Optimization Design of Traffic Marking in Urban CBD Area

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Abstract: With the increasing proportion of motorized traffic in urban transportation, the conflict between slow traffic and motorized traffic has become more and more serious, which is especially prominent in urban CBD area. This paper proposes the solution to the three-dimensional optimization of the deceleration marking and the guidance marking, innovatively puts forward using CAD 3D modeling to design the shape and dimension of traffic markings. By analyzing the human visual perception and visual illusion principle, the design method and basis of the three-dimensional marking are gradually obtained. Three-dimensional marking was applied in Nanjing, Jiangsu Province. The practice shows that three-dimensional marking has been significantly improved in reducing vehicle speed and the degree of deviation, which can ensure the safety and order of traffic in CBD area.

1 INTRODUCTION

Road traffic safety is a worldwide problem, and researches on traffic accidents have been paid more and more attention by the government recently. As the core of one city, CBD area has high density of humans and vehicles. Although the speed of vehicles is not too fast in CBD area, for the deceleration zone with intertwined traffic flow, a speed of 40 km/h is high enough to threaten pedestrians. At the same time, intertwined vehicles are also prone to traffic accidents, and one accident may bring congestions to the entire CBD area.

Due to land shortages in urban CBD area, some necessary management facilities have to be replaced by traffic marking. However, some of the marking did not play a good role. Because the right of way for pedestrians was ignored, the crosswalk line, originally considered to be the "secure line", has become a kind of "dead line". On roads without supervision, vehicles pass through the guidance marking arbitrarily, which is easy to cause traffic disorder. In addition, the noise problem caused by the uplift deceleration belt is more and more concerned by the public, so researches on the three-dimensional marking based on driver's psychological effect began to rise.

Through the study of road visual illusion and human visual illusion, this paper finds out the scientific and rational design method of three-dimensional marking. The research team also carried out three-dimensional optimization design for the existing traffic marking in CBD area in order to improve the ban, warning and indication effect of the marking, and to promote the harmonious development of the road transportation in CBD area.

2 DESIGN PRINCIPLES

2.1 Design Ideas

The main idea of this research is that the traffic marking is designed into a seemingly 3D shape based on the analysis of human visual perception and visual illusion. The three-dimensional marking can attract driver's attention easily using the illusion of obstacles, so as to optimize the deceleration or guidance effect of the traffic marking. However, the nature of traffic marking is the two-dimensional graphics set on the road, therefore, in order to make the traffic marking simulate the 3D effect better, the research needs to start from the driver's perspective, making the three-dimensional graphics plane in order to obtain the shape and dimension of the traffic marking.

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2.2 Design Methods

2.2.1 Simulation of CAD Software

Open the 3D modeling window in AutoCAD software and some feature parameters need to be determined in the model firstly. As shown in Figure 1, the simulation of obstacles in front of the driver requires three parameters, respectively:

A: The horizontal distance between the driver and the front of road obstacle;

B: The dimensions of the road obstacle;

C: The vertical distance between the driver's line of sight and the obstacle.

The horizontal distance between the driver and the front of road obstacle shall not be less than the safe braking distance of the vehicle, that is,

$$A \geq S = V_i \times t + \frac{V_i^2 - V_f^2}{2a} \tag{1}$$

Where S refers to the safety braking distance, V_i refers to the initial velocity (the speed before braking), t refers to the brake reaction time, V_f refers to the final velocity (safety speed), and a refers to the deceleration of the vehicle. The dimensions of the road obstacle should be selected in conjunction with the shape of the existing marking and the width of the road. The vertical distance between the driver's line of sight and the obstacle can be taken in accordance with the relevant national standards. After selecting these parameters, shapes of the obstacle saw by the driver can be got by using camera preview functions in the CAD software.

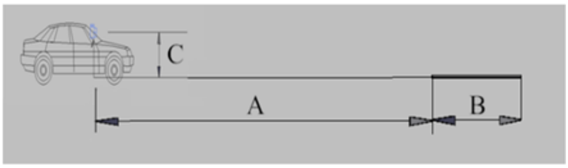

Figure 1 Simulation of road scene using CAD software.

2.2.2 Design of Marking Colors

Previous researches show that visual perception provides about 80% of traffic information to the driver, thus, visual perception is the most important way for drivers to obtain outside information. Colorfulness is one of the advantages of the three-dimensional marking because people's feeling for color is rapid and lasting. For three-dimensional marking, the combination of colors should be considered to make the overall effect better. Based on the hue circle and the national standard of road traffic sign and marking (GB-5768), and taking into account the color matching effect of pavement and marking, this research ultimately determines that the color combinations of the three dimensional marking are white, blue and yellow, and the specific color scheme is determined by the shape of the marking.

3 RESEARCH CONTENTS

3.1 Investigation of CBD Traffic

Taking Xinjiekou, the CBD area of Nanjing, as an example, the research team investigated the current traffic organization in the CBD area and analyzed the traffic organization problems according to the survey data.

One investigation was conducted at an unsignalized intersection in Zhongshan Road, Xinjiekou area. The research team captured video to record the situation of pedestrian crossing the street, and used the handheld radar tachometer to record the speed of vehicle through the crosswalk line. According to statistical analysis, in the surveyed 165 motor vehicles, 72.1% of the vehicles have safety speed which is below 30 km/h, but there are still 27.9% of the vehicles can reach the speed near 40 km/h or even higher.

Another investigation was conducted at the intersection of Zhongshan Road and Dashiqiao Street in Xinjiekou area, and there are guidance markings for traffic channelization on the main road. During the survey, it was found that when going straight on the main road and turning right on the secondary road were allowed at the same time, vehicles will pass through the guidance marking arbitrarily, there will be obvious traffic conflicts in the diversion island so that influence the smooth operation of the entire intersection.

In view of the above problems, this paper proposes to realize the optimization of traffic organization by using three-dimensional marking. After the transformation, the three-dimensional marking can achieve two optimization effects: deceleration and guidance.

3.2 Design of Deceleration Marking

3.2.1 The Horizontal Distance between the Driver and the Traffic Marking

Firstly, determine the brake reaction time. It includes the response time of both the driver and the vehicle.

According to the results of previous studies, the brake reaction time is about 0.5-0.6 seconds under normal circumstances. Thus, in this paper, the value of brake response time *t* is 0.5 s.

Secondly, determine the brake deceleration. For ordinary passengers in the vehicle, when the brake deceleration is less than 1.8 m/s^2, people's feeling is not so significant; when the deceleration reaches 3.6 m/s^2, the feeling of people is obvious. Thus, in this paper, the value of brake deceleration a is 1.8 m/s^2.

Finally, determine the initial and final velocity of the vehicle. It is considered to be high speed when vehicles can reach the speed of 40 km/h in CBD area, and relevant statistics show that when the collision speed is 30 km/h, the pedestrian mortality rate is less than 5%, but when the collision speed is 40 km/h, the rate is up to 45%. Thus, in this paper, the value of the initial velocity V_i is 40 km/h, and the value of the final velocity V_f is 30 km/h.

Substitute the above parameters into the formula 1, the safety braking distance S equals to 20.56 m. Considering that there is still some distance between the driver's position and the front of the vehicle, the value of the horizontal distance between the driver and the traffic marking *A* is 22 m.

3.2.2 The Physical Shape and Dimensions of the Obstacle

Firstly, select shape of the obstacle. Relevant data indicate that the visual impact of the prism to human eyes is relatively moderate. The three-dimensional entity of triangular prism can properly create a reasonable sense of slope on the road, so that the three-dimensional effect of the marking simulation is more real. Thus the three-dimensional entity used in the simulation is triangular prism.

Secondly, when determining the cross-sectional dimensions of the obstacle, the compatibility with road width needs to be considered. Generally, the width of a single lane is 3.5 m, and the average width of vehicles is 2.5 m. In order to ensure that the distance between the designed markings is not less than the vehicle width, the distance between the edge of designed marking and the road edge should be 0.5 m. At the same time, considering that setting up two three-dimensional markings on the same cross-section of each lane can uniformly fill the entire width of the pavement. Thus the width of the three-dimensional marking is 1.0 m.

Finally, determine the projective length of the obstacle. In the national standard GB-5768, the spacing distance between most of the deceleration markings is in the range of 5 to 20 meters. Taking into account the cross-sectional dimension, choose 5 m as the projective length of the three-dimensional marking, that is, the value of the road obstacle dimension *B* is 5 m.

3.2.3 The Vertical Distance between the Driver's Line of Sight and the Obstacle

According to the national standards, the height of driver's eye in vehicle is 1.2 m, that is, the value of vertical distance between the driver's line of sight and the obstacle *C* is 1.2 m.

3.2.4 Simulation Results

The parameters *A* (22 m), *B* (5 m) and *C* (1.2 m) are input to the simulation scene (Figure 1). The projective pattern observed from the camera's perspective is captured, and the geometric dimensions are plotted in the software to complete the dimension design. Combined with the study of colors, the final design of the deceleration marking is shown in Figure 2.

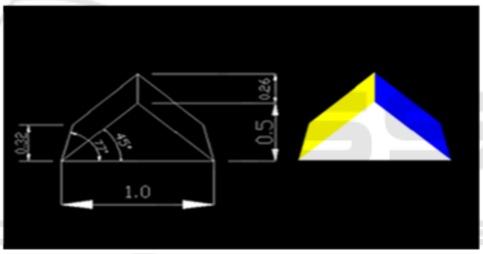

Figure 2 Deceleration marking design results.

3.3 Design of Guidance Marking

The prototype of the three-dimensional guidance marking is derived from the diamond longitudinal deceleration marking, and the design method is similar to that of the deceleration marking in section 3.2. In order to enhance the guidance function of the marking, sweep the diamond plane alone the oblique direction in AutoCAD software, and select the sweeping result oblique hexahedron as the three-dimensional entity. The specific design of the guidance marking is as follows (details similar with the deceleration marking are not repeated here):

3.3.1 The Dimensions of the Obstacle

According to the relevant regulations in the national standard GB5768, the length of road longitudinal deceleration marking should be 100 cm, which is the same with the length of three-dimensional guidance marking. In order to avoid too much pressure for the driver in the process of driving, the width of three-dimensional marking is set to 32.5 cm. The road width is more than 3.1 m after subtracting the marking width, which still belongs to the driver's acceptable range.

3.3.2 Simulation Results

Considering the requirement of convenient construction, the perspective projection is simply optimized to remove the small angle change caused by the sight distance. The optimized result is the final design result of the three-dimensional guidance marking which is shown in Figure 3.

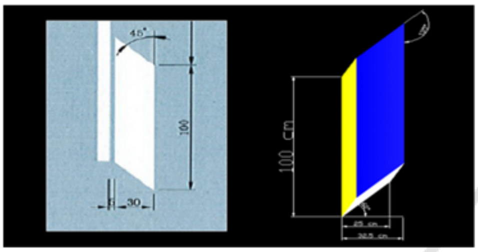

Figure 3 Guidance marking design results.

4 EXPERIMENT VERIFICATION

The research team set up two kinds of three-dimensional markings in Southeast University Jiulonghu campus and carried out two sets of experiments to test the deceleration and guidance effect of the three-dimensional markings in practical application. The speed change rate on the straight and the deviation of the trajectory on the curve were selected as the evaluation index in the experiments.

4.1 Deceleration Marking Verification

The experimental verification of the deceleration marking is located on the straight and consists of two groups of experiments, which belongs to the comparison experiment. The difference between the two groups is only in the way laying the same deceleration marking on the road, forward and reverse. The effect of layouts is shown in Figure 4.

Figure 4 Forward and reverse layouts.

In order to make the experimental results more universal, a total of 10 drivers participated in the experiment. When the test driver drove through the experimental section, the other two team members respectively measured the speed of the vehicle into and out of the experimental section with hand-held radar tachometer. A total of 20 sets of data were measured to calculate the speed change rate, the changes of vehicle speed are shown in Table 1.

Table 1 Speed change of vehicles passing through experimental sections.

ID	Forward Layouts			Reverse Layouts		
	V_i (km/h)	V_f (km/h)	Speed Change Rate (%)	V_i (km/h)	V_f (km/h)	Speed Change Rate (%)
1	21	14	33.3%	20	15	25.0%
2	30	19	36.7%	35	27	22.9%
3	35	26	25.7%	39	30	23.1%
4	37	25	32.4%	40	33	17.5%
5	38	28	26.3%	40	34	15.0%
6	42	33	21.4%	42	36	14.3%
7	45	36	20.0%	44	36	18.2%
8	50	30	40.0%	50	42	16.0%
9	58	40	31.0%	53	40	24.5%
10	61	46	24.6%	58	46	20.7%
Ave	41.7	29.7	29.2%	42.1	33.9	19.7%

It can be seen from the above table that the actual deceleration effect of the forward layouts (29.15%) is significantly better than that of the reverse layouts (19.71%). After vehicles passing through the deceleration marking in forward layouts, the average speed can be controlled below the safe speed at 30 km/h. Therefore we can draw a conclusion that the three-dimensional deceleration marking can achieve good deceleration effect in the practical application.

4.2 Guidance Marking Verification

The experimental verification of the guidance marking is located on the curve and consists of two groups of experiments, which belongs to the control experiment. There were no any treatments to the curve in the control group, but guidance marking was laid on the curve in the experimental group. The effect of layouts in experimental group is shown in Figure 5.

Figure 5 Guidance marking layouts.

Before the start of the experiment, take off the model aircraft near the experimental areas, and set the model aircraft hovering automatically above the experimental section to begin the observation mission. When participants drove through the experimental section, it was recorded by the camera. Latter using video processing software to extract the vehicle trajectory through the curve with or without the guidance marking respectively, and to compare the deviation of the trajectory when vehicles passing through the curve.

After the technical processing, the trajectory of vehicles passing through the curve is shown in Figure 6.

Figure 6 Comparison graphs of vehicles' trajectory.

It can be seen from the figure that the trajectory of the vehicle passing through the curve in the case without the guidance marking is closer to the edge of the road than the trajectory in the case with the guidance marking, and the guidance marking plays a role in reducing the lateral deviation of the vehicle on the curve. By contrast we can draw a conclusion that the three-dimensional guidance marking can achieve good guidance effect in the practical application.

5 CONCLUSION

In this paper, through the analysis of human visual perception and visual illusion principle, designing method and basis of three-dimensional marking are gradually got. This paper aims to make up for the lack of research on three-dimensional marking, so as to form the research system for three-dimensional marking. Finally the design of the three-dimensional marking applicable to different road conditions can be used directly for the traffic departments. The research results are summarized as follows:

First, this paper presents a scientific method to design three-dimensional marking, which can achieve good visual illusion of obstacles, and gives a detailed design scheme of three-dimensional deceleration and guidance markings;

Second, the three-dimensional guidance marking designed in this paper can be used to reduce the lateral deviation of the vehicle, and the deceleration marking can be optimized by analogy to make it have a three-dimensional effect;

Last, this paper makes three-dimensional optimization design to some traffic markings in urban CBD area, which can solve some problems existing in reality and improve safety and order for traffic in CBD area.

Reasonable traffic organization is particularly important for the urban CBD area with shortages of land and high traffic flow. The three-dimensional marking proposed by this paper can adapt well to the traffic characteristics of the CBD area, and solve some traffic problems. What's more, the three-dimensional marking with low cost and obvious effect, is suitable for promotion in urban CBD area to ensure the safety and order of the CBD area. For urban CBD area, the three-dimensional marking will have very broad prospects for development!

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