**EFFECTS OF HEAVY VEHICLES ON FOLLOWING BEHAVIOR IN TWO-LANE HIGHWAY SECTIONS**

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## 1. Introduction

A huge part of Japan's road network is comprised of two-way, two-lane highway sections. It plays a very critical role in the transport of people and goods between prefectures, cities, towns and even up to the most rural parts of the country. A typical two-lane highway, by definition, is a road that has one lane for each direction where the opposite lane can be used for passing other vehicles going in the same direction. However, most of the major two-lane highways in Japan, with an average daily traffic in excess of 10,000, restrict vehicles from using the opposite lane for passing purposes.

Recent studies have shown that the number of followers and their behavior are significant factors in the analysis of two-lane highway operations, especially where passing is not allowed.[1)] Slower vehicles usually cause stress and dissatisfaction to other drivers who have higher desired speed levels, thus making the vehicle following factor a primary consideration in the evaluation of two-lane highway service levels. With the considerable presence of trucks and other heavy vehicles in major two-lane highway sections, platoon formation and consequently, follower density are expected to increase further. Thus, it is important to analyze the extent of the influence heavy vehicles on follower behavior to further understand how to correctly assess two-lane highway level of service (LOS).

(1) Objective and scope

This study aims to identify and analyze the effects of heavy vehicles on the behavior of following vehicles and the overall operations of two-lane highway sections without passing zones.

This study has some limitations. There is only one selected study section where all the data types were taken. For a more comprehensive analysis of two-lane highways, several other segments with varying characteristics should be considered in the future. Additionally, this study focuses only on sections where passing is restricted. Different conclusions may be derived if typical two-lane highways, where passing is allowed, are also analyzed.

## 2. Data Collection and Analysis

Raw pulse data were gathered from vehicle sensors strategically installed at a section of Route 19 (KP 119.9) in Kiso-gun of Nagano prefecture. This segment represents a typical major two-lane highway in Japan where passing is not allowed. It is in between two signalized intersections about 4.2-kilometers apart, with an annual average daily traffic (AADT) of about 15,500. Furthermore, this section is the usual road used by freight vehicles traveling in major cities within Aichi, Gifu and Nagano prefectures, as an alternative toll-free route to the parallel toll-road, Chuo Expressway. The installed detector is not the usual loop inductive detector typically used in Japanese roads and highways. It is based on magnetic field sensor technology, which basically senses the vehicles' distortion of the earth's magnetic field to detect and classify vehicles. It is a much cheaper alternative to usual loop detectors and it is relatively easy to install with low maintenance requirements. This is the first time a vehicle sensor of this type is being used for traffic analysis in Japan. Figure 1 shows the schematic layout of the installed detector in Route 19.

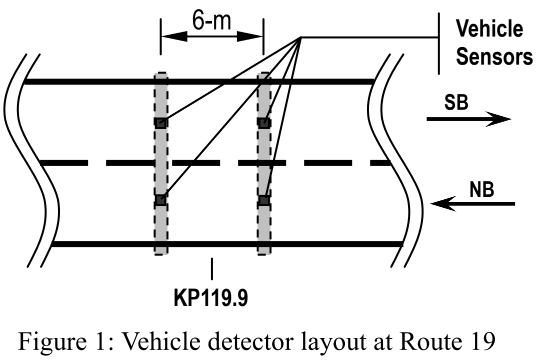

Figure 1: Vehicle detector layout at Route 19

Video data were also taken during one of the days of the Golden Week (GW), which is considered one of the peak seasons for traffic demand in Japan. Cameras were placed 100 meters from the detector on both sides to capture vehicle movement in both directions. These data were mainly used to verify the types of vehicles being recorded by the detector.

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(1) Vehicle Classification

The vehicle detector is capable of producing individual vehicle data including spot speed, duration of detector occupancy and the approximate length of the vehicle. This last data output was used to classify vehicles into either passenger cars or heavy vehicles.

The initial task was to determine the detected vehicle length that should be considered the threshold value that would distinguish the two vehicle types. The video data included vehicle count, time headway and vehicle classification. Vehicles were categorized as passenger car, heavy vehicle or motorcycle through visual inspection. These were then compared to the detector data for verification. As expected, not all vehicles recorded from the video survey were detected by the vehicle sensor. This is especially true for motorcycles, which form about 66% of all the undetected vehicles. For this study's purpose, the motorcycle classification was included in the passenger car category since the detected number of motorcycles is insignificant relative to the total volume. This is also to somehow compensate for the detector error because in reality, based on the actual video footages, a considerable number of motorcycles passed the segment without being detected by the vehicle sensor. This issue shall be addressed later in another study which would hopefully calibrate the detector to account for motorcycle detection errors.

The classified vehicles were segregated and compared to their corresponding lengths estimated by the detector. Probability density curves were drawn to show the distribution of vehicles according to the detector data on individual vehicle lengths. Figure 2 shows that while the detected lengths for passenger cars ranged from 0.9-m to 15.1, the concentration of this vehicle type were within 2 to 6 meters. The heavy vehicle distribution however varied more widely across the estimated lengths. This however is not so much of a concern since only the lower limit is desired to be calculated.

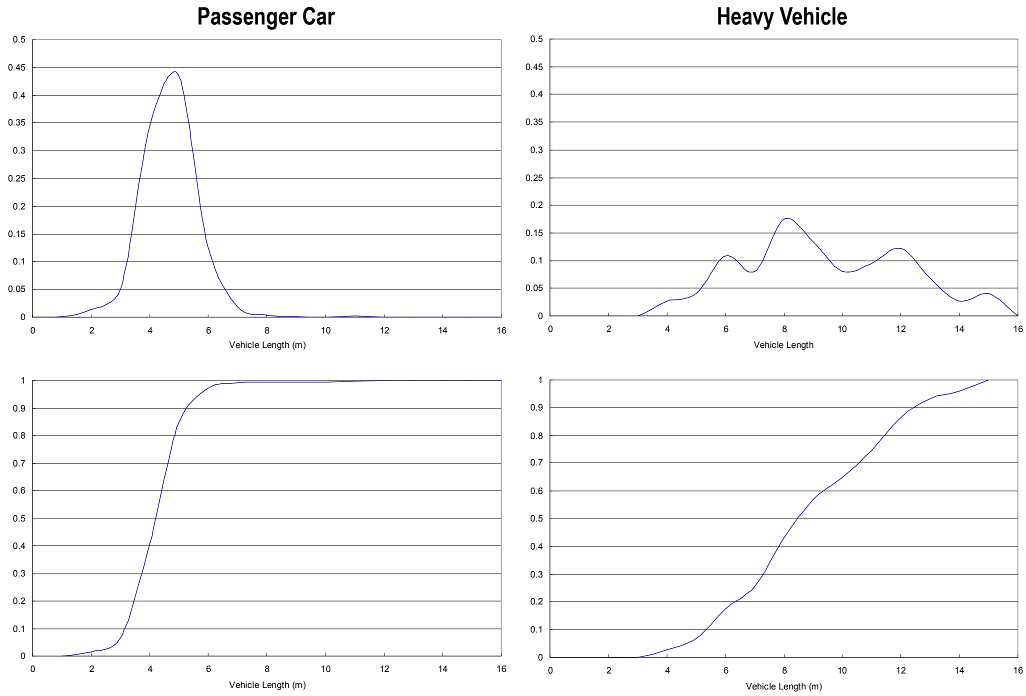


Figure 2: Passenger car and heavy vehicle distribution across estimated vehicle lengths

From the figure, at around the $85^{th}$ percentile value for passenger cars, the estimated length is about 5 meters. Taking the lower threshold for heavy vehicles at the $15^{th}$ percentile mark, the length falls around 6-meters. For this study's purpose, the value of 5-meters was assumed to be the limiting length that would distinguish a passenger car from a heavy vehicle.

Followers are assumed to be those vehicles with time headways less than or equal to 3 seconds relative to their respective lead vehicles[2)], similar to the HCM methodology. This 3-second threshold however is still a subject for verification in a later study, where user perceptions will be the major factor that would establish the actual headway for a vehicle to be considered 'following'.

## 3. Heavy Vehicle Effects

The detector data used for the subsequent analyses were taken during the GW period (May 1 – 7, 2006) to observe traffic characteristics during peak periods and to maximize the evaluation for a wider range of scenarios.

Heavy vehicle parameters were calculated and compared with the different traffic operational characteristics of the subject two-lane highway section. One of the more significant findings is the effect of the average heavy vehicle speed to the average follower speed, where both parameters are found to be directly related to each other. As expected, follower speed increases as the speeds of heavy vehicles go up. Figure 3 shows the relationship trend between the speeds of heavy vehicles and followers.

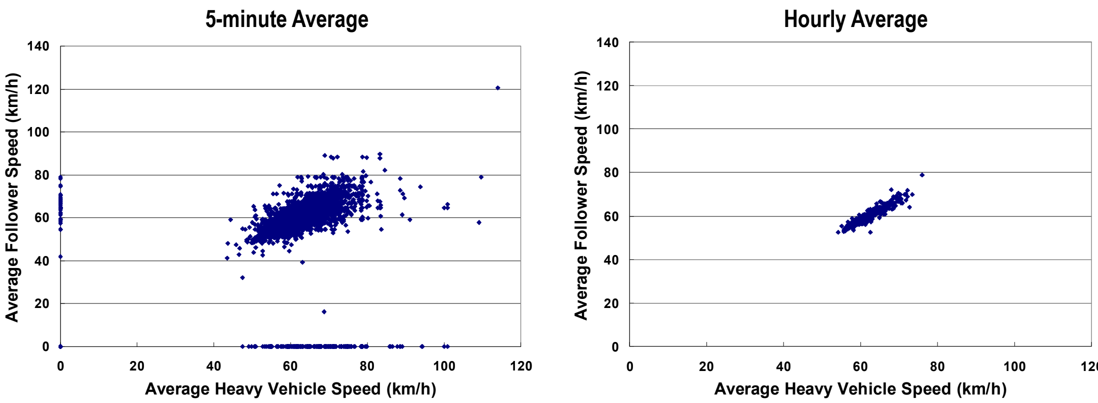


Figure 3: Relationship between average speeds of heavy vehicles and followers

In contrast, it was found that heavy vehicle percentage does not have any significant effect on both average follower speed and the average speed of all vehicles, as shown in Figure 4. Regardless of the percentage of heavy vehicles present, the average speeds do not seem to be drastically affected and just maintains values within the 60 – 70 km/h level. This however may be somewhat misleading since heavy vehicle percentage values do not exactly reflect the actual flow rates. High heavy vehicle percentages are usually recorded during low flow conditions (i.e., off-peak, night-time, etc.), when the vehicles present are mostly, if not all, large trucks. Additionally, the assumed 3-second headway threshold may not be applicable to truck drivers as they may feel more comfortable being in a platoon of heavy vehicles, as they may perceive it as a less onerous state.[3)]

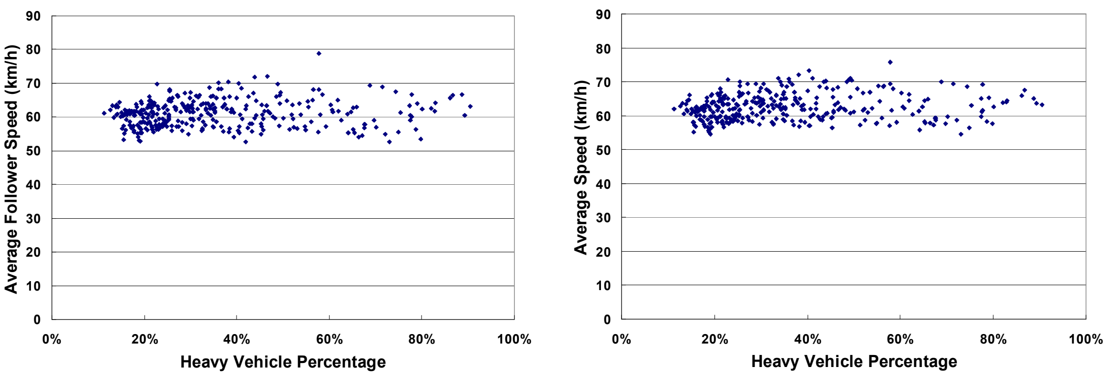


Figure 4: Relationship between heavy vehicle percentage and average speeds

Finally, the effect on follower density was investigated. Follower density is defined as the number of followers per kilometer of traveled lane and was found to be a suitable measure of service level for two-lane highways.[1)] It was found that follower density becomes more sensitive to heavy vehicle percentage as flow rate increases. Figure 5 shows the relationship between heavy vehicle percentage and follower density at different volume ranges and different time periods during a day.

It can be seen that at flow rates of 0 – 100 veh/h, follower density hardly goes past the 1 foll/km mark. As the volume increases however, the heavy vehicle percentage range narrows down to the 10 – 30% range with follower densities ranging from 3 foll/km onwards. This is probably due to the increase in passenger car flow, which consequently reduces the heavy vehicle percentage but also increases the number of followers since most passenger car drivers have a higher desired speed than heavy vehicle drivers. Similarly, at relatively low-flow periods of the day (0:00 – 6:00 and 18:00 – 24:00), follower density is not very sensitive to the percentage of heavy vehicles but its effect becomes more apparent during the daytime (6:00 – 16:00).

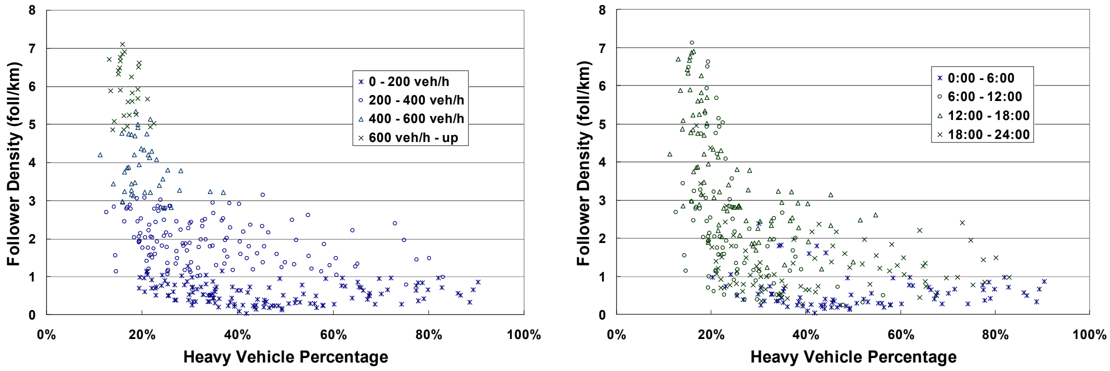

Figure 5: Relationship between heavy vehicle percentage and follower density

It should be noted that during peak periods (GW, etc.), the number of passenger cars increase in the study segment owing to the fact that it is also a link to some major tourist spots in Japan. Therefore, the results presented here may (or may not) differ from a typical weekday or weekend scenario.

## 4. Conclusions and Recommendations

The findings showed several factors how heavy vehicles influence following behavior in two-lane highways without passing zones. Heavy vehicle speed directly affects follower speed since the latter increases if the former goes up. Heavy vehicle percentage however does not seem to have a significant impact on average speeds, but this may be due to the fact that this relationship does not take into account the actual flow rate. Follower density on the other hand is sensitive to heavy vehicle percentage as flow rate increases.

Given that the analysis periods presented here were during peak periods, similar evaluations for off-peak or typical weekday and weekend scenarios may be necessary. For a more comprehensive analysis, other similar sections should also be considered to be evaluated in the future.


Acknowledgments

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