The Analysis of Traffic Flow Characterizes for Heavy Highway on Rainy Days

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Abstract—With the development of economy, highways play an important role in transportation system, especially for heavy highways. In order to learn traffic flow characterizes of heavy highway on rainy days, this study focuses on a heavy highway, Xuanda Highway, in Hebei Province. The research selects traffic data of seven days, collected by weigh-in-motion (WIM) system at Haierwa Bridge, to analyse the effect of rain on traffic flow characterizes, including volumes and speed. Specific issues evaluated that the traffic volumes were not sensitive to little rain, while speed of each time period has different degree of reduction during rainy days. The research further indicates people’s willingness to travel. In addition, the study quantifies the speed characteristics for each class, and the relationship between speed and heavy vehicle ratio on rainy days.

Index Terms—traffic flow, heavy load highway, weight-in-motion, rainy, total weight

I. INTRODUCTION

As known, speed, flow and density are three most important characteristics of traffic. Especially, speed is significant affects traffic safety and quality of service. Numerous studies have investigated the relationship between speed and accident [1]. Some of researchers believe in that variance of speed results in accidents, not high speed [2]. Besides, Jian Li et al. [3] further modelled the effects of rainfall intensity on the heteroscedastic traffic speed dispersion. Many studies have analysed various factors affecting traffic speed and its coefficient of variation, such as heavy vehicle ratio, rainfall, slope, flow, and so on.

Sungjoon Hong and Takshi Oguchi [4] investigated the effects of rainfall and heavy vehicles on speed-flow relationship for multilane expressways, finding that the change of rainfall from 0~1mm results the greatest speed deduction, and heavy-vehicle ratio also have influence on it. Babak Mirbaha et al. [5] established a prediction of average speed for a two-lane highway, based on its analysis of vehicle speed with different weather condition and traffic characteristics, which can be useful in traffic management plan. As for highway service under rainy days, Nordiana Mashros and Johnnie Ben-Edigbe [6] addressed that light and moderate rainfall resulted in slight qualitative service reduction, while heavy rainfall led to significant reduction in all cases.

Except rainfall, heavy vehicles have a significant impact on highway traffic flows [4]. Typically, the majority of vehicles in traffic flow can be divided passenger cars and others, such as trucks, motorcycle, Jeep, various big vehicles for entertainment and so on. Among them, trucks, large buses and recreational vehicles belong to heavy vehicles, which are large in dimension and have different traffic performance from passenger cars. Therefore, heavy vehicles have a great influence on traffic stream, although they account for small proportion of vehicle traffic. [7] Historically, Karen K. Dixon et al. [8] have found that the presence of heavy vehicles did not substantially impact the average speed for low volume rural conditions with heavy vehicle ratio up to 0.3 in generally level terrain. Chang-Gyun R et al. [9] indicated that the average speed was stable when HV ratio was range of 0.25-0.45 and recovered after 0.45. Therefore, the impact of HVs on average is not accurate under different conditions, need to further investigate.

Nevertheless, some factors have not been sufficiently clarified, even vary with different combination or conditions. All above focused traffic flow on highway or roads, which did not cover conditions of heavy highway. In order to learn traffic flow characterizes of heavy highway on rainy days, this study focuses on a heavy highway, Xuanda Highway, in Hebei Province. The research selects seven days traffic data, collected by WIM system at Haierwa Bridge, to evaluate the effect of rainfall on traffic flow characterizes. Specific issues evaluated include the change of traffic volumes and speed of each time period during rainy days, to further indicate people’s willingness to travel. In addition, the study will quantify the speed characteristics for each class vehicle, and the relationship between speed and heavy vehicle ratio on rainy days.

II. BACKGROUND

A. Bridge and Equipment

Xuanda Highway, namely xuanhua - datong highway, is one of the main channels for transporting coal from
Datong to other places in Hebei Province. The Highway is started from xuanhua, via a Shaohua Ying, YangYuan to shanxi provincial boundary, whose total length is 127.8 km. Xuanda Highway is the first mountainous area heavy highway in Hebei province. It is a two-way four-lane highway, with a speed limit range of 90 km/h to 110 km/h.

The Haierwa Bridge (as Fig. 1) is located in the Xuanda Highway in Hebei province, nearly by Xuanhua. The number of the starting mileage pile is K168+400, and the terminal pile number is K168+612, which total length is 191.6 m, and the bridge width is 24.5 m. It was completed and opened to traffic in December 2000. Bridge design span is combination of 14m+138m+10m+2x8m, which design load is car-20, trailer-120. The main span is composite truss arch bridge with pre-stressed concrete structure. The bridge is two-way four-lane. Especially, lane 3 and lane 4, from Datong to Xuanhua direction, are heavy traffic lanes of the heavy highway, regarded as the research object of the paper.

There is a Weigh-In-Motion (WIM) station setting on the pavement of Haierwa Bridge (as Fig. 2), which is aimed to record traffic information as vehicle pass over its sensors at normal speeds. The traffic information collected by WIM included individual passing time, class designation, speed, spacing between adjacent axles, number of axles, load of each axle, as well as total weight [11].

**B. Data Collection**

Many of previous studies have analysed WIM data [11]-[14]. There was traffic information lasting for three years collected by WIM, about two million vehicle records per year. The paper focused on traffic volumes, speed and total truck weight to analyse heavy highway traffic flow. The writer selected one-week records, from September 7 to September 13, 2015, for two lanes from Datong to Xuanhua. It is noteworthy that the writes defines heavy truck, total weight exceeds 49t, as heavy vehicle in the paper. The ratio of heavy vehicles of Datong to Xuanhua direction was twice as much as other two lanes. It can represent heavy highway better.

In order to analysis effect on above variables on rainy days, the corresponding rainfall data was obtained from National weather service. The rain class is conducted corresponding with rainfall for one hour. Specifically, light rain is 0.1-2.5mm rainfall per hour, called class 1 in the paper. Similarly, moderate rain is 2.6-8.0mm per hour, called class 2, and heavy rain is 8.1-15.9mm per hour, called class 3. The first day and last three days are sunny; pouring rain occurred during 6:00-7:00 on the second day; follow by light rain on the third day, and moderate rain on the fourth. Fig. 3 shows that the traffic volumes declined on third day with light rain and the fourth day with moderate rain, while slight increased on first light rain. After rainy days, the traffic volumes began to recover. The relationship between volumes and rainfall indicated that moderate rain or heavy rain decreased people’s willingness to travel, which was not sensitive to light rain or shower.

**III. CHARACTERS OF TRAFFIC FLOW**

**A. Traffic Volume**

The rainfall data was counted for each one hour. There are 129 hours no rain, and 32 hours are light rain. Additionally, 6 hours are moderate rain and only one hour is heavy rain. The part combines all rainy conditions, up to 39 hours, computing the average traffic volumes of each hour for one day. At the same time, the volumes of heavy vehicles were distinguished.

As Fig. 4 shown, the traffic volume distribution of light vehicles for heavy highway belongs to bimodal distribution, similar to ordinary highway. While the heavy vehicles keep stable regardless day or night, even...
no matter what rain or sunny. It was deem that the traffic volumes of light vehicles declined result from rainfall during 5:00-21:00. In conclusion, the rainfall decreased light vehicles volumes during the day, but made slightly difference on heavy vehicles.

To heavy highway as Fig. 5. Rainfall class 0~4 means no rain, light rain, moderate rain and heavy rain respectively. The average speed distribution was generally represented by central tendency distribution. The average speed was range from 82km/h to 103km/h during sunny days, while range from 79km/h to 100km/h when rain. Due to the time of moderate rain and heavy rain is only 7 hours, the speed change is unrepresentative. The writer focused on the speed reduction result from the light rain. It is shown that rainy days average speed decrease by 2-10km/h than sunny days during 5:00-1:00 (the second day) in Fig. 5, but still belong to central tendency distribution.

C. Speed of Different Weight of Heavy Trucks in Free Flow

For different total weight vehicles, speed reduction is different under different rainy class. The scatter diagram shows individual speed distribution of different weight vehicle as Fig. 6. The total weight is range of 0~30t and 50~80t. Among them, the total weight of passenger cars centralized less than 10t. With the increase of rainfall, the speed of passenger cars centralized to lower value. The maximum individual speeds respectively were 183km/h, 171km/h, 144km/h, 135km/h, corresponding with rainfall class 0~3. The average speed of 0-10t vehicles can also confirm it in Fig. 7. 10~40t and exceed 60t vehicles were not sensitive to light rain. Moderate rain have an impact on vehicle speed with weight range of 40~60t.

It is important to note that there were only 81 traffic records under heavy rain conditions. Because most vehicles weigh lower than 10t, what differences heavy rain made on vehicles was not accurate. On the other hand, all points of heavy vehicles are under the dotted line in Fig. 6, also proved heavy rain may impact on speed of heavy vehicles.

D. Speed-Ratio of Heavy Truck on Rainy Days

When there was no rain the average speed decreased as the proportion of heavy vehicles increases. In case of light rain and moderate rain, the average speed tendency was similar to sunny days. As shown in Fig. 8, it is important to note that most of average speed of rainy
days was lower than that of sunny days, when the heavy vehicles ratio range of 0~25% and exceeds 45%. In other words, the influence of rainfall on speed was more prominent at low or high heavy vehicles ratio.

According to previous traffic data analysis for three years, Harerwa Bridge traffic flow is hardly to be congestion. Therefore, the paper is based on free-flow of heavy highway, while congested traffic flow needs further investigation.

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