Study on the Speed Limit at Night in Expressway Maintenance Area

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Abstract. In order to improve the safety of expressway maintenance work area at night, taking the maintenance work area of two-way four lane Expressway in Anhui Province as an example, the traffic characteristics of the maintenance work area at night are analysed, and the variation characteristics of vehicle speed in the maintenance work area are studied, and the main factors affecting traffic safety are obtained. Based on the traffic flow theory and Greenshields speed density-linear relationship model, this paper analyses the correlation between the speed and traffic capacity in the maintenance work area. Through the simulation by VISSIM software, the speed limit value of the expressway maintenance work area in the day and night is obtained, which provides an important reference value for the expressway maintenance operation.

1. Introduction
Expressway has the characteristics of fast, convenient, safe and comfortable, which plays an important role in the field of transportation. However, some expressways in China have been damaged to varying degrees in the operation process, which cannot meet the existing traffic demand. In addition, in the process of maintenance, the increase of traffic volume and large vehicle rate are easy to cause serious "intestinal obstruction", which will affect the traffic efficiency and driving safety of Expressway [1]. Due to the reduction of the number of traffic lanes, the traffic capacity of the expressway maintenance work area is reduced, resulting in a high risk of lane change and car following [2]. Especially at night, the driver's vision will be reduced by about 50% [3], and the recognition distance of objects with 35% contrast is only 20% of that of objects with 88% contrast [4], and the visual field will become narrower with the increase of vehicle speed, which is prone to traffic accidents [5]. According to statistics, the death rate of road traffic accidents at night is 1.5 times that of daytime [6]. Therefore, it is necessary to speed limit the vehicles in the expressway maintenance area at night.

Based on the division of traffic control area, this paper analyses the traffic characteristics of different locations of expressway maintenance work area, puts forward the variation law of vehicle running speed in expressway maintenance work area, and analyses the influencing factors of traffic capacity of expressway maintenance work area Reason provides scientific basis.
2. Division of traffic control area in expressway maintenance work area

According to the safety operation regulations for expressway maintenance (JTG H30-2015), the maintenance work area is divided into six areas, namely warning area, upstream transition area, buffer, work area, downstream transition area and termination area. This paper makes a field investigation on the pavement maintenance of Shanghai Shaanxi Expressway (G40). Taking the typical two-way four lane maintenance work area as an example, the basic form of traffic control area in lane closed maintenance work area is shown in Figure 1.

![Figure 1. Traffic control division chart of expressway maintenance work area](image)

3. Analysis of night speed variation in each section of maintenance work area

Based on the investigation of the two-way four lane maintenance work area of Expressway in Anhui Province, the layout of the work area is: the outer single lane is closed. The typical data acquisition mode is adopted for the arrangement of acquisition equipment, that is five sets of equipment are respectively arranged in the basic section (in front of the first sign), warning area, transition section and work area in the upstream of the work area, as shown in Figure 2.

![Figure 2. Investigation site for closed maintenance work area of expressway single-lane road](image)

As an important parameter of traffic flow, speed can represent the characteristics of traffic flow in macroscopic aspect. When driving in the working area, due to the closure of some lanes, the speed characteristics of vehicles in the work area are different from those in the ordinary road sections, especially when the vehicle types are different. Therefore, according to the field survey data, this paper fits the night speed of different sections in the maintenance work area, and draws the speed probability density curve of small and large vehicles in the warning area, transition area and working area, as shown in Figure 3. At the same time, the cumulative distribution curve of vehicle speed at night in maintenance work area is drawn as shown in Figure 3.

![Figure 3. Normal distribution of vehicle speed in different traffic control areas of maintenance work area](image)
It can be seen from Figure 3 that the speed distribution of the two types of vehicles becomes smooth in the range of 80% - 95%. Therefore, in this paper, 85% bit speed is selected as the speed characteristic point in different regions of maintenance work area, which is the running speed. It is shown in Table 1.

| Vehicle type | Traffic control area running speed statistics |
|--------------|-----------------------------------------------|
|              | Warning area | Upstream transition | Work area   |
| LDV          | 91.3         | 82.7                | 77.1        |
| HDV          | 95.1         | 82.9                | 78.6        |

### 4. Study on traffic capacity of expressway maintenance area

According to the traffic flow theory and the Greenshields speed density linear relationship model, when the traffic flow reaches the maximum, the vehicles pass at the critical speed.

\[
Q = V \times K
\]

\[
V = V_f \times (1 - K / K_f)
\]

Where: \(Q\) — average flow(veh/h); \(V\) — spatial average speed(km/h); \(K\) — average vehicle density(veh/km); \(V_f\) — free running speed(km/h); \(K_f\) — congestion density(veh/km);

It is found that the main factors affecting the capacity of expressway maintenance area are: the proportion of large vehicles, the length of work area, road slope, road width, light conditions, etc. The traffic capacity of the work area can be calculated by the following formula:

\[
C_B = C_c \times f_{HV} \times f_L \times f_w
\]

Where: \(C_B\) — basic traffic capacity of work area; \(C_c\) — maximum hourly traffic volume corresponding to different maintenance methods; \(f_{HV}\) — correction coefficient of large vehicles in work area; \(f_L\) — correction coefficient of length of work area; \(f_w\) — correction coefficient of illumination intensity in work area;

Through the establishment of expressway maintenance work area model in VISSIM, the simulation speed is set according to the speed change rule in Figure 4, and the influence of different factors on the traffic capacity is studied respectively, and the maximum traffic volume passing through the work area under the congestion condition is simulated, and the speed limit value is obtained by setting a detector on the lane behind the work area.

| Arrival flow (veh/h) | 3500 | 3000 | 2500 | 2000 | 1500 | 1000 | 500 |
|----------------------|------|------|------|------|------|------|-----|
| Work area flow (veh/h)| 1482 | 1478 | 1486 | 1490 | 1494 | 1096 | 564 |
| Occupancy (%)        | 55.6 | 55.0 | 54.3 | 53.7 | 52.1 | 6.0  | 2.1 |
| Minimum forward speed | 0.3  | 0.4  | 0.5  | 0.6  | 0.8  | 8.7  | 38.6 |
As shown in Table 2, when the vehicle traffic volume reaches 1486veh/h, the traffic flow in the work area reaches the maximum value. When the vehicle continues to increase, the speed of the vehicle will decrease and there will be a certain traffic jam. Therefore, the basic capacity of the work area is 1486veh/h. The traffic capacity of the above maintenance work area only considers the influence of the closed lane, which is taken as the basic traffic capacity of the maintenance work area.

4.1. Impact of large vehicle rate on traffic capacity

Compared with small vehicles, large vehicles have slow acceleration and deceleration and poor braking performance, so different proportions of large vehicles in traffic flow have different impacts on the capacity of maintenance work area. The simulation conditions are designed as follows: the length of maintenance work area is 0.2km, the longitudinal slope is 0%, and the proportion of large vehicles is 0%, 5%, 15%, 25%, 35%. The analysis results of the influence of large vehicle rate on the traffic capacity of maintenance work area are shown in Table 3 and Table 4.

| Arrival flow | Proportion of large vehicles (%) |
|--------------|----------------------------------|
| 1000         | 5                                |
| 1500         | 15                               |
| 2000         | 25                               |
| 2500         | 35                               |
| 3000         | 40                               |

Table 3. Influence of large vehicle rate on traffic capacity of maintenance work area

| Project name | Large vehicle rate (%) |
|--------------|------------------------|
| Capacity value of | 1486                |
| Reduction ratio | 1.00                 |

Using SPSS software, regression analysis of the above data was carried out, and the correction coefficient of large vehicle rate in maintenance work area was obtained $f_{HV}$:

$$f_{HV} = -0.026x + 1.0052 \quad R^2 = 0.9648$$

4.2. Influence of work area length on traffic capacity

The simulation conditions are set as closed one side of the road, the cart rate is 0%, the slope is 0%, and the work area length is 0.2km, 0.5km, 1km, 1.5km, 2km, 3km and 4km respectively. The analysis results are shown in Table 5.

| Length of working area (km) | Traffic capacity |
|-----------------------------|------------------|
| 0.2                         | 1486             |
| 0.5                         | 1482             |
| 1                           | 1479             |
| 1.5                         | 1475             |
| 2                           | 1467             |
| 3                           | 1460             |
| 4                           | 1451             |

Table 6 shows that as the length of the maintenance area increases, the capacity gradually decreases. Through the software, the reduction ratio of traffic capacity is about 0.38%. Taking 0.2km as the standard value, the capacity decreases by about 0.38% for each unit added in the maintenance work area, and the length correction coefficient of maintenance work area is obtained $f_L$:

$$f_L = 1 - 0.0038(L - 0.2)$$

(5)
4.3. Influence of light conditions on traffic capacity

According to the observation of the road traffic flow in the actual work area, the traffic capacity of the work area will be greatly reduced in the dark night, that is, the light conditions have a great impact on the traffic capacity of the work area. Simulation conditions: Cart rate 0%, longitudinal slope 0%, work area length 0.2km, analysis results are shown in Table 3.

| Light conditions | Reduction factor |
|------------------|------------------|
| Day              | 1                |
| Night            | 0.96             |

5. Empirical research

A two-way four lane expressway has a design speed of 100km/h and a basic capacity of 1486pcu/h. Due to the maintenance work, the length of the work area is 2km and the longitudinal slope of the road is 1.5%. According to the survey and statistics, the rate of large vehicles in this section is 20%. Using VISSIM simulation, the basic traffic capacity of the maintenance work area is 1375 PUC/h and the blocking density is 115 veh/km in the daytime. The smooth running speed of the work area is calculated to be 48 km/h. The basic traffic capacity of the maintenance area at night is 1200 PUC/h and the blocking density is 110 veh/km. The smooth traffic speed of the work area is 43.6 km/h.

6. Conclusions

This paper studies the law of speed change in expressway maintenance work area, and concludes that the speed is the main influencing factor of expressway maintenance work area. Based on the traffic flow theory, the relationship between capacity and speed is obtained. The influencing factors of traffic capacity are analysed by VISSIM simulation software, and the day and night speed limit value of maintenance work area is deduced. Through the reasonable speed limit of the maintenance work area, improve the traffic efficiency of vehicles in the work area, reduce the traffic accident rate, and provide important reference value for the operation of expressway maintenance work area.

Acknowledgments

The project relies on the technology project of Anhui Transportation holding Group Co., Ltd. (Project No:GSKY-2019-01).

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