Estimating Visual Quality of Scenic Highway using GIS and Landscape Visualizations

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Abstract:

With ever increasing use of highways for transportation in modern life, Highway landscape has gradually become one of the major elements of the roadside environment that people experience on a frequent basis. The project has harnessed the power of GIS to investigate the relationship of landscape features including topography, landscape elements and visual closure with scenic preference. A number of experimental landscape visualizations, in the form of video clips, were statistically generated using GIS and Continuous rating data were then recorded for scenic preference. A procedure for measuring the scenic quality of the highway landscape and explaining how landscape features relate to the visual perceptions of drivers by collecting and analyzing the highway landscape visualizations are described in this paper, which would provide designers and decision-makers with a framework for incorporating multi-modal elements and their relationships into highway landscape planning and design.

1. Introduction

In the past, engineering and traffic related issues in construction and management of highways were of utmost importance, while landscape issues were often neglected by the highway authorities (Box and Forbes, 1992).With the ever increasing use of highways for transportation purposes, concern for landscape aspects has intensified considerably. People are beginning to demand highways not only to serve as utilitarian conduits but also to be part of the natural landscape. Highway landscape design has gradually become one of the major elements of the roadside environment that people experience on a frequent basis. Highway designers have begun to attempt to improve the scenic quality of the environment surrounding the highway. Yet, many of the effects of these improvements on individual's driving experience are little known.

As a concept, scenic quality is both elusive and complex. It has been described as being the product of the landscape according to the reactions of persons experiencing that landscape (Craik and Zube, 1976; Wohlwill, 1976; Ulrich, 1983; Chenoweth and Gobster, 1990). Meinter (2004) found that scenic beauty and driving experience significantly correlated with a high internal reliability. To better understand how scenic beauty could play into roadside landscape planning and design, it is necessary to begin researching how particular elements of design effect individual opinions and preferences. This would be helpful in analyzing how current highway landscapes are viewed from the public eyes and to enhance those design elements that bring about positive driving experiences.

We have developed a study to assess the scenic value of the highway landscape to explain how landscape features relate to the visual perceptions of drivers by collecting and analyzing individual's perceptions about the highway landscape. We have produced several different landscapes in the form of visualizations. The visualizations, driving by geographical information systems (GIS) were produced in the form of photographs and video clips. These were then used to in a perceptual study to learn how landscape features including topography, landscape elements and visual closure affected preference. The intent of the study was to provide designers and decision-makers with a framework for incorporating multi-modal elements and their relationships into highway landscape design. Furthermore, the study was created to show how additional studies similar to these could be conducted. By using GIS and controlling the environmental characteristics of a landscape, we can begin to discover what and if any specific design elements have upon a driving experience.

2. Methods

There are several approaches to landscape evaluation (Daniel and Vining, 1983; Zube et al., 1982), but the human perception-based approach is most dominant in research. It has been extensively used in a variety of environmental planning applications. In both practice and research, landscape quality is indicated by human observers' expressions of preference (choice, like–dislike) or ratings of visual aesthetic quality (including scenic quality, visual quality, and scenic beauty).

In order for highway landscape planning and research to perform effectively, accurate human assessments of "real" environments must be secured. (Meinter, 2004). Consequently, the use of surrogate stimuli is necessary and has been a preferred and cost-effective method to assess human perceptions and evaluations of natural environments. These surrogates typically include the use of color photographs or slides to represent a natural environment (e.g. Brown and Daniel, 1986; Buhyoff and Leuschner, 1978; Daniel et al., 1972; Kaplan et al., 1973; Latimer et al., 1981; and Zube et al., 1975).

Various independent studies have reported high levels of consistency (high positive correlations) between perceptual judgments and expressed preferences based on photographs and parallel responses based on direct experience of the represented landscapes. However, even with many studies supporting the notion that photographs and slides are suitable surrogates for onsite experience; some studies found examples where the surrogate can fail (Meinter, 2004). One problem in this approach is the differences in the selection of variables to represent scenic quality, as well as the general difficulties of two-dimensional representation of views seen in elevation (Appleton, 1994). Hetherington et al. (1994) found that for the evaluation of a scenic landscape, the addition of motion (via full motion video) resulted in ratings that were much more sensitive to flow levels. Scott and Canter (1997) found that photographs might not be sufficient for the evaluation of many potentially important actions, thoughts, and feelings that people associate with actual places.

Nevertheless, digital representations have shown to be an effective representative of real landscapes in laboratory studies of scenic beauty. In order to solve the problem of using still images to represent dynamic or real-life settings while focusing on some specific highway design elements, we have created several videos generated by Visual Nature Studio (VNS). VNS is a computer graphics imaging (cgi) program that allows for the input of GIS data, images and 3D models to simulate real environments.. The videos were used to immerse individuals in a driving simulation. During each simulate drive, real-time ratings were collected using a custom-built input device.

2. a. Materials and Apparatus

Six movies of driving simulation were created by GIS and VNS. The movies were designed to simulate three different kinds of topography: flat, rolling hills and mountainous. Each setting includes a variety of landscape elements such as bodies of water, barns, billboards, trees, etc. Each movie is two minutes in length, consisting of 2880 frames stitched together to create a cinematic 24 frames per second. The final resolution was 1024x768 pixels. The designed speed of the drive in each movie is 80km/h. The viewpoint is located slightly off-center of the road in the right lane and about 1.2 meters above the pavement. The horizontal visual angle is 70°.

To conduct the surveys a computer interface was developed to allow users to input a variety of ratings as well as display the videos. Each video was shown in the Landscape Immersion Lab in the Faculty of Forestry at the University of British Columbia on one of the laboratory's large projection screens. The screen stands roughly 3 meters high and 4 meters wide. The intent was to represent landscape elements in a reasonably realistic scale.

The apparatus used to collect the real-time data acts much like a slider volume control on a sound board. At the beginning of each movie, the slider control was set to the center. As the movies progressed, users were asked to lower or raise the value of the slider bard depending upon their perception of the quality of drive. The ratings, captured 2 times per second were then written into an excel spreadsheet.

2. b. Developing the movies

In order to create each movie we had to start by generating several different landscapes. There are three different types of landscapes: flat, rolling hills and mountainous. The first landscape (flat) was meant to provide a simulated agriculture landscape. The terrain was generated using ArcGIS's Inverted Distance Weighting (IDW) method based on a number of point values we provided. The landscape has some minor variation with the slopes along the road at approximately a 0° angle. We also included a single simple hill viewed only from a distance. After the terrain was developed we created a road with a few slowly undulating turns. The length of the road created was approximately 10km in distance. Then, from that road we derived an offset line feature that simulated the position of the driver. One of the important aspects of this survey was to test whether or not the amount of enclosure, derived from trees or hills, affected the drivers preferences. Therefore, we wanted to generate ecosystems on the landscape that simulated agriculture, grasslands and areas with tree coverage. Using GIS, we created several planned polygons and point features to designate the spatial location for each of these different ecosystems. Placing the point features was most difficult because when we wanted to place traffic signs or billboards we needed to ensure that the distance from the road would be similar to that in real-life.

The second landscape simulated a terrain more linked with rolling hills. Producing this landscape using the IDW algorithm proved too difficult. In order to have a more realistic environment, we used free SRTM data satellite imagery provided online by NASA. The spatial location of the data is not important; rather, its topography was much more vital to the results. We chose an area that had hills, flatlands and mountains. In a way this landscape type is a combination of the flat and mountainous terrain. The objective was to create a landscape where the slopes of the road would change but would not be maintained for an extended period of time. The range of slopes underlying the road varies from 0° to 6°. In the distance, roughly 15-30km, one can see numerous mountains. The ecosystems included grasslands and forested areas. Lakes were also introduced in these videos. Again, numerous polygon, line and point features were used to derive the spatial location of the landscape elements.

The final landscape was created to simulate a drive through a mountainous area. Again, STRM data was used at the topography as generating the complex formations of mountains to be life-like is virtually impossible using the standard interpolation methods provided in the ArcGIS suite. The range of slopes underlying the road for this scenario ranged from 0° to 15°. Only slopes with less than 9° were maintained for some distance, according to best engineering practices. The effect of this landscape was a more dynamic drive based on slope as well as a wider range of enclosure. The ecosystems used in this landscape were all forest types, but the density of trees range dramatically, sometimes with only a few scattered trees and others simulating a thick dense forest.

After the GIS data for each landscape had been created, we then used VNS to generate photo-realistic images. Figure 1 shows an example of how the data was created in a GIS environment and then simulated in a 3D environment. In order to create each movie 2880 frames were individually rendered and stitched together to form a two minute segment. To simulate an 80km/hr drive each frame was rendered approximately 2⅔ meters apart. Depending upon the landscape each frame could take 1-3 hours to render, the flat terrain requiring the least amount of rendering time.

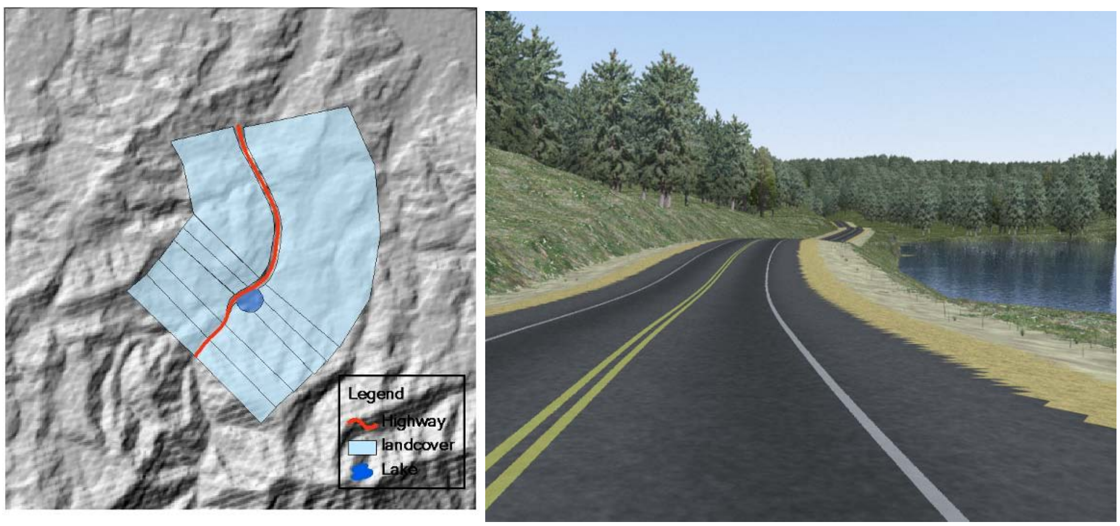

Figure 1. (Left) Sample GIS data showing the road, lake and landcover polygon. The light blue represents a variety of different landcover ecosystems, which in this case are only small variations in the amount of forest cover. (Right) A 3D rendering of the 2D data showing the lake feature.

2. c. *Rating scale*

In order to rate each video, participants were informed that their task was to rate a series of highway landscapes represented by a movie presented on the screen on a 10-point scale of scenic beauty, where 10 corresponds to very high scenic beauty and 1 corresponds to very low scenic beauty. Before each video began, participants were asked to preview nine photographs chosen *a priori*, which represented some of the specific landscape features and configurations they would see in the upcoming movie. This allowed the participants to get an idea of what the general landscape was like and appropriately anchor the 10-point scenic beauty rating scale. Then the participant was asked to rate each of the individual slides. Following the individual ratings, the subject was then shown the video and subsequently rated the quality of drive using the slider bar. The ratings were collected on a scale from 0-10, with a sensitivity of two decimal places, and taken every one-half second.

2. d. Participants

The participants were 37 students, faculty and staff from the University of British Columbia. Subject advertising was targeted at current students and staff of the University of British Columbia. The subject pool contained 14 females and 23 males ranging in age from 20 to 59. Subjects came from a variety of disciplines and had varying amounts of formal education, ranging from technical diplomas through to post graduate level degrees.

2. e. Procedure

The experiment was conducted in the Landscape Immersion Laboratory (LIL) in the Faculty of Forestry on UBC campus. The experimental instructions for the relevant condition were presented both visually and audibly (through headphones). Subjects were asked to rate driving experience of highway landscape depicted in the video segments by evaluating the experience in real time as well as entirely.

A short practice preview movie was shown firstly to familiarize subjects with the apparatus and task. Before subjects began each movie, there would be a message box to remind them to move the slider to the middle. While the movie played, subjects were asked to indicate their preference by adjusting the slider up or down, increasing the value when they preferred the landscape more and decreasing the value when they preferred the landscape less. Subjects were encouraged to use the whole range of the scale but realized that once they reach the top or bottom there was no way to indicate a higher or lower preference. Once the movie had finished playing, they were asked to rate their overall impression of the landscape they just virtually traveled through. This sequence of events will then repeat five more times until the study is completed. Then six movies with different landscape were presented in the same order. The potential order effects caused by sequential viewing were deemed to be less important. Time to complete the entire experimental procedure was approximately 45 minutes.

3. Results and Discussion

In this study, we sought to determine the status of scenic beauty of the highway landscape and to learn how landscape features relate to the visual perceptions of drivers. We also embarked on unique territory in regards to better understanding how individuals relate to their environment in a dynamic setting by creating realistic simulations driven by GIS data. The movies were designed in three different topographies featuring a variety of landscape types as shown in Figure 2.

Figure 2. The highway landscape in flat area, rolling hills and mountainous settings

Data relating to the distribution of scenic ratings, and the indications of preference among subjects, were generated using statistical software SPSS. Liner regression analysis was made to investigate the effects of landscape elements in perceptual preference. These results are provided on a preliminary basis as a full analysis has not yet been completed. In general, there is no strong correlation with any single natural landscape feature. However, an artificial feature such as a billboard has shown to have a strong negative correlation. Table 1 shows the correlation results for each of the features shown in the videos. Figure 3 shows examples of what low and high enclosure look like.

Table1 The β value of every movie

	Movie 1	Movie 2	Movie 3	Movie 4	Movie 5	Movie 6	All Movie
Billboard	-0.730				-0.828		0.549
Lake		0.226	0.884	0.442			0.360
Traffic Sign				-0.107			
Rural Barn							
Slope		0.093	-0.251	-0.494		-0.805	-0.167
Enclosure		0.953	0.138	-0.110	0.328	0.654	0.236

Figure 3. Low enclosure and high enclosure of highway landscape space

The first movie, simulating a flat terrain, consisted of several features like rural barn, billboard and traffic sign. In this movie, the presence of billboards $\beta = -0.730$, $t(238) = -16.488$, $p < .000$ significantly predicted the preference ratings. It is suggested in Figure 4 that the mean rating decreased a great deal on the presence of billboards. The rural barn and traffic sign had little effects on perceptual preference. And the change of mean rating mostly showed the same trend with that of enclosure.

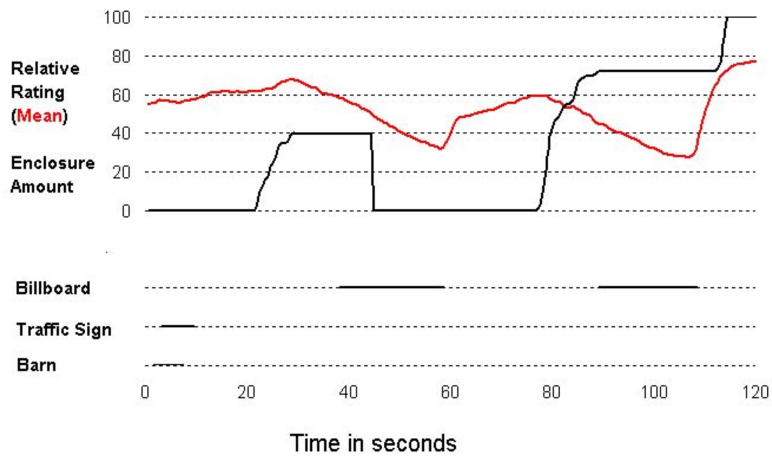

Figure 4. The relationship of Mean rating and the presence of landscape elements for movie 1

The second movie consisted of a rolling hills terrain with a lake on the roadside. The amount of Enclosure β = 0.953, t(236) = 30.997, $p < .000$, the presence of lakes β = .226, t(236) = 6.946, $p < .000$ and the effect of slope β =.093, t(236) = 2.945, $p < 0.004$ significantly predicted the preference ratings. These factors also explained a significant proportion of variance in preference ratings, R2 = 0.809, F(3, 236) = 332.875, $p < 0.000$. It was showed in Figure 5 that mean rating showed the similar trend of change with enclosure. The presence of lake caused the increase of preference rating.

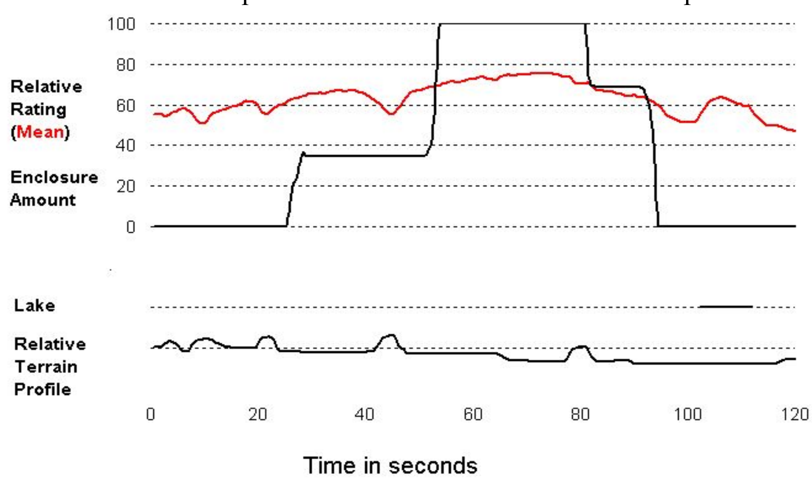

Figure 5. The relationship of Mean rating and the presence of landscape elements for movie 2

For movie 3, simulating a mountainous terrain type consisting a lake, the presence of lakes β = 0.884, t(224) = 24.387, $p < .000$, the effect of slope β = -0.251, t(236) = -7.522, $p < .000$, and the amount of Enclosure β = 0.138, t(224) = 3.794, $p < .000$, significantly predicted the preference ratings. These factors also explained a significant proportion of variance in preference ratings, R2 = 0.751, F(3, 227) = 225.742, $p < .000$. It was suggested in Figure 6 that people showed great preference for the presence of lake.

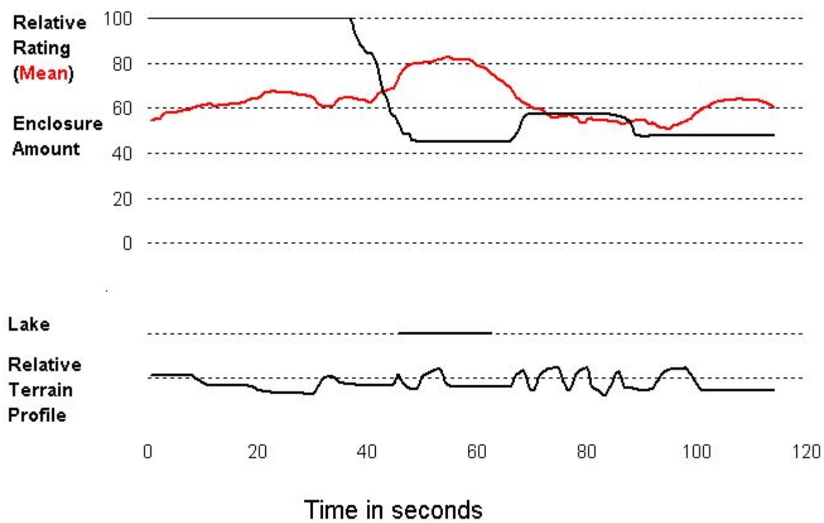

Fig.6 The relationship of Mean rating and the presence of landscape elements for movie 3

For movie 4, simulating a rolling hill terrain, consisted of several features like lakes and traffic signs, the effect of slope β = -0.494, t(235) = -12.491, p < .000, the presence of lakes β = 0.442, t(235) = 11.145, p < .000, the presence of traffic signs= -0.107, t(235) = -2.967, p < .003, and the amount of Enclosure β = -0.110, t(235) = -2.846, p < .005 significantly predicted the preference ratings. These factors also explained a significant proportion of variance in preference ratings, R2 = 0.711, F(4, 239) = 144.192, p < .000. Figure 7 strongly suggested that the presence of slope had an adverse trend of change with preference rating, and people showed greater preference for the presence of lake.

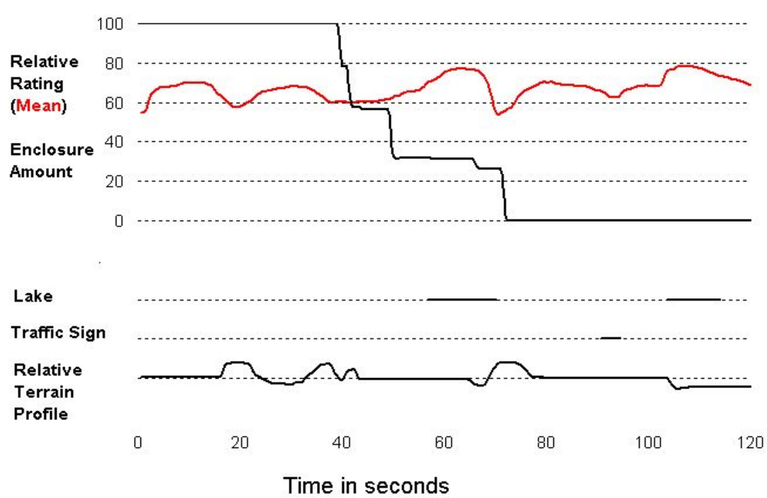

Figure 7. The relationship of Mean rating and the presence of landscape elements for movie 4

For movie 5, simulating a flat terrain, consisting a rural barn and several billboards, the presence of billboards β = -0.828, t(237) = -17.396, p < .000 and the amount of Enclosure β = 0.328, t(237) = 6.886, p < .000 significantly predicted the preference ratings. It was showed in Figure 8 that the billboard caused the sharp decreases of preference rating. The presence of rural barn and the changing of enclosure had little effects in preference rating.

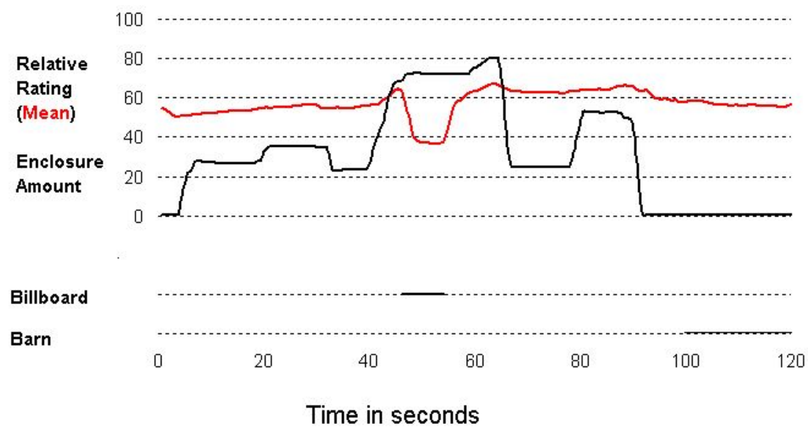

Figure 8. The relationship of Mean rating and the presence of landscape elements for movie 5

For movie 6, simulating a mountainous landscape, the effect of slope β = -0.805, t(237) = -13.160, p < .000 and the amount of Enclosure β = 0.654, t(237) = 10.698, p < .000 significantly predicted the preference ratings. It can be seen easily in Figure 9 that the presence of slope had an adverse trend of change with preference rating.

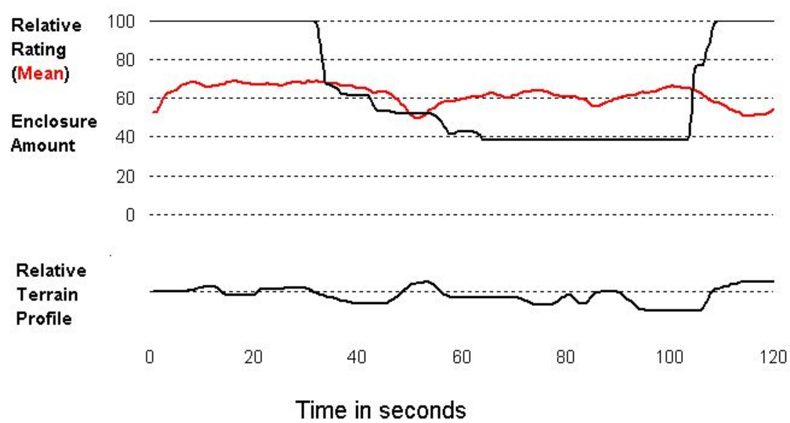

Figure 9. The relationship of Mean rating and the presence of landscape elements for movie 6

4. Conclusion

This research suggests billboards are major distracters with strong negative effects on the driving experience. Furthermore, billboards were found to negate the effects of other landscape features and terrain elements. When planning for a scenic drive, the location billboards should be heavily considered to ensure a minimal effect. Compare to billboards, traffic sign have a small effect on preference.

Lakes also influence the overall experience, but in a positive way. Slope (frequent changing in elevation) has a negative effect on preference, but further analysis of the results need to be conducted confirm this. When looking at the data it seems that preference increases when the vehicle crests a hill and begins downhill, but no statistical analysis has been done to verify this observation. The rating suggests that people prefer to go downhill then uphill. The rural barn has a small positive effect on preference ratings. This human-made feature is an intrusion to the natural landscape, but it did not affect the drivers preference. However, the placement of the barn in the time order did not suggest any interference with billboards or enclosure. In an open and agricultural setting the barn can be viewed as a pleasing element within the natural surroundings. Enclosure is relatively complex; it depends on the elements which create the enclosure. If the enclosure is created by vegetation like trees or bushes people tend to prefer more enclosure. However if enclosure is associated with artificial objects such as a concrete wall or billboards, people would prefer the open space.

Another important result of this research derives from the preference of majority of highway landscape for native, natural elements. This finding supports one of the principles of environmental aesthetics that suggest the natural environment is usually preferred than when the natural environment is modified with foreign objects. In the future, more studies are necessary to investigate the representational validity of various presentation methodologies for the use in quantifying perceptual characteristics of natural landscapes. As well, issues surrounding temporal aspects in highway landscape such as rate, frequency and rhythm of change need to be further investigated. This paper presents an initial concept whereby dynamic ratings are made in real-time. Furthermore, it suggests the possibility of creating dynamic, realistic simulations of natural real-life scenes in order to better understand how landscape elements and artificial objects affect a driver experience.

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