Research on Visual Quality Evaluation Method of Tourist Highway Based on Virtual Driving

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Abstract. This paper studies the visual quality evaluation method along the tourist highway from the driver's first perspective, selects five evaluation indexes from the aspects of driver's driving reaction and physiological reaction, and establishes a "man-vehicle-road" visual quality evaluation method model of tourist highway. Through BIM + VR technology, the tourist highway scene is built for virtual driving experience and evaluation, and different landscape design schemes and dynamic effects of tourist highway are reproduced virtually. Combined with questionnaire survey and physiological data feedback, the tourist highway landscape is evaluated qualitatively and quantitatively, and a qualitative and quantitative evaluation method for the visual quality of tourist highway is put forward. It provides decision-making basis for local relevant departments to carry out landscape design quality evaluation along tourist highways, and realizes high-quality development of tourist highways.

1.Introduction

With the rapid development of highway transportation and the enhancement of people's awareness of environmental protection and aesthetics, people have higher and higher requirements for highway transportation, which not only requires it to be safe, convenient and economical, but also requires it to provide more comfortable driving experience and good highway landscape, giving people spiritual pleasure. Excellent highway landscape can make drivers get a good journey experience, enhance the pleasure and excitement of drivers and passengers, and increase the pleasure of the journey. At the same time, unreasonable highway landscape will also affect the driving experience and driving safety of drivers and passengers.

At present, the depth and speed of highway landscape research in China can't keep up with the development level of highway construction, and most of the understanding of highway landscape still stays at the level of "highway greening". In practice, highway landscape is often limited to simple tree planting and grass planting, and only puts forward landscape design requirements for some important positions. In the research of highway landscape evaluation, qualitative research is more and quantitative research is less. Quantitative research mostly relies on experts to assign professional values to indicators, ignoring the real feelings of road users. Based on the new generation of information technology and physiological sensors to carry out highway landscape visual quality evaluation research is also less. In the practice of highway landscape design, more rely on the personal preference of project owners and designers, lack of systematic and rational highway landscape design methods.

Therefore, taking the driver's feeling as the starting point, using the new generation information technology (BIM, VR, etc.), questionnaire survey and physiological sensors, it is necessary to study the evaluation method of highway landscape visual quality in the form of qualitative and quantitative combination, so as to improve the highway landscape quality.

The research on landscape design and evaluation in foreign countries started earlier, and the related research is also abundant. Many scholars have pointed out that highway landscape design has an impact on driving safety. And verified in the experiment that the environment on both sides of the road will directly affect the driver's visual judgment; TOPP[1] pointed out in the research that the central landscape belt and vegetation on both sides of the road can relieve drivers' mood, effectively improve road driving safety and play a positive role in traffic order. K. F. Akbar[2] used interviews and questionnaires to investigate the aesthetic degree of vegetation landscape on highways in northern England. Gary R. Clay[3] compares and evaluates the aesthetic degree of several highway landscapes from the perspective of psychophysics, and puts forward effective measures to improve the aesthetic degree of highway landscapes. In recent years, information technologies such as BIM[4-6], GIS[7], GPS have also been widely applied in highway construction, landscape design, and evaluation, and have achieved tremendous results.

Until 1980s, the highway departments in China paid attention to the evaluation of highway landscape environmental impact. In 1998, the Ministry of

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Communications promulgated "Highway Environmental Protection Design Code", which promoted road landscape design and environmental protection. In addition, many scholars have used different mathematical methods or psychological theory to study the landscape evaluation in the construction of highway landscape evaluation model. Wu Hongtao[8] discussed the fuzzy comprehensive evaluation method of landscape, including the establishment of indicators, the establishment of weights and the evaluation process; Adopt fuzzy mathematics method to establish corresponding mathematical evaluation model, which can be used to evaluate highway landscape environment; Du Zhiming[9] put forward the corresponding landscape evaluation index system by using the multi-level fuzzy comprehensive evaluation method of analytic hierarchy process[10], which is used for highway landscape evaluation[11];Wei Zhonghua et al.[12] used chromatics and psychology to study the influence of highway landscape design on drivers'[13] physiological and psychological fatigue. Wang Jianjun et al.[14] analyzed the highway landscape[15] based on the driver's visual psychology, and studied it from the perspective of drivers and passengers.

In the analysis of the highway landscape perception and evaluation at home and abroad using questionnaire, fuzzy comprehensive evaluation, analytic hierarchy process, psychological theory and other methods for landscape evaluation research has achieved good results, but relatively lack of driver-passenger first perspective, collection of vehicle movement indicators, driver physiological indicators and subjective questionnaire survey to evaluate the visual quality of highway landscape. To solve this problem, this paper focuses on BIM modeling of landscape highway scene, realism optimization, interactive perception, architecture and function design of virtual roaming system of highway landscape scene, and construction of virtual reality interactive perception hardware experimental platform based on driving simulator, and studies the visual quality evaluation of tourist highway in a "people-oriented" immersive way from the driver's perspective.

2.Visual Quality Evaluation Method and Evaluation Index for Tourism Highways Based on Virtual

Through the experimental data and questionnaire survey results, using visual psychology, environmental psychology, driving behavior theory, analysis of data indicators and landscape types of internal relations. According to the current situation of highway landscape visual evaluation in China, the safety and pleasure of highway landscape are taken as the evaluation criteria. According to the construction principle of evaluation index, the evaluation index of each target layer in the evaluation system is screened and analyzed, and the weight proportion of each index is determined by analytic hierarchy process, so as to build a reasonable comprehensive evaluation system of highway landscape. Carry out landscape type investigation and feature analysis along the highway, use BIM modeling, realistic processing and other technologies to build realistic virtual highway landscape, and further use virtual driving technology to develop highway landscape perception and evaluation system, so as to build an experimental platform of software and hardware, carry out research on comprehensive evaluation methods of qualitative and quantitative analysis of highway landscape quality, and provide landscape quality evaluation means for decision makers. Research technology roadmap as shown in Figure 1.

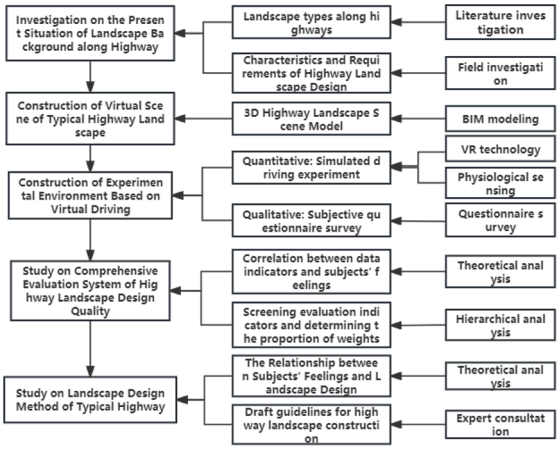

Fig. 1. Research Technology Roadmap.

Through the data collected from the experiment and the results of questionnaire survey, using visual psychology, environmental psychology, driving behavior and other theories, this paper analyzes the internal relationship between data indicators and landscape types, establishes the relationship between data indicators and people's feelings, and forms corresponding laws. Aiming at the problems of highway landscape in our country, this paper evaluates the typical highway landscape in the experiment, and takes the driver's driving safety and pleasure requirements as the reference layer of screening evaluation indexes. From the aspects of driver's driving reaction and physiological reaction, five indexes, acceleration and deceleration amplitude, steering wheel steering angle, heart rate change amplitude, skin electricity change amplitude and pressure change amplitude, are selected as visual evaluation indexes of highway landscape, reflecting drivers' attention concentration degree, acceleration behavior and physiological changes.

3.Development of BIM Modeling and Index Evaluation System

Based on the obtained highway design data, BIM modeling of highway is carried out by using Autodesk Revit modeling tool, and the highway foundation scene with accurate structure is obtained. In the virtual scene, we can build multi-element model of highway landscape design, such as central isolation belt, sound barrier, green belt on both sides of highway, etc., and complete the construction of three-dimensional interactive scene of highway landscape virtual simulation.In order to

restore the highway landscape scene as much as possible, the model needs high-quality rendering to meet the visual requirements of various experiments in virtual scenes, so it is necessary to process the highway engineering model realistically. Compared with the real highway environment, add materials, textures, trees, surrounding vegetation and other elements to the model to form a realistic virtual highway scene. According to the effect to be presented in the real scene, the overall layout of the scene is illuminated, so as to enhance the overall realism of the model, and then achieve the effect of real scene in the scene simulation.

The interactive roaming system of virtual driving highway landscape is mainly based on BIM modeling technology and virtual reality technology of Unreal Engine graphics engine. It is connected with driving simulator, triple screen and other hardware to build a virtual interactive roaming system of highway landscape, so that people can be immersed in the virtual highway landscape scene and better carry out related research on highway landscape quality evaluation. The system includes virtual driving, autonomous roaming, questionnaire filling, weather system simulation, physiological data collection and other functions, and realizes highway landscape analysis and evaluation under virtual and real interactive scenes. The overall framework design of the system is shown in Figure 2.

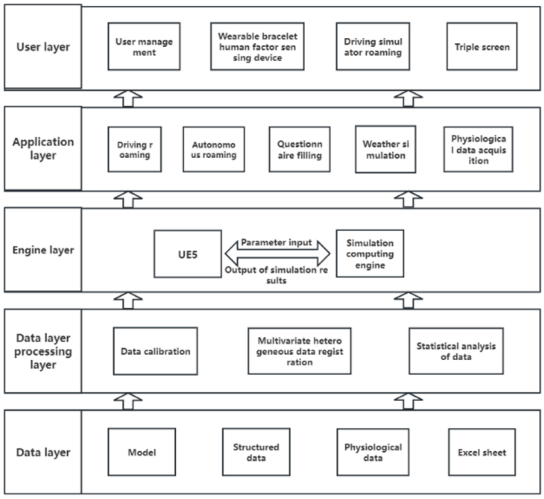

Fig. 2. Design drawing of overall system framework.

Hardware such as driving simulator, steering wheel, throttle, brake, gear lever and triple screen are used as interactive peripherals to realize the interaction between highway scene roaming and nature. Combined with virtual driving simulation technology, a virtual driving system for highway landscape design evaluation is built, so that the experiencer can immerse himself in the virtual driving environment. In operation, the real steering wheel is replaced by a simulated driver to meet the basic operation required by driving, thus generating the driving feeling of real vehicles. Connecting typical landscape scenes with drivers' cognition and perception. Basic driving data such as driving speed and steering angle are obtained during the experiment. The scene supports multiple groups of different highway landscapes, virtual driving perception and evaluation analysis under different time periods, different weather conditions and different visibility conditions, and provides a "people-oriented" landscape design evaluation experimental platform. Human factor perception and calculation equipment with wearable bracelet can be selected to obtain physiological data such as heart rate, skin electricity and pressure of drivers in real time. These feedback data are the key data support for human factors research, so wearable bracelets can help synchronously collect and analyze physiological data of subjects, and provide strong support for qualitative evaluation of highway landscape visual quality.

4.Experiment and discussion

After completing the experiment of quantitative evaluation of driving reaction and physiological index data, each subject should complete subjective qualitative questionnaire survey, which focuses on the safety, comfort and aesthetics of landscape elements. Statistical analysis of the questionnaire results, combined with the analysis of heart rate, skin electricity and pressure physiological data of the subjects, quantitative evaluation of cardiac sympathetic nerve tension and uniformity of the subjects can reflect their heart excitement, emotion, fatigue, cognitive load and other states. Through the combination of qualitative and quantitative methods to judge whether the subjective feelings of the tested drivers are consistent with the changes of physiological indicators.

4.1.Construction of experimental environment

Experimental equipment: Logitech simulated driver, human factor perception and computing equipment of wearable bracelet and triple ring screen are selected for experimental platform integration. As an interactive peripheral, the simulated driver realizes roaming and natural interaction in highway scene. The simulated driver includes steering wheel, throttle, brake, gear and other components. Wearable bracelet can obtain physiological data such as heart rate, skin electricity and pressure of drivers in real time.

Subjects: Ten drivers of different ages and industries were recruited in the experiment, which met the requirements of driving experience of more than one year, visual acuity of more than 1.0, no physiological defects and driving experience on expressways. In order to avoid the influence of external factors, the subjects did not exercise vigorously within 1 hour before the experiment, so as to ensure the rationality and objectivity of the experimental data.

4.2.Experimental Case Design

4.2.1.Tourist highway landscape evaluation experiment

In this experiment, three groups of highway BIM models with the same alignment were built in the same experimental scene. Among them, the control section

includes sound barrier + central isolation belt + greening on both sides of the highway, that is, the first group of test sections includes sound barrier 1 + central isolation belt 1 + greening on both sides of the highway 1, the second group of test sections includes sound barrier 2 + central isolation belt 2 + greening on both sides of the highway 2, and the third group of test sections includes sound barrier 3 + central isolation belt 3 + greening on both sides of the highway 3.

4.2.2.Experimental procedures

(1) Lines connecting driving simulator, wearable bracelet physiological sensor, triple screen and other equipment. (2) Before the experiment, the driver's 5min static physiological data were collected at the starting point of the simulated road section. (3) After static test, the driver starts the vehicle and drives along the middle lane of the road from the starting point to the end point of the road to complete a group of road sections. The main test collects the data of heart rate, skin electricity, pressure and driving behavior of the subjects in real time in the background of the simulator. (4) After driving in each group, the subjects fill in the questionnaire and need to rest for 10min. (5) After the driving of the three groups of road sections, the driver is required to sort the three groups of driving environments. Workers check and store test data. (6) Repeat the above experimental process until all 10 drivers complete the experiment.

4.3.Analysis of experimental results

According to the experimental data, the psychological indicators and behavioral indicators of drivers are statistically analyzed. The data is the average value of 10 drivers' indicators, and the results are shown in the table.

Table 1. Overall statistics of psychological and behavioral indexes of drivers

Scene style	Average vehicle speed	Average fluctuation of steering wheel angle	Mean heart rate variability	Mean value of skin electricity/ μV	Mean pressure /Pa
Landscape painting style	99.05	0.76	44.80	2.36	79.55
Brick wall type	110.55	2.32	38.90	2.58	73.60
Matte aluminum strip type	98.90	7.38	40.70	2.88	74.00
Anti-glare plate type	108.60	2.52	42.23	2.45	74.41
Single plant planting type	101.20	1.75	42.50	2.56	74.95
Alternate planting of two kinds of plants	104.25	9.21	42.61	2.49	73.42
Claustrophobic	93.80	2.36	43.10	2.42	76.40
Semi-open type	100.20	3.91	42.40	2.41	76.00
Open type	101.20	2.73	43.80	2.38	76.32

Table 2. Analysis and statistics of driver questionnaire

	Title	Results	Fluctuation	Corresponding hierarchy
1	The style of brick wall sound barrier is not beautiful	The whole subjects agreed with this description	Opinions are relatively unified	Sound barrier 2 aesthetics
2	The sound barrier of landscape painting pattern is beautiful	The whole subjects agreed with this description	Opinions are relatively unified	Sound barrier 1 aesthetics
3	The design of matte aluminum bar sound barrier is not beautiful	The whole subjects agreed with this description	Opinions are relatively unified	Sound barrier 3 aesthetics
4	When driving, the reflection of matte aluminum sound barrier stimulated my vision	The whole subjects agreed with this description	Opinions are relatively unified	Sound Barrier 3 Comfort
5	While driving, the sound barrier attracted my attention	The whole subjects agreed with this description	Opinions are relatively unified	Safety of sound barrier
6	I was very impressed by the design of the central separation zone where two plants were planted alternately	The whole subjects agreed with this description	Opinions are relatively unified	Aesthetics of the middle zone 1
7	The single plant-planted median makes me feel relaxed physically and mentally	The whole subjects agreed with this description	Opinions are relatively unified	Middle Zone 2 Comfort
8	The style of ordinary anti-glare plate median belt is	The whole subjects agreed with this description	There are great differences in	Aesthetics of Middle Zone 3

	monotonous		opinions	
9	Greening on both sides of the highway has increased my uneasiness to a certain extent	The whole subjects agreed with this description	Opinions are relatively unified	Safety of greening on both sides
10	The green space on both sides of the semi-open highway has the most aesthetic feeling	The whole subjects agreed with this description	Opinions are relatively unified	Greening on both sides 1
11	The green space on both sides of the fully enclosed highway increased my visual fatigue	The whole subjects agreed with this description	Opinions are relatively unified	Greening on both sides 2

It can be seen from the table1 and table2 that different scene forms in the same project site have different influences on drivers' psychological and behavioral state. According to relevant literature, the faster the vehicle speed, the simpler the visual content to be processed, and the slower the vehicle speed, the more complex the visual content to be processed; The greater the fluctuation of steering wheel angle, the more uncomfortable the driver feels; The lower the heart rate variability, the more regular the heart rate, and the higher the heart rate variability, the greater the difference in heart rate interval. The higher the skin electric value, the higher the stimulation or excitement brought by the current landscape scene; The greater the stress, the greater the response of the subjects to the current stimulus.

4.3.1.Highway landscape security analysis

By analyzing the vehicle speed of the sound barrier, we can see that the visual information of brick wall sound barrier is relatively simple, while that of matte aluminum strip sound barrier is relatively complex. However, the brick wall type has the lowest heart rate variability, which shows that this type causes the driver's heartbeat interval difference to be relatively smallest and the heartbeat to be more regular, while the landscape painting type is relatively largest. Therefore, it can be confirmed that brick wall sound barrier is the safest among the three styles. Drivers have relatively little information to deal with when passing through the anti-glare plate median. In the index of heart rate variability, two kinds of plants are planted alternately > single plant is planted > anti-glare plate, that is, the driver's heart rate is stable and orderly when driving through the anti-glare plate median zone. By synthesizing the two factors, it can be concluded that the anti-glare plate median zone is the safest among the three styles. The speed corresponding to the green space on both sides of the claustrophobic highway is the fastest, which may be due to the psychological fear of drivers caused by the confined space to a certain extent, thus speeding up the speed. Because the three forms of green space are close to each other, the driver's heart rate variability is the largest when driving to the last open space, which indicates that his psychological feelings fluctuate greatly.

Subjective evaluation of safety for different landscape parts all get the same result, that is, the subjects are not sure whether different landscape parts attract their driving attention. Because the scores fluctuate greatly, it may be because some subjects are more attentive in the driving process and do not pay full attention to the landscape parts.

4.3.2.Highway landscape comfort analysis

Questionnaire survey results for different landscape comfort evaluation are not obvious conclusions, that is to say, the subjects give vague answers to whether the three landscape parts affect the visual comfort, so it is necessary to further study with objective indicators such as physiological, psychological and behavioral characteristics.

When driving to the matte aluminum bar sound barrier, the subjects frequently rotate the steering wheel, showing obvious uncomfortable reaction, and the skin electricity data also show that this type of sound barrier brings great irritation to the subjects. Landscape painting sound barrier shows relatively good comfort experience and relatively little stimulation, but its corresponding pressure index value is relatively high, which may be because this form of scene is the first one that drivers encounter after entering the driving simulation state, which brings a certain degree of pressure. Among the three styles of median belt, the comfort of single plant planting style is relatively the worst, but its corresponding steering wheel angle fluctuation is the smallest, which may be because its style is composed of only one plant and is visually simple. The claustrophobic green space is the form with the highest data of skin electricity and pressure among the three green spaces, which shows that this form has relatively strong stimulation and brings the greatest pressure to the subjects, so its comfort is relatively poor. In the virtual scene, the paragraph length and interval of the three green spaces are short, and the driver's behavior reaction lags behind for a period of time, so the steering wheel angle fluctuation appears when driving to the semi-open green space behind claustrophobic.

4.3.3.Aesthetic analysis of highway landscape

The subjective evaluation of different landscape parts has a clear conclusion, that is, among the three design schemes of sound barrier, the subjects generally think that brick wall type is not beautiful, while landscape painting type is beautiful; Among the three design schemes of the middle zone, most of the subjects think

that the alternate planting type of two plants is beautiful, and the common anti-glare plate type is monotonous; The green space on both sides of semi-open highway is the most aesthetic among the three forms, and the subjects have obvious likes and dislikes in aesthetic evaluation.

5.Conclusion

In view of the difficulty in evaluating the visual quality of highway landscape, this paper supports the application of visual quality evaluation of tourist highway with virtual driving through the selection of evaluation indexes of tourist highway quality, BIM modeling of highway landscape, development of virtual driving index evaluation system, and construction of highway landscape perception evaluation platform based on simulated driver. In the experiment set up different control group experiment, collect the physiological data of the tester at the same time, fill in the questionnaire synchronously after the experiment, carry on the statistical analysis to the physiological data and the questionnaire result, put forward a kind of qualitative and quantitative evaluation method to the visual quality of the tourist highway, provide the tool support for the security, comfort, aesthetic evaluation of the tourist highway landscape design.

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