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Article

Study on traffic efficiency of driver groups at different green light time based on entropy change model

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Abstract: The difference in psychological behavior when drivers cross the road has a certain impact on the efficiency of crossing the road. On the basis of analyzing the subjective and objective factors of drivers, the entropy change model of green light time is established and verified. The model can simply judge the time when the driver faces different traffic lights, so as to effectively calculate the drivers driving speed, analyze the traffic situation, and improve the traffic efficiency.

Keywords: traffic; entropy change principle; driver group; traffic efficiency

1. Introduction

According to the traffic accident statistics of the National Bureau of Statistics of China, intersections are the main nodes of the road network, with frequent traffic conflicts, lack of traffic, illegal driving and improper traffic management [1]. The results show that intersection accidents account for about 50% of the total traffic accidents, and the accident rate is significantly higher than other sections, and most of them are related to cars. According to statistics, due to the increase of road traffic demand, the total number of people dying from traffic accidents every year exceeds 1.2 million, and 20–50 million people are injured or disabled by traffic accidents. Road traffic accidents not only seriously affect peoples lives, but also have a significant impact on economic development. The cumulative annual economic valuation of traffic injury losses is about $20 billion, or about 1% to 3% of the global gross national product [2]. Compared with developed countries, Chinas road traffic safety problem is more serious, so the control and prevention of road traffic safety is an important link in the stable development of Chinas society and economy. Traffic psychology originated from the American professor of psychology Monsonsterbarger in his measurement of the psychological quality of road drivers in 1912 [3]. With the development of transportation, the traffic density on the road gradually increases, and the road traffic accidents also increase increasingly. In order to maintain the safety of road traffic, it is necessary to analyze the root cause of traffic accidents and study the various elements of traffic system construction in detail. However, for a long time, research has focused on vehicles and roads.

The driving situation of vehicles at urban signal intersection is very complex, and the driver's traffic behavior psychology is also very complex, but the existing psychological model of drivers can not cover all the real situation. According to the driver crossing the road, the traffic lights time change of psychological and behavioral factors, according to the principle of entropy change influence model, the

factors affecting the road efficiency, the efficiency of the driver judge the road and order, and according to the confusion constructive suggestions, to ensure the safety of the vehicle cross the road, improve traffic safety.

2. Literature review

Many studies have shown that traffic efficiency is affected by many factors, including the setting of traffic lights, drivers psychological behavior, road conditions and so on. Among them, the change of green light time has a significant impact on the drivers psychological behavior, and then affects the traffic efficiency. For example, drivers tend to pass the intersection smoothly when the green time is long, while when the green time approaches the end, some drivers will choose to accelerate through to avoid waiting for the red light [4]. Traffic light intersection is an inevitable integral part of urban traffic. However, due to the frequent acceleration, deceleration and speed changes at the traffic lights, it greatly affects the efficiency of urban driving [5]. The change in the green time of the signal light will lead to subtle changes in the drivers psychology. Observing driving behavior in specific scenarios and situations is an important tool for traffic research [6]. Felicio et al. [7] Through the investigation of drivers, understand the driver reaction to different traffic lights at the intersection, and the driver reaction to different types of traffic lights (flashing lights, signal lights with countdown timer and signal lights without alarm mechanism). The results show that traffic conditions, road conditions, lighting design, light intensity, and neighborhood relations play a key role in traffic light behavior [8]. The effects of countdown devices on driving behavior, front spacing, and safety level at six intersections (including three with countdown devices and three without countdown devices) were studied. It was found that the countdown device had little effect on the initial delay, but had a significant effect on the forward distance, believing that the countdown device would lead to a higher red light violation rate. Yuan et al. [9] Through the camera data collection and data analysis, the influence of traffic light countdown display on the driver behavior is studied, and the safety problem of traffic light intersection is analyzed by using the countdown display. The results show that the countdown display has a great influence on the drivers decision-making ability. When the countdown display is not used at signal intersections, violation to running red light decreases but start delay increases. Yang et al. [10] A comprehensive summary of the effects of countdown signal intersections on driving behavior, traffic safety and intersection efficiency. The results show that the effectiveness of countdown signal control in China is still controversial, pointing out that the simulation experiment based on driving simulator is very suitable for the study of traffic lights. Liechtenstein [11] Collecting vehicle running data from the intersection method to analyze the driving behavior of these methods resulted in a 10 km/h difference in the average speed between scenes with and without a countdown timer, with higher efficiency in non-countdown scenes.

By understanding how the driver approaches the traffic lights while driving without an auxiliary system, Rittger et al. [12] to assess the impact of driver assistance systems on driver cognitive and mental activity and to determine whether and improve the efficiency of approaching traffic lights. Nygårdhs conducted a study

on cyclists' adaptation to green traffic light countdown timers and found that such timers can influence the behavior of cyclists [13]. Different signal light durations can lead to different psychological environments affecting drivers, which in turn influence their judgment and reactions [14].

Almutteri et al. [15] found that countdown signals increased the acceleration behavior of vehicles approaching intersections as drivers pay more attention to traffic efficiency. Another study found that green countdown signals could limit driver driving behavior and improve traffic efficiency and safety at intersections [16].

3. Factors influencing traffic psychology and behavior at different green light times

3.1. Traffic psychological behavior when crossing the road at different green times

Psychology determines behavior, and behavior is the embodiment of psychology. There is an interaction between human mental activities and adaptive behavior [17]. According to psychological knowledge, we can understand that behavior is a response mechanism of an organism, which includes a series of responsive behaviors and activities. Behavior is different from psychology, but it is closely related to psychology. The occurrence of behavior is often accompanied by a certain motivation, and the stimulation is often through a psychological medium. First, external changes and complex environments will stimulate peoples demand, and the demand will trigger a mechanism to control and trigger behavioral responses. Throughout human behavioral responses, human mental activity is central, dominating, regulating, and controlling human responses.

The storage of cognitive atlas content in the brain may vary, which can be gained through educational knowledge or personal experience. The cognitive process is to judge the current environment based on the recognition of the brain and the comparison with previous stimuli, such as whether it is safe to cross the intersection and whether horizontal driving will threaten the safety of their own vehicles. Exercise sessions will vary by age, gender, and education level. If the drivers brain cognitive map changes in the behavioral responses to driving a vehicle, even the same driver will react differently. For example, if a driver witnessed a traffic accident on the road while driving, his behavioral response after that would be different from that seen prior to witnessing the accident. After witnessing the accident, he will be more cautious on the road. Therefore, various psychological, physiological and behavioral factors, such as perceived distance to intersections, perception of remaining time, understanding of signal light, attention and other control, drive [18] And psychological load [19] , Both affect drivers appropriate decisions at signal intersections.

3.2. Data collection

In order to explore the influence of psychological factors on the efficiency of drivers crossing the river and to ensure the objectivity and requirements of the

sample size, the location and area of the data collection was located at the intersection of Cuiping Street and Huanghe Road, Pingyin, Yushan County, Shandong Province, Jinan, China. This intersection has a signal period of 80 s, 33 s green time, 3 s yellow light and 34 s red light. Data collection time was set from 8 am to 12 am. The traffic flow at the signal intersection is relatively large. In the period of busy traffic, the traffic problem of drivers when crossing the road is more obvious and prominent.

The speed ratio of drivers was obtained by radar speed measurement, the influencing factors of drivers crossing the road were determined by questionnaire survey, and the objective factors of drivers crossing the road were determined by observation and investigation. Photos were recorded of the drivers crossing the road.

3.3. Data analysis of driver groups crossing the streets at different green light times

A survey at the intersection of Cuiping Street and Huanghe Road showed that the traffic light cycle is 80 s, green light for 33 s, green light flashing for 10 s, yellow light for 3 s and red light for 34 s. When the traffic light turns green, the driver waiting at the stop line is it to continue and start crossing the street. The survey found that the peak of vehicles passing through the traffic light cycle appeared within 0–15 s, the number of vehicles decreased sharply between 15 and 20 s, and by 20–30 s, the vehicles had begun to decrease.

Through field data collection, it is found that when the lights start to flash from the green light, drivers who want to cross the road start to increase their speed, and most drivers will turn the traffic light red before crossing the stop line, and then pass through the cross-section. However, quite a number of drivers will choose to slow down and wait for the next green light, thus forcing the vehicles behind not to pass through, although ensuring the traffic safety to a certain extent, but also affecting the traffic efficiency.

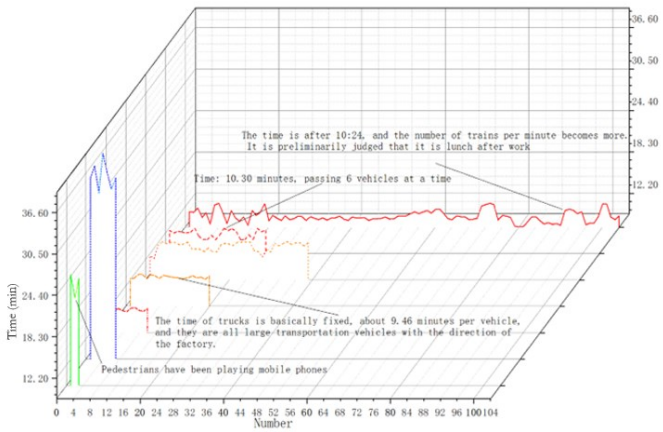

Figure 1. Analysis of the drivers crossing time at the intersection.

As can be seen from **Figure 1**, small vehicles will choose to drive at a normal speed at a long green time, and often will choose to accelerate at a short green time. When faced with longer green times, large vehicles choose to pass at normal speed,

and when faced with shorter green times, they often choose not to accelerate and wait for the next green cycle.

3.4. The internal factors affecting the traffic psychological behavior of driver groups under different green light duration

The internal factors that affect the psychological behavior of drivers crossing the road are mainly bad traffic habits. Mobile psychology is a word often mentioned in daily life. People with fluke mentality believe that when something happens, the probability of safety and danger accounts for 50% in theory, and people with this mentality are more likely to be 100% safe, and subjectively think that dangerous events will not occur [20]. Those lucky ones thought they were not in danger, even if they broke the traffic laws while crossing the road. In the long run, the fluke mind will develop into a psychological collection and behavioral habit.

Most drivers are anxious to green or yellow light even red light after yellow light in the past few seconds think that they are relatively familiar with the intersection to accelerate, in the psychological expectation that the vehicle on another street has passed the crossing has not started. In order to successfully cross the next intersection and pass quickly at this intersection to save traffic time. The impact of bad traffic habits is not significant, because these groups are not easy to blindly follow others. However, large vehicles like box trucks may obstruct the view of the driver following smaller vehicles, making it difficult to accurately determine the type of signal light and can lead to traffic violations.

When drivers deal with unexpected events and rapidly changing environment for a long time in the process of performing driving tasks, their energy is always in a highly concentrated state, which will naturally show positive and moderate tension, and their psychological quality will change significantly. It is in this medium tension state, long-term or long-distance driving, the biggest impact is the physical function and cardiac activity directly related to the driver, leading to physical and psychological disorders. This bad mental state will first make the driver not awake, slow reaction, not concentration, unable to accurately judge and fast processing of various abnormal conditions; second, the limbs pain lazy, yawning, movement accuracy, slow movement, hands and feet do not listen; third, depressed, restless, tired of work, psychological mood is often not in the normal operation state 4. When the driver faces different traffic lights, there will be different psychological fluctuations [21].

In the process of performing the driving task, the drivers psychology is also constantly changing, but in the normal driving process, the drivers psychological change is very little. When encountering the intersection, the drivers heart rate will increase slightly, when the green time is rich, the drivers heart rate will not change significantly, but when the green vehicle passes through the intersection for a short time, the driver will choose to accelerate through the intersection, the drivers heart rate has significant psychological fluctuations.

Chinese traffic laws and regulations require that cars must control their driving speed before entering a horizontal intersection. Generally, vehicles must not cross at a speed of more than 20 km/h. Vehicles shall start slowing down from 50 to 100 m

from the intersection to reach the required speed per hour. When passing the plane intersection with narrow pavement and large blind area, the speed shall be controlled at 5 km/h–10 km/h. When facing different green times and the driver passed through the intersection at different speeds, we tested the speed of the vehicle through the vehicle fixed point, as shown in **Figure 2**.

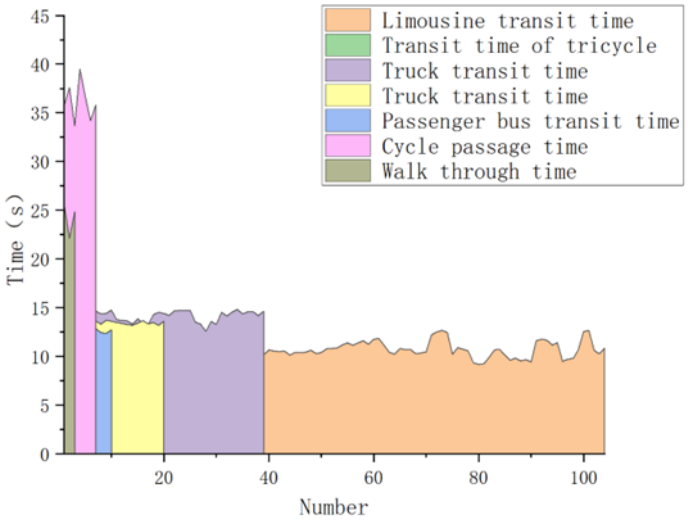

Figure 2. Fixed-point record diagram of the vehicle passing through the traffic signal lights.

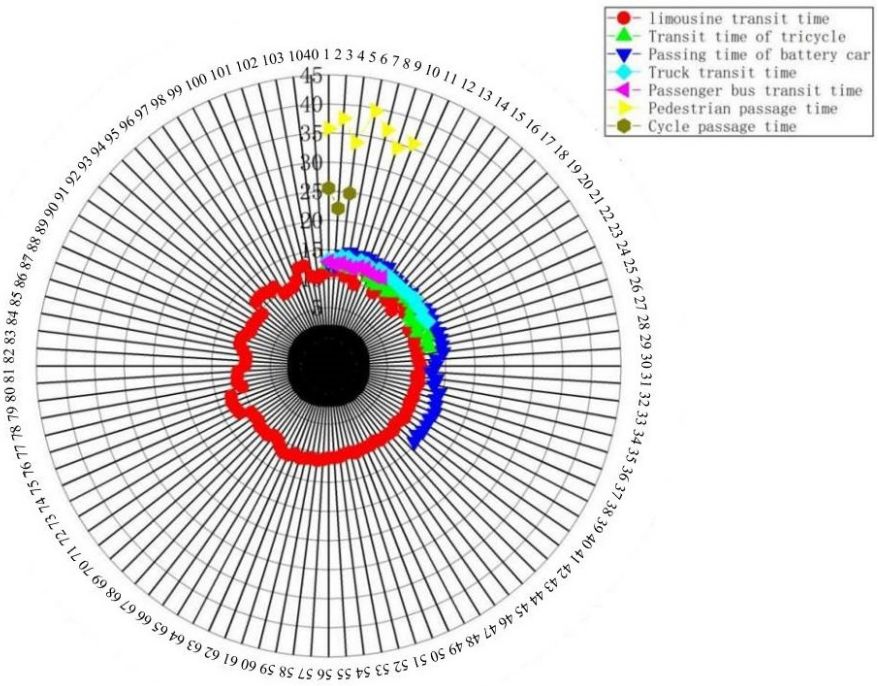

Figure 3. Wind direction rising chart of vehicle traffic time.

Figures 2 and **3** are the intersections of the statistical analysis of the speed chart and time chart, Pingyin County, Jinan, Shandong Province, when the peak traffic flow is from 11 am to 12 am. We can see that the speed of the vehicles passing through this intersection tends to stabilize at the beginning, but there will be

individual vehicles passing through this intersection will be very fast. Combined with the actual observation, due to the reduction of green time, the driving psychology of the vehicle driver has changed. We hope to pass this intersection in this green time period, so we choose to accelerate to reduce the driving time.

3.5. External factors that affect the traffic psychological behavior of driver groups under different green light duration

In daily traffic travel, there are many external factors affecting the psychological behavior of drivers crossing the road: pedestrian signal cycle, road length of the signal intersection, speed and driving direction, number of people crossing the road, passenger behavior and the use of mobile devices [22], These factors can affect the psychological behavior of drivers when crossing the road. By analyzing the psychological behavior of the Doppler radar speedometer. The vehicle speed stipulated in the Code for Planning and Design of Urban Road Traffic in China is 5.56 m/s [23], The intersection length is 18 m, so the crossing time ($t = S/v$) is calculated to be 3.23 seconds. Time t = 3.23 s was used as the critical value for assessing the crossing efficiency, t < 3.23 s indicates overspeed during the crossing, and t > 3.23 s indicates normal driving.

Table 1. Effect of remaining green time on driver crossing efficiency.

	Green time for less than 5 seconds	Green for more than 5 seconds
Speed across the streets (m/s)	9.72	4.16
Time to cross the road (t)	1.85	4.32
Street intersection efficiency	high	high

According to the analysis in **Table 1**, when the remaining green time is less than 5 seconds, the speed of the driver driving the vehicle through the intersection will soar to 30 km/h, and the risk factor will greatly increase. However, when the remaining green time is more than 5 seconds, the speed of the driver passing through the intersection is basically stable to 15 km/h. The expected time of the driver crossing the intersection is shown in **Figure 4**.

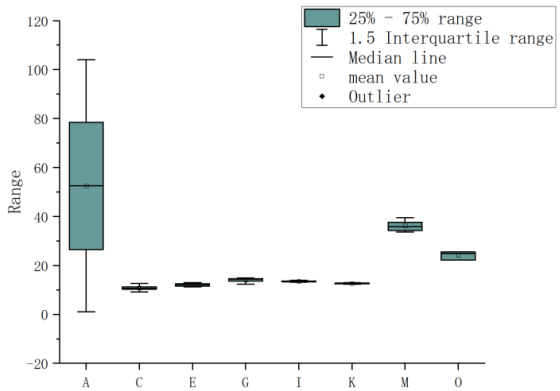

Figure 4. Diagram of the driver's expected time frame.

As can be seen from **Figure 4**, the expected time for the driver to cross the intersection is about 4 s, but during the driving process, due to the limitation of the drivers visual field, when the signal light appears in the drivers field of view, the rest time of the green light will affect the psychological expectation of the driver crossing the intersection. When the remaining time of the green light is less than 5 s, the psychological expected time for the driver to cross the intersection is reduced to 2 s. Accordingly, when the remaining time of the green light is sufficient, the psychological expectation time of the driver passing through the intersection is generally stable at about 4 s.

4. Establishment and validation of the model of entropy of drivers facing the change of green light duration

4.1. Model construction

Entropy is one of the parameters that describe the state of matter in thermodynamics. It was proposed by the German physicist Rudolf Clausius in 1865. It is used to represent the uniform distribution of any type of energy in space, indicated by the letter s. The more uniform the energy distribution, the greater the entropy, and vice versa. And the entropy of the system reaches a maximum when the energy system is uniformly distributed. Definition of entropy in thermodynamics:

$$dS = \frac{dQ}{T} \tag{1}$$

The dQ is a lot of heat flow, the cause is heat, and T is a strong measure of heat.

The driver population cross system is an open system characterized by dissipative structure. According to the dissipative structure theory, the system entropy can be used to judge the change of order in the open system. If we want to investigate the drivers behavior system driving a vehicle across the street, the efficiency of driver groups crossing the street can be defined as a generalized force, and the number of driver groups crossing the street system can be defined as a generalized stream. Therefore, the form of the system entropy across the streets proposed in this study is as follows: ηdN

$$dS = \frac{dN}{\eta} \tag{2}$$

Using the intersection model established by Wang et al. as the entropy model of the traffic system of the expressway service lane, we can deduce the actual incremental traffic pressure (P) of the driver group at the intersection and the increment (kx) in the face of different time increment.

$$d_i S = S - S_0 = \int_x \int_{uf}^{u} \int_0^k kx \left[p + \left(q + \frac{q_x}{\tau} \right) (u_0 - u) + q_x u \right] dk du dx \tag{3}$$

The above formula represents a modified model of entropy generation in the system where the driver population crosses the street.

The results can be calculated by substituting the entropy value and traffic pressure into the formula.$S_0 p$

$$S = \int_x kx\left[\left(q + \frac{q_x}{\tau}\right)(u_0 - u) + q_x u\right]dx \tag{4}$$

In everyday life, the goal of a system of drivers moving through the street is to achieve order, which would mean reduced entropy. At the same time, we want to maximize the traffic flow in the car lanes to ensure that the system operates with its best performance, rather than simply minimizing the entropy values. Therefore, an entropy flow model was established.

$$S' = \int xq_x \times [p + (q + \frac{q_x}{\tau})(u_0 - u) + q_x u]dx \tag{5}$$

When the systems entry entropy flow $S < 0$, the model is a negative entropy flow model.

The state most consistent with the drivers traffic psychological expectation is assumed as the reference state, where and the entropy value is. At that time, a negative entropy flow was needed to reduce the entropy value to. In this state, the system of drivers crossing the street can reach a certain degree of order or the best working conditions. The negative entropy flow to be introduced is: $u = u_m k = k_m S_m S > S_m S_m$

$$S' = S - S_m \tag{6}$$

At this point, the total entropy on the motor lane is:

$$S = \int_x kx\left[p + \left(q + \frac{q_x}{\tau}\right)(u_0 - u) + q_x u\right]dx + \int_x q_x\left[p + \left(q + \frac{q_x}{\tau}\right)(u_0 - u) + q_x u\right]d \tag{7}$$

After integration, the results are:

$$S = \int x[kx + q_x] \times [p + (q + \frac{q_x}{\tau})\,(u_0 - u) + q_x u]dx \tag{8}$$

4.2. Validation of the model of entropy across streets at different green times

4.2.1. Identification of the threshold value

The size of the state recognition entropy value can be used as the basis to judge the operation quality of the driver population crossover system. Here, a state-discrimination model can be introduced [24]:

$$\bar{S} = \frac{10(u_f - u)k}{k_j u_f} \tag{9}$$

The formula for solving the blockage density is: K_j

$$k_j = 2k \tag{10}$$

According to the standard of driver traffic service level, the service level cannot be directly reflected. If you want digital discrimination, it is very important to

determine the threshold. The critical state is a special state that infuses negative entropy into the system to distinguish between chaotic or ordered systems. The value of this state is treated as a fixed value, while the values of the other states fluctuate.

4.2.2. Evaluation index of the traffic status of the drivers crossing the streets

When faced with different green lights, the drivers mentality changes, and their physical behavior is a further change in speed control.

Table 2. Average cross indicators for drivers facing different remaining green time.

running state	express	Average road-crossing time (s)
A	When the remaining green light time is less than 5 seconds	2.32
B	When the remaining green light time exceeds 5 seconds	4.57

Table 2 shows that the driver-selected crossing speed varies when the remaining green time is less than 5 s. When the remaining green time is less than 5 s, the average driver crossing time is 2.32 s. When the remaining green time is greater than 5 s, the average driver crossing time is 4.57 s. According to the comparison, when the green light rest time is less than 5 s, the average crossing time of the vehicle through the intersection is less than when the green light rest time is more than 5 s. The reason is that the drivers mindset will change in the face of different green lights left. When there is more time left, drivers tend to stay calm and choose normally driving vehicles to cross the intersection. However, the drivers mind changes when the remaining time of the green light is less than 5 s, which is usually manifested by accelerating through the intersection during the remaining green light time.

4.2.3. Results analysis

In daily life, when crossing the intersection, the corresponding entropy value can be calculated based on the measured average velocity of the driver population. By comparing this entropy value to the discriminative entropy, if, the remaining green light time is short. In this case, with increased speed of vehicles driven by the driver group, or increased probability of danger, traffic control should be enhanced. If this situation occurs frequently, the traffic police should be added to manually guide the traffic to ensure the safety of the drivers crossing the road and reduce the traffic pressure. If the remaining green light time exceeds 5 s, the crossing speed of the vehicle is normal and the safety is high, and the crossing behavior of the driver group is not required.$S < \bar{S}S > \bar{S}$.

5. Conclusion

This study is based on the statistical data and analysis of motor vehicle traffic accidents. In order to reduce the motor vehicle traffic matter

Therefore, the incidence rate, as far as possible to ensure the safety of people, this paper through the analysis of the analysis may affect the drivers road psychology

Factors, using the entropy change principle to establish the influence model and the test model. The conclusions of this article are summarized as follows:

(1) The change of intersection signal time is the impact on the intersection safety and traffic efficiency, and the impact on the drivers psychology and behavior. Existing research generally starts with intersections with no countdown lights and intersections with countdown lights, or starts with signal lights of different phases or colors, or combines multiple research contents to study and analyze the next possible traffic behaviors.

(2) Through the investigation and analysis, the conclusion is that the change of the psychological expectation of the green light through the intersection with traffic lights.

(3) The driver group crossing street system is similar to thermodynamics, and the entropy change model of the driver group crossing street is obtained by fluid dynamics. The model can effectively analyze the drivers facing the traffic lights in different time periods, and then judge the possible driving speed of the vehicle, thus solving the traffic congestion and traffic safety problems to a certain extent.

(4) In this study, the principle of entropy change is adopted to establish a model affecting the traffic psychological behavior of drivers, which is the traffic center.

Science and traffic engineering offer new theoretical perspectives. Meanwhile, the model can effectively analyze different time periods.

The behavior of the driver facing the traffic light, and then judge the possible speed of the vehicle, to solve the traffic congestion.

Traffic congestion and traffic safety problems provide a scientific basis. Further optimize the entropy change model to improve its accuracy Sex and applicability.

Despite the certain achievements of this study, there are still some limitations:

(1) Simplification of model assumptions: in the establishment of entropy change model, in order to simplify the calculation and analysis, the complex factors such as drivers traffic psychological expectation are simplified and assumed. This simplification may lead to the failure of the model to fully accurately reflect the actual situation, and future research needs to further refine the model to more accurately describe the traffic psychological behavior of drivers.

(2) Insufficient consideration of external factors: This study mainly focuses on the influence of green light time changes on drivers psychological behavior, but ignores the comprehensive impact of other external factors (such as weather, road conditions, traffic flow, etc.) on driver behavior. Future studies need to consider multiple factors to analyze drivers traffic behavior more comprehensively [25].

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