EVALUATION OF THE EFFICIENCY OF THREE-DIMENSIONAL VISUALIZATION TOOLS FOR DETECTING SHORTCOMINGS IN THE COORDINATION OF THE ALINEMENT´S A GEOMETRIC HIGHWAY PROJECT – FIRST STEPS

Ana Paula C. Larocca
Docent of Civil Engineering, Polytechnic School, University of São Paulo
São Paulo, Brazil, e-mail: larocca.ana@usp.br

Aurenice da Cruz Figueira
MSc. Candidate, Engineering, Polytechnic School, University of São Paulo
São Paulo, Brazil, e-mail: aurefig@hotmail.com

José Alberto Quintanilha
Associated Professor of Civil Engineering, Polytechnic School, University of São Paulo
São Paulo, Brazil, e-mail: jaquinta@usp.br

Felipe Issa Kabbach Jr.
Docent of Civil Engineering, Polytechnic School, University of São Paulo
São Paulo, Brazil, e-mail: fkabbach@planservi.com.br

Submitted to the 3rd International Conference on Road Safety and Simulation,
September 14-16, 2011, Indianapolis, USA

ABSTRACT

The use of three-dimensional (3-D) visualization technologies applied in the field of Transportation has contributed not only to accessing the impact of a highway design in the region and its surroundings, but mainly to providing a corrected combination of a horizontal (plan) and vertical alinement (profile) of the highway design. Thus, in the design of highway alignments, horizontal and vertical design elements are necessarily superimposed. Combining the cross-section of the road, which includes hard-shoulders, pavements and their widths and edge markings, results in a three-dimensional design element. The application of these technologies to highway projects, especially in Brazil, and particularly with regard to the design of road projects in public or private areas, almost in its entirety, is still conducted in three stages - the projection of vertical alignment, horizontal alignment and cross sectioning with the use of computational programs which work in a 2-D environment. Taking this scenario as a base, the objective of this study is to investigate and test the effectiveness of three-dimensional visualization tools to identify shortcomings in horizontal coordination and vertical alignment for the geometric design of highways, based on 3-D visualization tools associated with 3-D animation and questionnaires. The evaluation will be in the form of tests conducted with groups of individuals who are Civil Engineering students with no experience in the development of the geometric design of roads. They will evaluate a real stretch of highway in two different situations, with proper horizontal coordination and vertical alignment and with the intended introduction of deficiencies in the design. For this step, software for geometric design of highways providing 3-D visualization of horizontal and vertical alignment will be used. The group of individuals will be submitted to tests supported by videos with 3-D simulation of the driving space in a non-immersive drive-through environment concept.

Keywords: transportation, 3-D visualization, safety, drive-through.

INTRODUCTION

The use of advances in computer imaging technologies applied to the area of transportation has contributed not only to the 3-D visualization of the interference that a rural road project may cause to its surrounding region, but also to the development and study of the geometric elements of the project itself that must be suited to the topography and normative documents. The adoption of the concept of visualization applied to highway projects by U.S. agencies is the result of discussions supported by the National Surface Transportation Policy and Revenue Study Commission in the United States (Manor, 2007; Doug et al. 2006).

Visualization is a simulated representation of proposed transportation improvements and their associated impacts on the surroundings in a manner sufficient to convey to the layperson the full extent of the improvement (NCHRP, 2006).

These reflections are supported by the questions concerning how this tool can help a future vision of the transport system in the United States, where they are facing a need for better data and analysis tools to assist professionals who find it difficult to discern the coordination of the design elements of a highway project.

Later, visualization began to provide support for government entities. It was clear that projects which are in the design phase cannot be visualized and it becomes more difficult to calculate the size of the investments required as well as to estimate any possible environmental impact. (Manor, 2007; Doug et al. 2006; Suzuki et al., 2004).

However, nearly a decade has passed since the first initiatives taken by the U.S. Transportation Agencies in the use of three-dimensional visualization technologies in road projects and there are still very few projects, including academic projects, which effectively apply them.

These technologies have continued to develop at a considerable rate and can now be complemented with tools and techniques for rendering, animation and multimedia interactions - immersive environments. An immersive virtual environment is a dynamic three-dimensional scene stored on a computer and displayed using computer graphics techniques, in real time, leading the user to believe that they are immersed in the environment. The non-immersive environment, in its turn, is characterized when the user is partially transported to the virtual world through a window (a monitor or projection, for example), but still feels predominantly in the real world (Hobson et al. 2009; and Hendrik and Kuhn, 2010; Pine and Rebelo, 2006; Zimmermann and Roos, 2001).

The application of these technologies to land-route projects, especially in Brazil, is still lagging behind its peers in the areas of Aerospace Engineering, Architecture and Automotive Engineering when it comes to the adoption of three-dimensional visualization tools to aid in the designing of projects.

The design of road projects in particular, in both the public and private spheres, is still almost entirely conducted in three stages - the projection of vertical alignments (*profile*), horizontal alignments (*plan view*) and cross section with the use of computational programs which operate in a two-dimensional environment (2-D). The latter is particularly important for 3-D visualization in order to provide platform features such as lane width, hard-shoulders and median, and other elements that will go towards the composition of the project's digital model.

As highway users and designers are exposed to three-dimensional images whilst driving, it becomes interesting and closer to the driver's reality to calculate the project's development with the addition of the three phases mentioned associated to 3-D visualization, right from the beginning of the project (Hobson et al. 2009; Kühn and Jha, 2006).

Under these conditions, although the design of a highway plan may consist of individual elements, the combination of horizontal (plan) and vertical (profile) alignment results in a spatial or three-dimensional creation because of the superimposition of all design elements. The result is a description of the driving space (Smith and Lamm, 1994).

These procedures, however, are still only moving ahead slowly, since commercially, the application of visualization tools simply for the aesthetic effect of the project, substantially outweighs the technical applications aimed at the development of geometric design, mostly in the use of new tools - which necessarily requires a new evaluation of the software, and often also much more powerful computers.

Thus, according to the scenario presented, this study aims to investigate and analyze the effectiveness of 3-D visualization tools to identify technical shortcomings in the coordination of horizontal and vertical alignment with regard to highway esthetics that cannot be observed in the current way of designing the project, which is still supported by 2-D procedures.

THE PROBLEM

As previously mentioned, geometric highway projects are traditionally designed in 2-D and in three distinct stages: horizontal projection, vertical projection and the cross section.

However the horizontal and vertical alignments are among the most important of the permanent highway's design elements and should not be studied independently, since improper combinations can affect the aesthetics, operational efficiency and safety on certain parts of the highway. They should also fit gracefully into their surroundings and become acceptable components of the landscape as viewed from off the highway. The coordination of the proper fitting together of the horizontal and the vertical alinement is an important technique for achieving an esthetically pleasing highway alignment design. It is the coordination of horizontal and vertical alignments that indicates the degree of comfort and safety of the driver while driving.

Certain shortcomings such as short circular curves between tangents appear as optical breaks if they are viewed from a long distance, whilst a short tangent used between two succeeding sag vertical curves can give the impression of a crest vertical curve and both these situations must be identified and avoided in the design process.

The identification of shortcomings in the coordination of the alignments is still a laborious step, and even the designer can make mistakes which are only identified after the deployment and use of the highway, which is charged into the cost factor of social work (CNT, 2010).

Although the use of 2-D parametric computational programs that make a dynamic analysis of several alternatives, since it is possible to change the existing ground as the horizontal alignment is changed, the procedure for coordination between the alignments is generally based on a planimetric diagram, which indicates the beginning and end of each curve and the stretches between tangents, and are compared with the vertical alignment of the project, taking into account also the volume of earth moved.

The recommendations of the National Department of Transport and Infrastructure of Brazil (DNIT), the organization responsible for providing the criteria surrounding the physical and geometrical characteristics (DNER, 1999), note that the coordination of horizontal and vertical alignment should be sought right from the beginning of the academic studies for the highways, being perfected in the later stages of the project, which can be costly if the highway has already been implemented.

Within the scenario presented, the main purpose of this study is to evaluate the effectiveness of three-dimensional visualization tools, through the use of 3-D visualization and animation in the identification of shortcomings of the coordination of the horizontal and vertical alignments of a geometric highway project. The individuals used for testing this hypothesis are Civil Engineering undergraduate students at the University of São Paulo's Polytechnic School, located in the São Paulo state capital, Brazil.

MATERIALS AND METHODOLOGY

The test methodology proposed in this work will involve the visualization of a stretch of the 3-D geometric design developed in specific software using the concept of drive-through, questionnaires and the videotaping of individuals' reactions via webcam and software applications. Final results will be recorded in an Excel worksheet and analyzed.

Computer for testing

Individuals will be subjected to tests on computers (laptop) consisting of 1Gb of RAM, the Windows XP operating system and an installed webcam. The choice of notebook computer is due to the mobility needs of the test station to interview Civil Engineering graduate students currently studying the Infrastructure Highway Project course.

Computer Programs

The development of the tests will take place with the use of an application program for geometric highway planning that has a 3-D visualization tool. The software is named 'CLIP' and has been developed by the TOOLS Company. No free software was found that met the needs of the research. The program chosen for recording the reactions of individuals is Windows Media Player, an application that is integral to the operating system.

Model for the Tests

In the first phase, an adjustment of the tests will be made to define parameters that guided the generation of video simulation that will be used in final tests: the texture of the runway, lighting, color of the inclinations, distortion or not of the project template and relief, and length of application of the tests.

The concept used to generate the video simulation mentioned above is a walk-through or drive-through that provides the ability to move through a virtual three dimensional environment and to observe the content of that environment from a given eyepoint or height above the ground. This ability may be the result of an animation sequence where the path, eyepoint, and direction of the gaze have all been pre-defined, or may be the result of the viewer's real-time control over those parameters (AASHTO, 2003).

The technical part of the tests (stretches) will be extracted from the correct geometric project of a highway. The design of this highway will disregard the recommendations of DNIT and shortcomings will be included in the coordination of horizontal and vertical alignments. Following the steps for defining the geometric elements of the section the plan and profile design at a scale yet to be defined will be printed and the sequence will be produced in the 3-D visualization multimedia file format named Audio Video Interlave (AVI) - which is part of the operating system technology - as shown below.

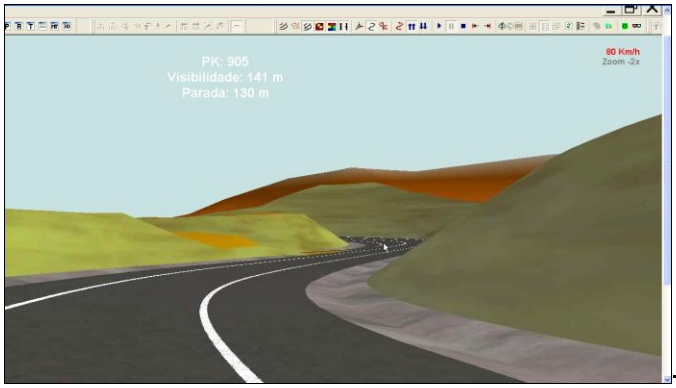

Figure 1: Screen from AVI video
Font: CLIP software

Methodology

The methodology will require that individuals watch and analyze 3-D drive-through video simulation to try to identify stretches with shortcomings that are not normally detected in two-dimensional views (plan and profile).

A number of screens showing flaws taken from the video simulation are presented below. Figure 2 presents a type of shortcoming in the geometric project known as "optical break" – a short tangent between succeeding sag vertical curves. Figure 3 shows another type known as "fluttering" that involves multiple diving or a rapidly rolling profile. Figure 4 presents a defect in the form of a jump. A dive takes place when the driver loses sight of part of the highway and the remaining segment reappears in the distance. The disappearance is caused by a steep crest vertical curve, which limits the driver's sight distance, followed by a sag vertical curve and an upgrade section, which brings part of the highway back into the driver's view (Smith and Lamm, 1994).

Figure 2: Screen from AVI video – “optical break” shortcoming
Font: CLIP software, modified by author

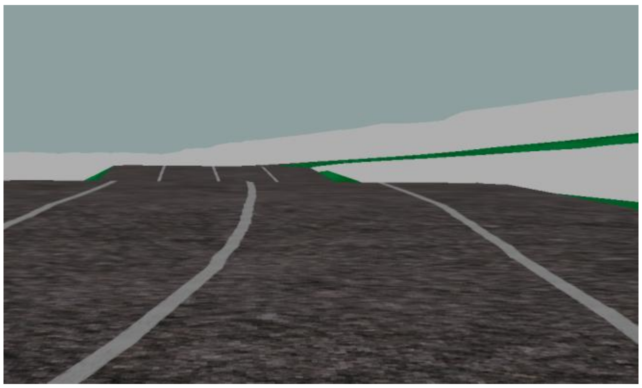
Figure 3: Screen from AVI video – “fluttering” shortcoming
Font: CLIP software, modified by author

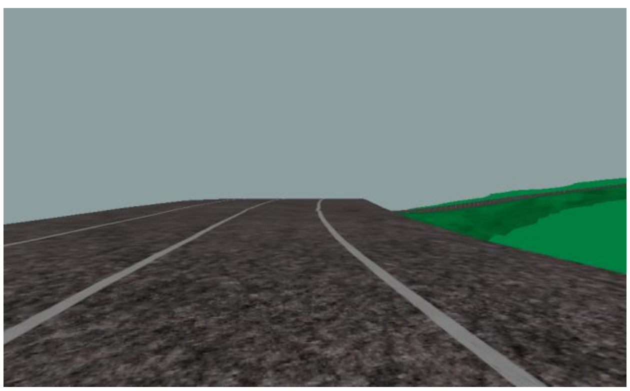
Figure 4: Screen from AVI video – “dip” shortcoming
Font: CLIP software, modified by author

Questionnaire

The questions that will initially be posed to the individuals are set out below.

Gender	Female ( )	Male ( )
Has experienced some kind of 3-D viewing (i.e. games, 3-D films, etc.)	Yes ( )	No ( )
Is a current vehicle driver?	Yes ( )	No ( )
Drives frequently?	Yes ( )	No ( )
Are you aware of the theoretical concepts of coordination between horizontal and vertical alignment?	Yes ( )	No ( )

When watching the video simulation of a planned stretch, have you been able to identify any stretches with faults in the coordination of horizontal and vertical alignment?

How would you rate the video simulation of the planned stretch considering the points below? Assign a score of 0 if it is considered bad and a score of 10 if the review is excellent.

	SCORES										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Feeling of Comfort											
Feeling of Safety											
Monotony											
Visual Handling											

EXPECTED RESULTS

The field tests are being conducted with students.

Throughout this process we expect to confirm that visualization significantly improves the range of capability that project teams have to more thoroughly test designs, better communicate possible alternatives and weigh up potential impacts. Reliance upon traditional engineering drawings such as typical plans, profiles and cross-sections is no longer sufficient to satisfactorily convey a clear understanding of transportation improvement alternatives and their associated impacts.

The results may be used as an incentive for the adoption of three-dimensional tools in the conception of geometric highway design by newly-trained engineers who are not yet addicted to designing only in 2-D.

ACKNOWLEDGMENTS

The authors would like to thank the TOOLS Company for licensing the use of the CLIP geometric highway project software and the CNPq – the National Council for Scientific and Technological Development – that provided funds for the author to attend this conference and support the research by means of the Universal 2010 scholarship and the authors' productivity grants (PQ-CNPq).

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