

Vehicle Delay Analysis at Signalized Intersection

Yufan Ren, Fuchao Geng

School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo 454000, China

Abstract: Traffic delay is an important measure to evaluate road operation efficiency and service level, which can reflect the rationality of road design and intersection signal control scheme design. Therefore, delay analysis is of great significance to the evaluation of road service level and intersection signal control scheme design. In this paper, the point sample method and VISSIM simulation software are used to study the traffic delay of Yingbin Road and Century Road intersection in Jiaozuo City, and the traffic condition of the intersection is evaluated according to the calculation results. In this paper, the point sample method and VISSIM simulation software are used to study the traffic delay of Yingbin Road and Century Road intersection in Jiaozuo City, and the traffic condition of the intersection is evaluated according to the calculation results.

Keywords: Signalized intersection, The point sample method, VISSIM simulation, Delay.

1. Introduction

The key to the capacity constraints of urban road traffic is at intersections, and signal intersection delay is an important indicator to evaluate the operational efficiency and service level of intersections. It not only reflects the rationality of signal intersection traffic control and traffic design, but also reflects the degree of obstruction and perceived service quality of road users, as well as energy consumption and environmental impact. Therefore, the delay analysis of signal intersections is of great significance to the design of urban road traffic planning and signal control schemes of intersections [2]. In this paper, the point sample method and VISSIM microsimulation software will be used to calculate

the delays at the intersection of Yingbin Road and Century Road in Jiaozuo City, respectively, and the results will be analyzed and compared.

According to the regulations, the vehicle is converted into the flow of small vehicles. The conversion factors are shown in Table 1.

Table 1. Conversion factors for each vehicle

| Vehicle type | Minibus | Large bus |
|-------------------|---------|-----------|
| Conversion factor | 1.0 | 2.0 |

The flow rates for each inlet direction at the intersection are shown in Table 2.

Table 2. Flow rate of each inlet at the intersection

| | | |
|--------------|----------------|-----|
| East import | Straight ahead | 135 |
| | Turn left | 8 |
| | Turn right | 5 |
| Total | | 148 |
| West import | Straight ahead | 118 |
| | Turn left | 9 |
| | Turn right | 7 |
| Total | | 134 |
| South import | Straight ahead | 131 |
| | Turn left | 13 |
| | Turn right | 9 |
| Total | | 153 |
| North import | Straight ahead | 126 |
| | Turn left | 11 |
| | Turn right | 10 |
| Total | | 147 |

2. Delay calculation

2.1. Point Sample Method

The point sample method is to record the number of vehicles without stopping i.e. the number of vehicles that have passed the stop line without stopping and the total number of vehicles after the stop line at a predetermined time interval at the signal-controlled road intersection inlet lane. Within a predetermined time interval, the number of vehicles

that pass the stop line without stopping is recorded, and the number of vehicles that pass the stop line after having stopped and the total number of vehicles behind the stop line are recorded. The above process is repeated continuously for the desired measurement time period.

The point sample method requires a sufficient sample size to ensure the accuracy of the road intersection delay survey, and the minimum sample size of the survey is determined by the binomial distribution, as shown in the following equation.

$$N = \frac{(1-p)x^2}{pd^2}$$

In the formula: N: Minimum sample size;
 p: Percentage of vehicles stopped on the inlet lane of a road intersection, %;
 X²: The value of X² at the required confidence level, which

in general is taken to be 95%, when X²=3.84;
 d: The error allowed for the estimated value of the percentage of stopped vehicles, the value of d is taken to be between 0.01 and 0.1 depending on the purpose of the survey, and here it is taken to be 0.10.

Table 3. East intersection traffic volume

| Start time | Number of vehicles parked on the approach road during the following hours | | | | Approach Road Traffic Volume | |
|------------|---|--------|--------|--------|------------------------------|-----------------------------|
| | 0~15s | 15~30s | 30~45s | 45~60s | Number of parked cars | Number of non-stop vehicles |
| 17: 30 | 5 | 6 | 6 | 7 | 7 | 0 |
| 17: 31 | 0 | 0 | 3 | 5 | 5 | 3 |
| 17: 32 | 5 | 7 | 7 | 10 | 10 | 0 |
| 17: 33 | 0 | 2 | 3 | 5 | 5 | 5 |
| 17: 34 | 5 | 7 | 8 | 8 | 8 | 0 |
| 17: 35 | 0 | 2 | 3 | 3 | 3 | 2 |
| 17: 36 | 3 | 5 | 7 | 10 | 10 | 0 |
| 17: 37 | 0 | 1 | 3 | 3 | 3 | 4 |
| 17: 38 | 6 | 7 | 7 | 11 | 11 | 0 |
| 17: 39 | 0 | 0 | 4 | 5 | 5 | 6 |
| Subtotal | 24 | 37 | 51 | 67 | 67 | 20 |
| Total | 179 | | | | 87 | |

Total Delay = Total number of parking · Observation interval = 179 · 15 = 2685(Vehicle·s)
 Average delay per out-of-service vehicle = Total Delay/Total number of parked vehicles = 2685/67 = 40.07(s)
 Average delay per vehicle on the intersection approach = Total Delay/Total traffic volume on approach roads = 2685 / 87 = 30.86(s)
 Percentage of parked vehicles = Total number of parked vehicles/Total traffic volume on approach roads = 67 / 87 = 77 %

Minimum sample size calculation, Confidence level X²=3.84, d=0.10. N=(1-0.77·3.84/0.77·0.10²) = 115(Vehicle)
 Estimation error of parked vehicles = [(1-p)X² / (pN)]^{1/2} = [(1-0.77) · 3.84 / (0.77 · 115)]^{1/2} = 9.99%
 From the last indicator, it can be seen that the error of the percentage of parked vehicles is 9.99%, with an allowable error of 0.10 or 10.0%, indicating that the survey meets the accuracy requirements and the results are valid.

Table 4. West intersection traffic volume

| Start time | Number of vehicles parked on the approach road during the following hours | | | | Approach Road Traffic Volume | |
|------------|---|--------|--------|--------|------------------------------|-----------------------------|
| | 0~15s | 15~30s | 30~45s | 45~60s | Number of parked cars | Number of non-stop vehicles |
| 17: 30 | 0 | 2 | 4 | 5 | 5 | 0 |
| 17: 31 | 7 | 8 | 0 | 0 | 7 | 2 |
| 17: 32 | 3 | 3 | 3 | 6 | 6 | 0 |
| 17: 33 | 6 | 8 | 0 | 0 | 8 | 6 |
| 17: 34 | 2 | 2 | 3 | 5 | 5 | 0 |
| 17: 35 | 5 | 5 | 0 | 2 | 7 | 5 |
| 17: 36 | 3 | 3 | 2 | 3 | 3 | 0 |
| 17: 37 | 6 | 7 | 0 | 1 | 8 | 3 |
| 17: 38 | 0 | 3 | 3 | 6 | 6 | 0 |
| 17: 39 | 5 | 7 | 0 | 0 | 7 | 4 |
| Subtotal | 37 | 48 | 15 | 28 | 62 | 20 |
| Total | 128 | | | | 82 | |

Total Delay = Total number of parking · Observation interval = 128 · 15 = 1920(Vehicle·s)
 Average delay per out-of-service vehicle = Total Delay/Total number of parked vehicles = 1920/62 = 30.97(s)
 Average delay per vehicle on the intersection approach = Total Delay/Total traffic volume on approach roads = 1920 / 82 = 23.41(s)
 Percentage of parked vehicles = Total number of parked vehicles/Total traffic volume on approach roads = 62 / 82 = 75.61 %

Minimum sample size calculation, Confidence level X²=3.84, d=0.10. N=(1-0.7561·3.84 / (0.7561·0.10²)) = 124(Vehicle)
 Estimation error of parked vehicles = [(1-p)X² / (pN)]^{1/2} = [(1-0.7561) · 3.84 / (0.7561 · 124)]^{1/2} = 9.99%
 From the last indicator, it can be seen that the error of the percentage of parked vehicles is 9.99%, with an allowable error of 0.10 or 10.0%, indicating that the survey meets the accuracy requirements and the results are valid.

Table 5. South intersection traffic volume

| Start time | Number of vehicles parked on the approach road during the following hours | | | | Approach Road Traffic Volume | |
|------------|---|--------|--------|--------|------------------------------|-----------------------------|
| | 0~15s | 15~30s | 30~45s | 45~60s | Number of parked cars | Number of non-stop vehicles |
| 17: 30 | 7 | 8 | 0 | 1 | 9 | 6 |
| 17: 31 | 2 | 3 | 5 | 5 | 5 | 0 |
| 17: 32 | 8 | 8 | 0 | 1 | 9 | 5 |
| 17: 33 | 3 | 5 | 5 | 6 | 6 | 0 |
| 17:34 | 6 | 7 | 0 | 3 | 15 | 6 |
| 17: 35 | 4 | 4 | 5 | 7 | 9 | 0 |
| 17: 36 | 8 | 10 | 0 | 0 | 10 | 5 |
| 17: 37 | 3 | 5 | 5 | 5 | 5 | 0 |
| 17: 38 | 8 | 8 | 0 | 3 | 11 | 6 |
| 17: 39 | 4 | 4 | 6 | 6 | 6 | 0 |
| Subtotal | 53 | 62 | 26 | 37 | 85 | 28 |
| Total | 178 | | | | 113 | |

Total Delay = Total number of parking · Observation interval = 178 · 15 = 2670 (Vehicle · s)

Average delay per out-of-service vehicle = Total Delay / Total number of parked vehicles = 2670 / 85 = 31.41 (s)

Average delay per vehicle on the intersection approach = Total Delay / Total traffic volume on approach roads = 2670 / 113 = 23.63 (s)

Percentage of parked vehicles = Total number of parked vehicles / Total traffic volume on approach roads = 85 / 113 = 75.22 %

Minimum sample size calculation, Confidence level $X^2=3.84$, $d=0.10$. $N=(1-0.7522) \cdot 3.84 / (0.7522 \cdot 0.102) = 127$ (Vehicle)

Estimation error of parked vehicles = $[(1-p)X^2 / (pN)]^{1/2} = [(1-0.7522) \cdot 3.84 / (0.7522 \cdot 127)]^{1/2} = 9.98\%$

From the last indicator, it can be seen that the error of the percentage of parked vehicles is 9.99%, with an allowable error of 0.10 or 10.0%, indicating that the survey meets the accuracy requirements and the results are valid.

Table 6. North intersection traffic volume

| Start time | Number of vehicles parked on the approach road during the following hours | | | | Approach Road Traffic Volume | |
|------------|---|--------|--------|--------|------------------------------|-----------------------------|
| | 0~15s | 15~30s | 30~45s | 45~60s | Number of parked cars | Number of non-stop vehicles |
| 17: 30 | 6 | 7 | 7 | 8 | 8 | 0 |
| 17: 31 | 0 | 3 | 3 | 3 | 3 | 3 |
| 17: 32 | 6 | 7 | 7 | 10 | 10 | 0 |
| 17: 33 | 0 | 0 | 2 | 4 | 4 | 2 |
| 17: 34 | 6 | 6 | 7 | 8 | 8 | 0 |
| 17: 35 | 0 | 1 | 2 | 5 | 5 | 5 |
| 17: 36 | 5 | 6 | 9 | 9 | 9 | 0 |
| 17: 37 | 0 | 0 | 1 | 2 | 2 | 5 |
| 17: 38 | 5 | 5 | 5 | 7 | 7 | 0 |
| 17: 39 | 0 | 1 | 3 | 3 | 3 | 7 |
| Subtotal | 28 | 36 | 46 | 59 | 59 | 22 |
| Total | 169 | | | | 81 | |

Total Delay = Total number of parking · Observation interval = 169 · 15 = 2535 (Vehicle · s)

Average delay per out-of-service vehicle = Total Delay / Total number of parked vehicles = 2535 / 59 = 42.97 (s)

Average delay per vehicle on the intersection approach = Total Delay / Total traffic volume on approach roads = 2535 / 81 = 31.30 (s)

Percentage of parked vehicles = Total number of parked vehicles / Total traffic volume on approach roads = 59 / 81 = 72.84 %

Minimum sample size calculation, Confidence level $X^2=3.84$, $d=0.10$. $N=(1-0.7284) \cdot 3.84 / (0.7284 \cdot 0.102) = 143$ (Vehicle)

Estimation error of parked vehicles = $[(1-p)X^2 / (pN)]^{1/2} = [(1-0.7284) \cdot 3.84 / (0.7284 \cdot 143)]^{1/2} = 10.00\%$

From the last indicator, it can be seen that the error of the percentage of parked vehicles is 9.99%, with an allowable

error of 0.10 or 10.0%, indicating that the survey meets the accuracy requirements and the results are valid.

2.2. VISSIM Simulation Methods

VISSIM software is a microscopic, interval-based and driving behavior-based traffic simulation modeling tool developed by PTV Germany, which can generate both online visualization of traffic operation and offline output of various statistical data (such as delays, etc.), and is an effective tool for evaluating traffic engineering designs and urban planning schemes, and is therefore widely used in various universities and research institutes [3].

The signal timing diagram and simulation run chart during the cross-port VISSIM simulation are shown in Figure 1 and Figure 2.

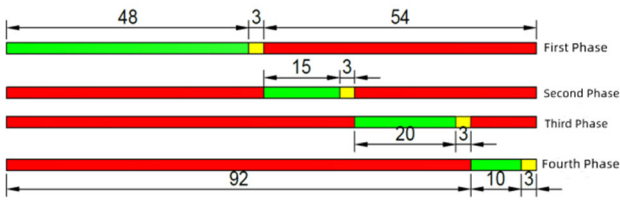


Figure 1. Signal timing diagram during cross-port VISSIM simulation

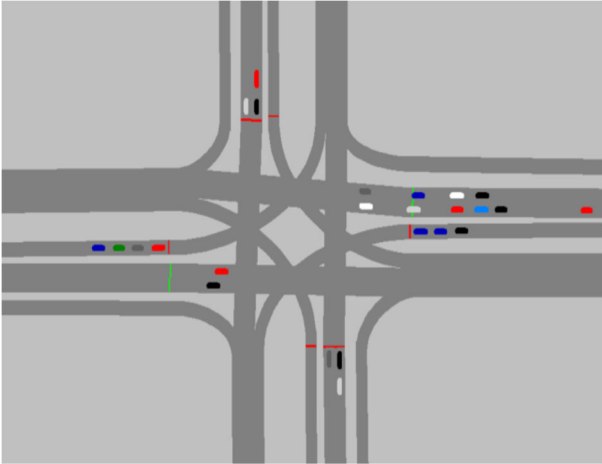


Figure 2. Intersection VISSIM simulation run diagram

The first step is road network mapping, as shown in Figure 3.

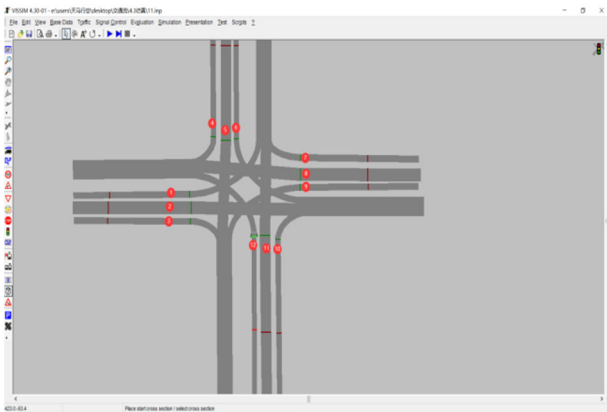


Figure 3. Road network mapping

The second step is to time the input signal, as shown in Figure 4.

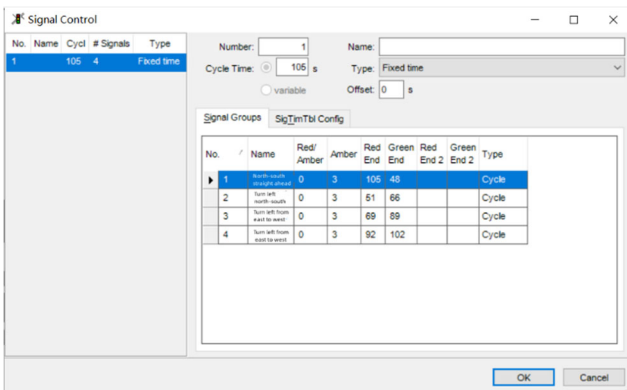


Figure 4. Signal Timing

The third step is to enter the surveyed traffic volume data,

as shown in Figure 5.

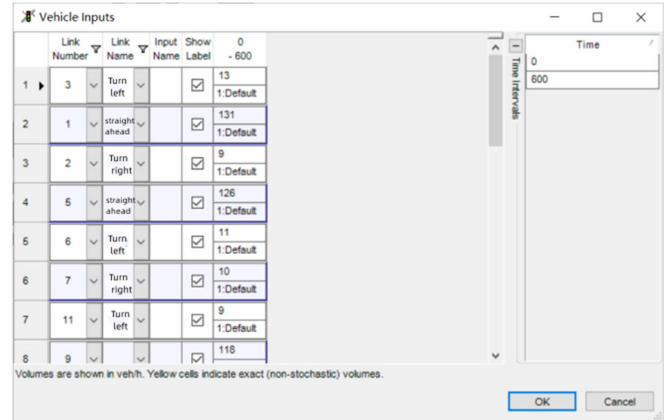


Figure 5. Enter traffic volume data

The fourth step is to output the delay data, as shown in Figure 6.

| Delay | Stopd | Stops | #Veh |
|-------|-------|-------|------|
| | | All | |
| | 2 | 2 | 2 |
| 25.6 | 22.8 | 0.5 | 2 |
| 0 | 0 | 0 | 1 |
| 16.8 | 14 | 0.4 | 5 |
| 30 | 26.5 | 0.6 | 5 |
| 29.8 | 25.1 | 0.83 | 6 |
| 24.4 | 21 | 0.58 | 19 |

| Delay | Stopd | Stops | #Veh |
|-------|-------|-------|------|
| | | All | |
| 5 | 5 | 5 | 5 |
| 44.9 | 40.3 | 0.67 | 3 |
| 5.6 | 3.2 | 0.5 | 2 |
| 19.7 | 17.2 | 0.5 | 6 |
| 0 | 0 | 0 | 1 |
| 13.6 | 12.1 | 0.33 | 3 |
| 20.3 | 17.8 | 0.47 | 15 |

| Delay | Stopd | Stops | #Veh |
|-------|-------|-------|------|
| | | All | |
| 8 | 8 | 8 | 8 |
| 31.4 | 26.6 | 0.83 | 6 |
| 25.1 | 21.7 | 0.67 | 6 |
| 35.8 | 31.4 | 0.8 | 5 |
| 45.5 | 39.2 | 1 | 5 |
| 33.9 | 29.1 | 0.86 | 7 |
| 33.9 | 29.2 | 0.83 | 29 |

| Delay | Stopd | Stops | #Veh |
|-------|-------|-------|------|
| | | All | |
| 11 | 11 | 11 | 11 |
| 52.7 | 48.2 | 1 | 1 |
| 13.4 | 11 | 0.4 | 5 |
| 38 | 32.1 | 1 | 4 |
| 10.7 | 8.2 | 0.5 | 2 |
| 22.8 | 18.5 | 0.71 | 7 |
| 23.8 | 19.9 | 0.68 | 19 |

Figure 6. Output delay data

3. Contrast Analysis

The analysis of the intersection straight lane delay calculation results is shown in Table 7.

Table 7. Straight lane delay calculation results

| Import | Lanes | Point Sample Method /s | tVISSIM/s |
|--------|----------------|------------------------|-----------|
| East | Straight ahead | 30.86 | 33.9 |
| West | Straight ahead | 23.41 | 24.4 |
| South | Straight ahead | 23.63 | 23.8 |
| North | Straight ahead | 31.30 | 20.3 |

Through analysis, it can be seen that the delay data of each entry control obtained by VISSIM simulation has a small difference with the delay of each lane calculated from the point sample method. Only the delay data of the North Entrance Road has a large difference, which may be caused by inaccurate data records. The error is large. Therefore, attention should be paid to the accuracy of data records when collecting data. Moreover, the VISSIM system describes the behavior of traffic subjects in detail, and reflects the actual traffic conditions by setting corresponding parameters, so that the delay data is closer to reality. Therefore, using VISSIM, a traffic simulation software for traffic simulation in practical applications, can provide a detailed and scientific basis for the planning of urban or non-urban traffic network and the comparison and adjustment of planning schemes [3].

4. Insufficient Research

In this paper, only the point sample method and VISSIM simulation software are used for comparative analysis, and only the traffic delays in each direction of the direct lanes are analyzed. The HCM2000 calculation model should be added

again, and the traffic delays of each inlet lane straight ahead and left turn should be calculated by the three model algorithms for comparative analysis, and a graph of the traffic delays of each inlet lane at the intersection should be made, as well as a scatter plot of the measured traffic delays measured by the HCM2000 and the point sample method, so that the relationship between the three can be seen more intuitively and is more conducive to comparative analysis [1]. Moreover, by comparing and analyzing the results of observation and calculation by point sample method with the calculation results of the U.S. HCM2000 delay model and applying the least squares fitting method to modify the model, it is also possible to establish a delay calculation model that is consistent with the traffic delay pattern of this signal intersection.

References

- [1] Yibo Zhang . Research on Vehicle Delay Model for Signal-Controlled Road Intersections [D]. Hunan University, 2011.
- [2] Yupeng Wang. Intersection delay analysis based on VISSIM simulation [J]. China Municipal Engineering,2006(02):85-87+96.
- [3] Chun'e Wang, Qisheng Wu, Baoxiang Jiao, Dongqing Zhong. Comprehensive analysis of traffic delays in traffic management and control course design [J]. Laboratory Research and Exploration,2017,36(05):224-227.
- [4] Jianguo Yang. VISSIM-based comparison of traffic delays at unsignalized roundabouts and signalized intersections [J]. Shanxi Transportation Science and Technology,2021(01):99-102.
- [5] Chenxi Li. Traffic State Evaluation Analysis of Road Network Based on Traffic Delay [D]. Beijing Jiaotong University, 2010.
- [6] Shaokuan Chen, Zhenyi Guo, Xuan Wang, Baohua Mao. A comparison of signal intersection delay calculation methods [J]. Journal of Beijing Jiaotong University,2005(03):77-80.
- [7] Yihu Yao. Yueping Zhao. A comparison of several common methods for signal intersection delay analysis [J]. Journal of Wuhan University of Technology (Transportation Science and Engineering Edition),2009,33(04):687-690.