aims to bridge the gap between different geographical areas, in terms of the safety of the driver in following the vehicles. The study recognizes the fact that for numbers of drivers following the auto-rickshaw, buses are much less frequent when compared to cars. The average speed in Shillong was found to be higher than in Silchar. Three focus areas of traffic, namely: following headway, speed and frequency are examined in detail for plain and hill roads related to improvement and safety of traffic for all, thus initiating and sustaining the growth process.

METHODOLOGY

Identification of study area

The "North Eastern Region: Vision 2020" stated the north eastern region as the "land of the rising sun" as the springboard for economic integration with Southeast Asia, Southwest China and beyond. The region has largely remained isolated and hence underdeveloped and the study recognizes the strategic importance of the region in India's foreign policy in general and the Look East Policy (LEP) in particular. Silchar is the headquarters of the Cachar district in the state of Assam in India. It is 343 kilometres (213 m) south east of Gauwahati. It is the second largest city of Assam after Gauwahati, both in terms of population and municipal area, with an elevation of 22 m (72 ft). The area of Silchar town is 15.75 km^2.

Shillong (Khasi: Shillong) is the capital of Meghalaya, one of the smallest states in India. It is the headquarters of the East Khasi Hills district and is situated at an average altitude of 4,908 feet (1,496 m) above sea level, (70 times higher than Silchar city) with the highest point being Shillong Peak at 6,449 feet (1,966 m). Shillong is the 330th most populous city in India, with a population of 143,007 according to the 2011 census. It is said that the rolling hills around the town reminded the European settlers of Scotland. Hence, Shillong is known as "Scotland of the East". The population density of the state of Meghalaya in the current decade is 342 people per sq mile. Shillong is at 25.57°N 91.88°E. It is on the Shillong Plateau, the only major uplifted structure in the northern Indian shield. The city lies in the centre of the plateau and is surrounded by hills, three of which are revered in Khasi tradition: Lum Sohpetbneng, Lum Diengiei and Lum Shillong. Its weather conditions



(a) (b)

Figure 1 (a). Study area: Shillong

Figure 1 (b). Study area: Silchar

are pleasant, and pollution-free in summer. The temperature varies from 23 °C (73 °F) to 4 °C (39 °F) in winter. Shillong, the capital city of Meghalaya is just 55 km (34 mi) from Mawsynram, the world's wettest place. Shillong receives far less precipitation due to the orographic effect. The location marked on the study area is shown in Figures 1(a) and 1(b).

INSTRUMENTATION OF VEHICLE

An instrumented vehicle Video VBox was used in the car to follow the heavy vehicles that recorded a video picture of the driver in real traffic with a roadside video. Road NH3 and NH4 test routes were selected both in urban and free driving conditions in the morning, noon and evening peak in Silchar city. Similarly, in Shillong, five roads were selected both outside and inside the city.

DATA COLLECTION AND EXTRACTION

Data were collected in two different types of road conditions: one free, and one congested, in April 2012 and January 2013. The headway speed driving cycle data were carried out on different days at different sections. Data used for this study was collected for Silchar, Assam and Shillong, with both free flow and congested traffic types. The flow was interrupted because of intermingling of opposite vehicles, as there were no separators on the roads.

The data were collected through video recording and manual mode, both at different locations with different trap lengths. The camera was mounted on a vantage point for 15 minute intervals on a typical weekday. Simultaneously, manual data was also calculated for verification purposes. All the vehicles that passed through the selected section of road during that time were recorded and classified into different categories, as shown in Figure 2. From the video data, arrival and departure time of each vehicle was calculated.

The data were extracted from the video clip from the following headway template using coding for the lead and following vehicles that also generated traffic volume. Headway, speed data and arrival pattern for each vehicle type were extracted for each section in both free and forced traffic conditions.

DATA ANALYSIS

Selection of data variables

Seven variables were used in this study. Three involved the vehicles, in both the dynamic states of free and constrained conditions:

i. Response variable time headway between vehicles (T Hses) calculated as the following distance divided by the speed of the following vehicle.

Figure 2. Data extraction

ii. Distance was directly measured from the trap length rear of the preceding vehicle to the front vehicle in the active case and the front of the following vehicle to the rear of the instrumented vehicle in the passive case. In this study, the passive case has been followed.

iii. Two potential explanatory variables: the ground speed of the following vehicle (Vms-1) and relative speed between two vehicles (V1-V2) The value indicates the higher speed of the following vehicle.

iv. Time headway has been chosen as the primary indicator of driver performance.

v. Four situational variables

   a. SUB
   b. Type of leading vehicle (VEH, Car, Trucks)

vi. Road type (Road, NH, Urban City Road)

vii. Flow (FLOW, vehicles/hrs). Flow was calculated based on video recording on each test section.

TRAFFIC STUDIED

Traffic composition in Silchar

Traffic flow at Jani Gunj section (down) is congested and within the centre of Silchar city. The traffic composition is as follows: 43% rickshaw, 22% cycles, 15% two-wheeled, 4% car, 7% hand cart, 5% scooter, and 2% light commercial vehicles (LCV). There were 22% rickshaw, 26% cycle, 26 % two-wheeled, 10% car, 7% hand cart, 26% scooter, and 32% LCV.

UPSTREAM SONAI ROAD

The traffic composition is as follows: 24% cycles, 34% two-wheeled, 6% small car and 11% Sport Utility Vehicle (SUV), 19% auto-rickshaws, 7% hand cart, 3% truck, and 2% LCV and 1% buses in the congested conditions of Sonai road in upstream. In free flow conditions, LCV/tempo increases from 2. 5 to 21%, which shows that outside the city, tempo is being used by commuters to connect to other parts of the city. The same patterns were reflected in the case of SUV (Tata Sumo type vehicle used for passenger carrier), which increased from 11% in congested conditions to 19% in free flow conditions. The number of bikes reduced from 34% to 21% in free flow conditions. The percentage of auto-rickshaws remained the same in both free and congested conditions, which reflect the fact that auto-rickshaws are going outside the city as passenger carriers, both inside and outside the city. The increase in cycles from 3% to 21% shows the local influence of the cycle mode used for commuting between villages in free flow conditions.

DOWNSTREAM SONAI ROAD

There were 27% cycles, 28% two-wheeled vehicles, 6% small cars and 10% SUV, 22% auto-rickshaws, 2 % trucks, and 1% buses in the congested conditions of Sonai road in downstream. In free flow conditions, LCV/ tempo increases from 0.5 to 10%, which shows that outside the city, tempo is being used by commuters to connect other parts of the city. The same patterns were reflected in the case of SUVs (Tata Sumo type vehicle used for passenger carrier), which increased from 10% in congested conditions to 13% in free flow conditions. The number of bikes reduced from 28% to 30% in free flow conditions. The percentage of auto-rickshaws remained the same in both free and congested conditions, which reflects the fact that auto-rickshaws are going outside the city as passenger carriers, both inside and outside the city in Silchar. The decrease in cycles from 27% to 9% from congested to free flow shows the local influence of the cycle mode used for commuting between villages in free flow conditions. In both the up side and the down side, cycle composition in congested traffic was 24–27%, two-wheeled 34–28%, small cars 6–10 % and big cars 10–11%, auto-rickshaws 19–22%, truck 2– 3% and 1% buses. In free flow conditions in both the up side and the down side, cycle composition was 21–9%, two-wheeled vehicles 21–30%, small cars 4–6% and big cars 10–11%, auto-rickshaws 20–21%, trucks 0–7% and 1% buses. This indicates an increase in the proportion of trucks, and a decrease in the proportion of two-wheeled vehicles and cycles in free flow conditions.

TRAFFIC COMPOSITION IN SHILLONG

There were 48–57% cars and 8–16% big cars, 15–22% two-wheeled vehicles, 1–3% buses, 7–9% LCV, 1–3% trucks, 1–11% auto-rickshaws, 2% LCV and 1% buses in congested conditions in Shillong. In contrast, in free flow conditions, there were 35–56% cars and 7–19% big cars, 6–15% two-wheeled vehicles, 2–6% buses, 2–18% LCV, 1–17% trucks, and 1–9% auto-rickshaws in free flow conditions in Shillong. So it is clear that there is a significant increase in the percentage of LCVs, trucks and buses, and a decrease in the percentage of auto-rickshaws in free flow conditions. In this case, buses are the main mode of inter-regional transport. It should be noted that due to hilly terrain, the proportion of auto-rickshaws running in Shillong is less compared to those in Silchar.

RESULTS AND DISCUSSION

Different countries have slightly different rules with regard to the legal or recommended safety distance. In the US, several drivers training programmes (Michael *et al.*, 2000) state that it is impossible to follow a vehicle safely with a headway of less than 2 s. In Germany, the recommended minimum distance is "half the speedometer", which means, a car travelling at 80 km/h should keep a distance of at least 40 m. This rule translates to a recommended time headway of 1.8 s. Fines are imposed when the time headway is smaller than 0.9 s. In Sweden, the National Road Administration recommends a time headway of 3 s in rural areas, and the police use a time headway of 1 s as orientation for imposing fines. Researchers have investigated whether any connection between preferred time headway, accident involvement, and driver characteristics exists, but the results were not consistent. Evans and Wasielewski (1982) claimed that drivers who keep longer time headways tend to have a history of fewer accidents and violations. On the other hand, one year later, the same authors stated that no reliable relation between preferred time headway and accident involvement could be detected. In a simulator study, VanWinsum and Heino (1996) investigated whether a closer following distance was connected to more expertise in accurately estimating time-to-collision (TTC), but the relationship they found was not significant. Michael *et al.* (2000) found that a substantial percentage of drivers in several urban locations did not observe the 2 s rule, but compliance increased moderately when hand-held signs urged drivers to heed the rule. In the literature, different opinions can be found as to which value should be used as a safety limit—suggestions range from 1.5 s in urban areas (Svensson, 1998) to 5s (Maretzke and Jacob, 1992).

In Indian traffic conditions the effect of the leading vehicle on headway is not explored, which is the reason the traffic simulation model, driver safety behaviour and their risks are not properly understood. In the following section, the effect of different lead vehicles in both free and constrained conditions in mixed traffic conditions has been explored.

EFFECT OF LEADING VEHICLE ON HEADWAY IN SILCHAR CITY

Effect of different leading vehicle type congested flow – Janigunj Road UP Direction

Lead vehicle – Auto-Rickshaw (A): Drivers of buses, cars, rickshaws, two-wheeled and tempo feel safer when following an auto-rickshaw. Their time headway varies from 1.5 sec to 3.3 seconds. However, less than 1.5 seconds of headway is assumed to exceed the safety standard.

Lead vehicle – Bus (B): Big cars, two-wheeled vehicles and hand carts do not want to follow a vehicle too close to a bus, as the speed of the bus impedes the speed of the following car compared to the auto-rickshaw. Their following headway varies from 2.6 to 6.6 seconds, which is higher than the auto-rickshaw.

Lead vehicle – Car (C): Except for the auto-rickshaw and the cycle-rickshaw, all vehicles including buses, cars and scooters were following the car at 1.3 to 2.4 seconds. As the auto-rickshaw and rickshaw have lower operating speeds, they maintained following headway at 4.23 and 4.26 seconds.

Lead vehicle – Hand Cart (CG): All vehicles including cars, auto-rickshaws, buses, cycle–rickshaws and two-wheelers were following very close to the hand cart, since it impeded the speed of all motorised vehicles. Their following headway ranged from 0.65 seconds by two-wheeled vehicles to 2.28 seconds by rickshaws. This shows the risk level is higher for hand carts.

Lead vehicle – Rickshaw (R): All vehicles, including cars, autos, hand carts, rickshaws and two-wheelers were following at greater than 2.5 seconds. The bus drivers feel secure even when there is a rickshaw in front. Time headway between the bus driver and the rickshaw was found to be the lowest, i.e 1.94 seconds. This shows the risk levels are higher for rickshaws.

Lead vehicle – Two-wheeled (S): Since the running speed of two-wheeled vehicles is higher, the time headways for following rickshaws, cars, and auto-rickshaws were significantly greater than 5 seconds. Hand carts, buses and two-wheeled vehicles followed at the lesser headway of 1.85 to 2.3 seconds**.** This, again, compromises the safety standard.

Lead vehicle – Big Car (SUV): No other vehicles were found following the big cars except two-wheeled vehicles at a following headway of 2.3, seconds, since the running speed of big cars is high.

Lead vehicle – LCV (TE): The effects of LCV were significant. All vehicles were found to be safe and following very close to the time headway at 1.3 seconds to 2.3 seconds. This shows the risk level is higher when there is LCV in front of vehicles.

EFFECT OF DIFFERENT LEADING VEHICLE TYPE – JANIGUNJ ROAD DN-DOWN

Lead vehicle – Auto-Rickshaw (A): No other vehicles except cycle-rickshaws followed the auto-rickshaw at a 4 second time headway interval.

Lead vehicle – Bus (B): All vehicles (bus, car, hand cart and rickshaw) were following buses at a following headway greater than 6 seconds.

Lead vehicle – Car (C): Except the tempo and hand cart, all vehicles (bus, car, scooter, SUV) were following the car at 3.6 to 16.6 seconds. As tempo and hand carts both have lower operating speeds, they maintained a following headway of less than 1 second. This shows the risk level for cars is higher from tempos and hand carts.

Lead vehicle – Hand Cart (CG): All vehicles (car, auto-rickshaw, buses, rickshaw, two-wheeler) were following at a larger headway exceeding 4.8 seconds.

Lead vehicle – Rickshaw (R): The rickshaw exhibited similar patterns to those of the hand cart.

Lead vehicle – Two-wheeled (S): Since the running speed of two-wheeled vehicles is higher, the SUV's following time headway was significantly greater i.e. 4 seconds. Cars and two-wheeled vehicles followed in less than the time headway of 1 second. This shows the risk level for two-wheeled vehicles is higher when the following vehicle is a car and a two-wheeled vehicle.

Lead vehicle – Big Car (SUV): No other vehicles were found following the big car except the rickshaw, since the running speed of big cars is high.

Lead vehicle – LCV (TE): No other vehicles except buses were found to be following at 6.65 seconds.

EFFECT OF DIFFERENT LEADING VEHICLE TYPE FREE FLOW – SONAI ROAD UP DIRECTION

Lead vehicle – Auto-Rickshaw (A): In free flow conditions, cyclists, cars, rickshaws, trucks and tempos followed in a higher time headway gap when compared to constrained conditions. Their time headway varied from 1.6 s to 6.7 seconds higher than the constrained time. In contrast, two-wheeled vehicles, auto-rickshaws and SUVs maintained a larger gap in comparison with constrained vehicles as well as cyclists, cars, rickshaws, trucks and LCVs.

Lead vehicle – Bus (B): No vehicle likes to follow a bus in free flow conditions because the speed of buses is too low and their frequency in fleet is also low. Even in constrained conditions, big cars, two-wheeled vehicles and hand carts (CG) do not want to follow the vehicle too close to a bus, as the speed of buses impedes the speed of the following car, when compared to auto-rickshaws. One cyclist was found following a bus in free flow conditions at a following headway of 17 seconds, which is the highest following headway in free flow conditions.

Lead vehicle – Car (C): Trucks, tempos, auto-rickshaws and rickshaws were following the car at 1 to 3.75 seconds. As hand carts and cyclists have lower operating speeds, they maintained a following headway greater than the constrained flow of 6.1 seconds. In free flow, speed also remains higher, therefore the risk is higher.

Lead vehicle – Hand Cart (CG): No other vehicles except tractors and two-wheeled vehicles followed a hand cart at a headway of 2.2 and 4 seconds, which shows that no driver likes to follow a hand cart that might impede their speed in free flow conditions. However, in congested conditions, all vehicles (cars, auto-rickshaws, buses, rickshaws, two-wheelers) followed very close to the hand cart, since it impeded the speed of all motorized vehicles. Their following headway ranged from 0.65 seconds by two-wheeled vehicles to 2.28 seconds by rickshaws, since they were unable to change lanes. This shows the risk level for hand carts (CG) is higher regarding two-wheeled vehicles, as the speed in free flow is also higher.

Lead vehicle – Cycle (C) and Rickshaw (R): Interestingly, cycles were also found to be lead vehicles; however, the gap between a cycle and the following vehicle was found to be the lowest (<=4 seconds) for vehicles such as auto-rickshaws, two-wheeled vehicles, SUVs, tempo (LCV) and tractors, at less than 4 seconds. These drivers feel secure even when there is a rickshaw and a cycle in front. Exceptions were two-wheeled vehicles, hand carts and LCVs, whose following time was higher, at 4 seconds.

Lead vehicle – Two-wheeled (S): With the exception of auto-rickshaws, trucks and cycles, all other vehicles were found to be following with a larger time headway gap compared to other vehicles. Since the running speed of two-wheeled vehicles is higher, the following time headway for rickshaws, cars, SUVs, LCVs and auto-rickshaws was significantly greater than 5 seconds. This relationship is true for constrained conditions.

Lead vehicle – Big Car (SUV): With the exception of trucks and cycles, no other vehicles were found following the big car at less than 3.3 seconds, since the running speed of big cars is high. The same is true in the case of congested conditions.

Lead vehicle – LCV (TE): All vehicles were following at a time headway of 3.32 seconds to 15.4 seconds. SUVs, trucks and two-wheeled vehicles followed at an exceptionally larger headway of greater than 7.9 seconds.

EFFECT OF LEADING VEHICLE ON HEADWAY IN SHILLONG (HILL ROADS)

Trucks maintain the highest following headway. If a bus is ahead then big cars maintain larger gaps of 15.2 seconds. When a car is leading, all different vehicles follow at 8–9 second intervals. In contrast, when drivers found an LCV in front, other vehicles were much coser, except for trucks, LCVs and cars. In contrast, trucks maintain a gap at a smaller distance. Auto-rickshaws create a safer feeling amongst drivers; the auto-rickshaw as leader has the lowest following headway, at 6 seconds and 3 seconds. When a two-wheeler is moving ahead, the auto-rickshaw, bus and LCV maintain larger gaps compared to other types of lead vehicle. The car following headway inside and outside the city is shown in Figure 3.

Lead vehicle – Auto-Rickshaw (A): In free flow conditions, SUVs, buses and cars maintain a gap of 6.74 to 22.8 seconds, whereas drivers of two-wheeled vehicles follow the time headway gap of 2.4 seconds in constrained conditions. In contrast, LCVs maintained a lower gap in free flow at 3.55 seconds.

Lead vehicle – Bus (B): LCVs maintained similar time headway gaps of 7.5 seconds both in the case of constrained and free flow conditions. In congested flows, vehicles such as buses, trucks and two-wheeled vehicles normally followed with a headway of less than 7 seconds, except for cars. In free flow cases, the number of vehicles following the buses was very low (only two types of vehicle: cars and LCVs).

Lead vehicle – Car (C): In the case of congested flow on hills, car following behaviour by other vehicles was significantly different and remained little higher than in free flow conditions. Auto-rickshaws, trucks, buses and two-wheeled vehicles maintained larger gaps compared to SUVs and LCVs in both constrained and free flow conditions.

Lead vehicle – two-wheeled (S): For bus and truck vehicle types, two-wheeled vehicles maintained a higher time headway in free flow conditions compared to congested flow. In contrast, LCVs and SUVs maintained a lower gap in free flow conditions compared to constrained conditions. LCV and SUV in free flow conditions are a danger to motorcyclists. In contrast, buses are found to be dangerous to motorcyclists in congested traffic conditions.

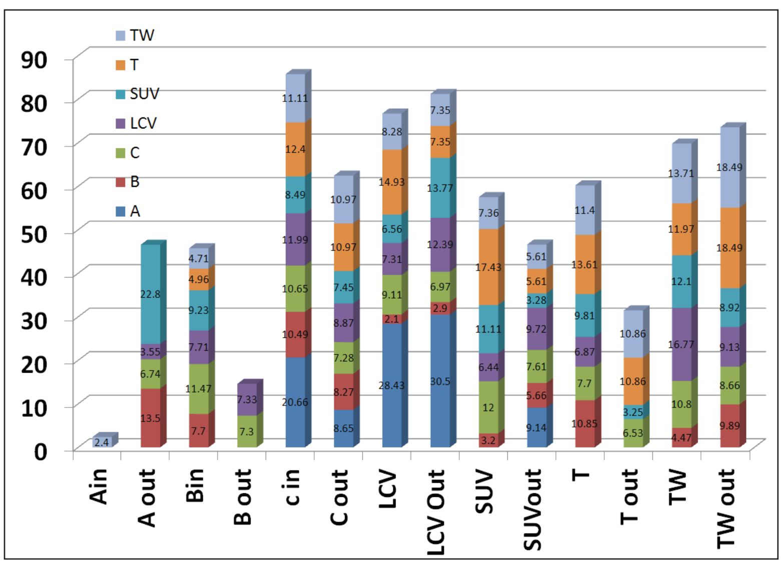


Figure 3. Effect of lead vehicle in both free flow and congested conditions

Lead vehicle – Big Car (SUV): Trucks, cars and SUVs were found to be following at higher following headways in congested environments as compared to free flow. With the exception of LCVs, all other vehicles (buses, cars, SUVs, trucks and two-wheeled vehicles) followed at less headways compared to congested flows.

Lead vehicle –Truck (TW): In free flow conditions, cars, SUVs, trucks and two-wheelers followed at less time headways compared to congested conditions. Trucks following the truck showed the highest time headway at 13.6 and 13.86 seconds, both in constrained and free flow conditions.

Lead vehicle – LCV (TE): Auto-rickshaws, trucks and cars maintained larger time headways when they encountered LCVs on hilly roads. In contrast, buses were found to maintain the lowest gap when they encountered LCVs in front, i.e. 2.1–2.9 seconds. This shows that bus drivers feel safer with LCVs and at the same time, compromise the safety limit. The following headway between LCVs and auto-rickshaws was observed to be the highest (28 and 30 seconds) both in constrained and free flow conditions respectively.

EFFECT OF FLOW ON DRIVER FLOWING

The comparison of time headway in congested and uncongested conditions is shown in Figure 4. The time headway in free flow conditions increased by 50% on the same road when extended from congested to free flow conditions.

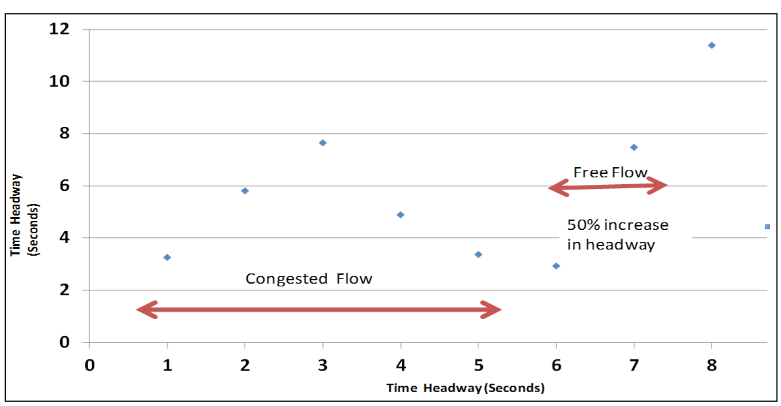


Figure 4. Effect of flow on driver flowing

TRENDS AND SPEED WHILE FOLLOWING THE VEHICLE

From the scattered plot of time headway (second) and speed (km/hr) for different vehicles, it is inferred that the number of following events for cars, SUVs, two-wheelers and LCVs is higher amongst all the different types of vehicle. It was found to be lower for auto-rickshaws, trucks, buses and LCVs. The majority of cars were running at a speed in the range of 40 and a following time headway of less than 20 km/hr. Similar findings are reported for SUVs. The variation of time headway was found to be greater than 60 seconds to 2 seconds minimum, whereas speed variation was found to be from 1km to 110 km/hr. The box plots of different vehicles show frequencies, speed, and headway in terms of maximum, minimum, median and average values (Fig 5 to Fig 10 respectively).

SUMMARY OF FREQUENCY, HEADWAY AND SPEED IN TERMS OF LOWEST, HIGHEST, MEAN AND MEDIAN VALUE

In Shillong city, the highest number of vehicles were following cars and the lowest were following buses, auto-rickshaws, SUVs, LCVs and trucks. This also confirms traffic composition. In contrast, in Silchar city, the highest number of vehicles followed rickshaws, two-wheelers and buses, which represents their composition and the effects on the following vehicle. The highest number of vehicles followed rickshaws, auto-rickshaws, cycles and LCVs. The lowest number of vehicles followed LCVs and tempos in Silchar city. Speed was found to be higher for SUVs in Shillong, whereas in Silchar, it was LCVs. LCVs following headway ranged from 3–28 seconds in Shillong and 4–58 seconds in Silchar. In both cities, the ranges were too large compared to the other lead vehicle. This also indicates that vehicles following LCVs have typical characteristics that also conform to the literature. In following headway, SUVs ranged from 5–14 seconds in Shillong and 3–12 seconds in Silchar. Hand carts and cycle-rickshaws could not go beyond a speed of 10 km/hr, whereas their respective following headway ranged from less than 2 to 5 seconds. This indicates that they are compromising the safety threshold. The speed of trucks in Shillong were in the range of 18–32 km/hr, contrasting with 10–125 km/hr in Silchar city, and their respective headways ranged from 8 to 16 seconds and 4–22 seconds. The lowest following headway conforms to the bus, truck and rickshaw in both cities, which ranged from 5–10 seconds in Shillong and even less in Silchar, 5–12 seconds in Shillong and higher in Silchar at 5–25 seconds, and 2-5 seconds for rickshaws in Silchar, which constitutes a high risk.

Headway is recommended for use in enforcement purposes, because small headways generate potentially dangerous situations. However, time to collision (TTC) should be used when a certain traffic environment is to be evaluated in terms of safety, because it indicates the actual occurrences of dangerous situations.

CONCLUSION

Headway characteristics are of great importance for planning, analyzing, designing and operating roadway systems (Jakimavicius and Burinskiene, 2009; Mesarec and Lep, 2009). Therefore, data must be analyzed as accurately as possible based on the real behaviour of drivers (Kerner 2009).

In the driver-following conditions, a large number of drivers adopt headways which are less than safe. This reveals the concentration of short headways, in that many drivers choose less than safe headways. In the case of cycles as the lead vehicle in particular, the following vehicles (such as auto-rickshaws, cycles and tempos) are crossing the time headway limit. This is due to the high risk-ability of the driver population, which results in safety reduction. Time headway in free flow conditions increased by 50% on the same road when extended from congested to free flow conditions. The number of following events for cars, SUVs, two-wheelers and LCVs is higher amongst all different types of vehicle compared to the auto-rickshaw, truck and bus. The presence of non-motorised vehicles in mixed traffic creates relatively short headways, resulting in the possibility of higher accident rates.

This paper provides a detailed evaluation of one particular aspect of behaviour, namely the choice of the following headway behind the vehicle in front. This will also provide an understanding of how the choice, which is part of the following car's process, varies with local conditions and an assessment of the evidence if choice is affected by the behaviour of the driver of one or more vehicles ahead.Time headway or inter-arrival time is one of the important flow characteristics which affects the safety, level of service, driver behaviour and capacity of transportation systems. Time headway is used to determine the opportunity for passing, merging and crossing lanes on NH. This also gives more insight into the behaviour of the traffic. The distribution can be used as an input to traffic simulation models. To develop the entrance ramp on NH and urban roads, headway distribution is required.

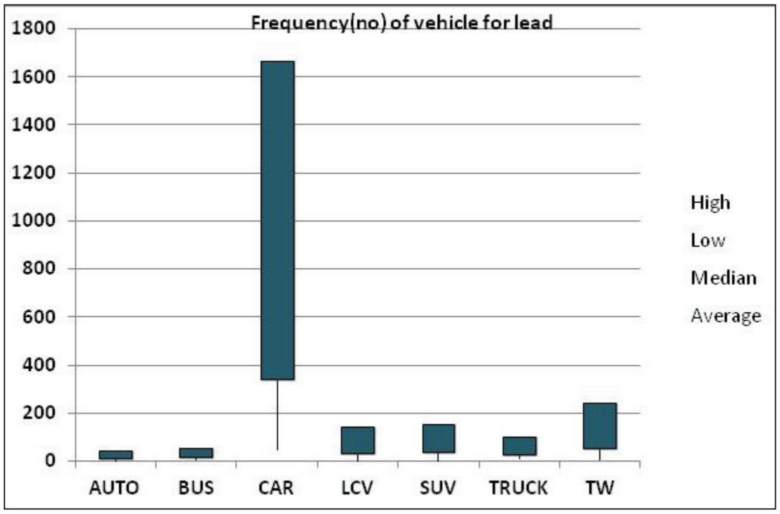


Fig 5. Number of vehicles per 8 hrs of vehicle for lead in Shillong

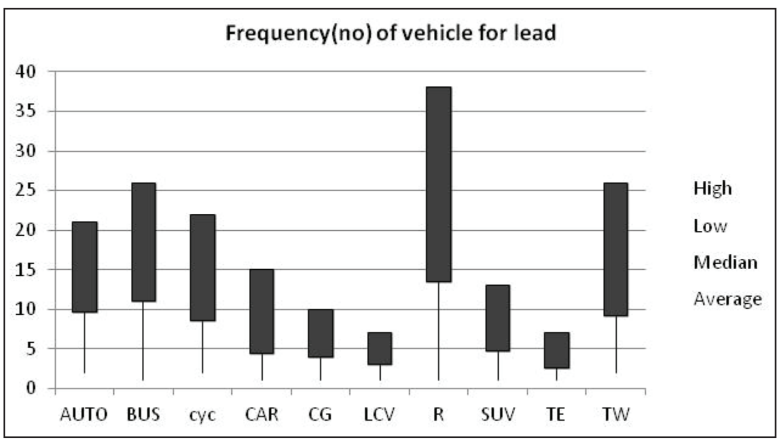


Fig 6. Number of vehicles per 1/2hrs of vehicle for lead in Shilchar

Investigation and simulation of ramp metering strategies depend on headway. The study will be used to understand a vital contributing factor for the design and operation of vehicles and identification of causative mechanism in the traffic process. An accurate estimate of headway is essential for road design and intelligent traffic signal control. It is recommended that headway should be used for enforcement purposes, because small headways generate potentially dangerous situations and time to collision. It is recommended that authorities use headway as a

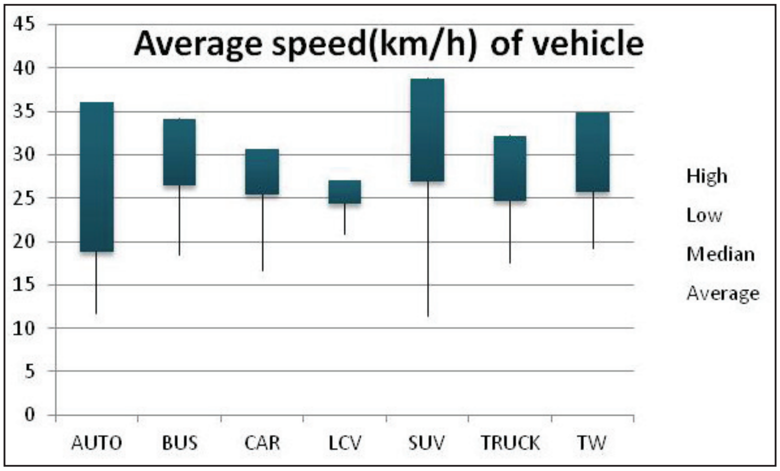


Fig 7. Average speed (Km/h) for different lead vehicle in Shillong

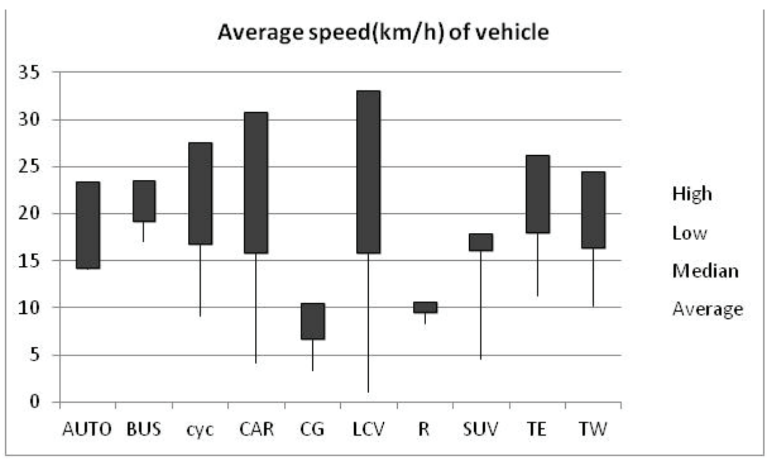


Fig 8. Average speed(Km/H) for different lead vehicles in Shilchar

criterion for tailgating, because it is easy to measure, understand and interpret, and most important of all, it is directed against potential danger, which effectively prevents dangerous time-to-collision values from occurring at all.

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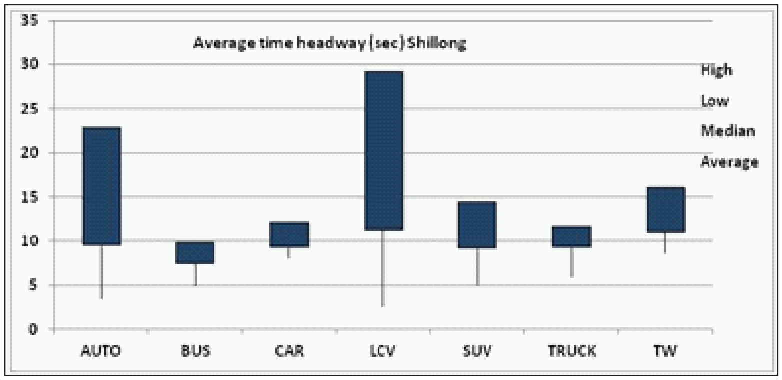

Fig 9. Average time headway in Shillong for different lead vehicle (Sec)

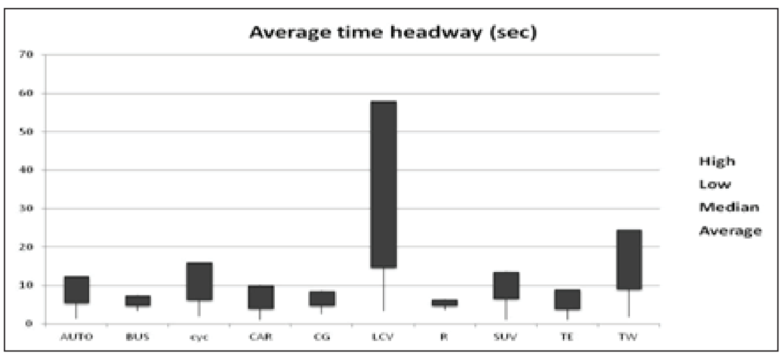

Fig 10. Average time headway in Shilchar for different lead vehicle (Sec)

Lyngdoh, Secretary PWD (retd.) Shillong, Shri M. M. Sun, Secretary & Chief Engineer, Shri T. G. Nengnong, Superintending Engineer, Dr Purnima Parida, Head TPD, Mr Sanjay Kumar, TA, Dr S. Gangopadhyaya, Director CRRI and other staff who have directly or indirectly supported this project.

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