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Visualizing Safety

3-Dimensional Models for Smart Work Zone Design

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SWZDI
Smart Work Zone Deployment Initiative

Iowa's leading role

The Smart Work Zone Deployment Initiative (SWZDI) is an on-going, pooled-fund study that has successfully promoted and coordinated enhancement of safety and mobility research in work zones since 1999. This pooled-fund study currently consists of several Midwest states, including Iowa (the lead state), Kansas, Missouri, Nebraska, and Wisconsin. The SWZDI is currently administered by the Iowa Department of Transportation (DOT) through the Center for Transportation Research and Education (CTRE) at Iowa State University. Member states contribute funding (generally from State Planning and Research funds) necessary for these activities, prioritize products for evaluation considering potential benefits, and cooperate with university researchers to identify evaluation sites and conduct studies. These five states actively participate in funding roughly 10 projects, and Iowa is preparing to award four or five more contracts for the 2009 fiscal year.

This research shows that it is feasible to use relatively simple software programs as tools for public communication and visualization of traffic work zones at different construction phases.

Simulation tools for small and rural projects

One important aspect of SWZDI research is visualizing work zone traffic control. Visualization improves understanding of project design intent and concepts, facilitating effective decision making. Although visualization is a tool only recently available, current visualization techniques are generally used to communicate within the design and construction team, and between the team and external stakeholders. These techniques include image composites, video composites, 2-dimensional (2-D) drawings, drive-through or fly-through animations, 3-dimensional (3-D) rendering models, virtual reality, and 4-dimensional computer-aided design (4-D CAD). Typically, visualization tools are used for presentation of large-scale urban projects and seldom considered for small- and medium-sized or rural projects, or projects where external stakeholder communication is not a major issue. Also, there is a perceived high cost of investment in both financial and human capital in adopting visualization tools. However, a recently completed SWZDI study proves that visualization technology provides cost-efficient tools for improved safety and mobility for smaller and rural transportation projects.

Recently completed research

A recently completed SWZDI research project titled "Feasibility of Visualization and Simulation Applications to Improve Work Zone Safety and Mobility" examined the use of visualization and software simulation applications for improving highway safety and mobility for small-scale and rural projects. Conducted by Iowa State University (ISU) between Sept. 1, 2007, and May 31, 2008, and sponsored by the Iowa DOT, the research team studied a wide range of available visualization software varying in level of sophistication.

Standard 2-D drawings, such as those produced by MicroStation or AutoCad, common in the industry, represent the lowest level of sophistication in terms of visual data. The most sophisticated system is represented by virtual reality. However, this advanced visualization technique has only been used in academic settings and with 4-D CAD on a very limited basis for highly complicated specialty projects. 4-D CAD is an approach that visualizes a project schedule by evolving 3-D construction models over time.

This research shows that it is feasible to use relatively simple software programs as tools for public communication and visualization of traffic work zones at different construction phases. Designers can develop various traffic control strategies and evaluate them utilizing the driver's

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perspective. Computer-generated visuals allow for a more objective evaluation of alternative traffic-control strategies.

Visualizing a highway work zone requires a 4-D CAD-type simulation since the time dimension is also of interest. Because of this need, 2-D drawings and image composites add little value. Consequently, the team studied the feasibility of using commercial 4-D software or adapting current 3-D environment software.

Comparing software

To compare the feasibility of different visualization approaches, several major software factors were examined:

- Costs – What would costs be for development of software compared with commercially available software? What are maintenance costs for each?
- Real-time navigation – To what degree would the selected software allow users to browse 3-D models from any angle?
- Accessibility – What are the end-user benefits? What are the hardware/software requirements? How easy is it to use?

Figure 1 shows a comparison of the software considered for use in the research.

Issues	Google™ SketchUp and Earth	Second Life®	Adobe Acrobat 3D®	Walkinside™	4-D software
Software cost	Free	Low	Medium	Higher	Higher
Maintenance cost	No	No	No	Yes	Yes
3-D development cost and time	Low	Medium	High	High	High
Real-time navigation	Yes	Yes	Yes	Yes	Yes
Availability to end-users	Yes	Yes	Yes	No	No
Internet connection required	Optional	Yes	No	No	No

Figure 1 – Comparison of visualization programs

Simulation using Google® freeware

After review, the research team selected a combination of Google SketchUp® and Google Earth® software for testing. The downloadable simulation software is free and can be used to rotate, zoom and pan to the specific work zone areas of interest.

Council Bluffs 24th Street bridge project

To test the feasibility of using Google Earth as a platform for low-cost visualizations of construction work zones, the research team tested the application on the 24th Street bridge project in Council Bluffs, Iowa. The 24th Street Bridge renovation project is a part of the Council Bluffs Interstate System (CBIS) improvements project and has gained attention from local businesses due to periods of road closures which potentially affect their customers. To communicate between engineers and non-engineers, visualization and simulations are more likely to enhance communication than typical construction drawings.

The location of the 24th Street bridge construction site is near the Iowa-Nebraska border, where high traffic volumes merge from two interstate highways (I-29 and I-80), into one highway (I-29/I-80) underneath the project site. The traffic management plan utilizes six different work zone configurations in six construction stages, and has three sub-stages in stage 4. The project will replace an existing four-span, pre-tensioned, pre-stressed concrete beam bridge with a two-span steel welded-girder bridge. 24th Street will be widened and the highway ramps reconstructed. I-29/I-80 traffic will be shifted as necessary to accommodate the bridge and ramp construction, and traffic control on 24th Street will provide for one-lane traffic in each direction and a center lane for left-hand turns.

Developing the models

To develop the pilot test of the Google visualization, both 3-D modeling data and scheduling data are required. Existence of scheduling data is common in highway projects; however, a major obstacle is that 3-D models are not generally created for transportation projects as part of the design process. Instead, 3-D models are typically created for major construction projects requiring public involvement or multijurisdictional approvals. The cost to develop 3-D models is usually not included in the original design proposal, and there are currently no methods to generate 3-D models from 2-D drawings.

For this project, the 3-D models were constructed based on the 2-D layout. Then the models were coded in Keyhole Markup Language (KML) to work with schedule data in Google Earth. Development time was tracked and analyzed for estimation of labor hours required for development of similar visualizations on future projects. Both 3-D models for this project were created and saved using Google SketchUp. These included: 1) project-specific models; and 2) library models. They were also saved as an interoperable format to use in Google Earth.

Project-specific models

Project-specific models are tailored to specific parts of the project, including different types of roads, bridges, intersections, ramps, and so forth. The models were created based on 2-D drawings retrieved from the bridge designer. The PDF drawings were converted into 2-D JPG images to use as a base for 3-D models. **Figure 2** shows the completed 3-D model of a six-lane bridge over the base 2-D drawings.

Figure 2 – Completed 3-D model of a six-lane bridge over the base 2-D drawings

After the 2-D outlines were created, the 3-D models were created by specifying heights to each region as shown in **Figure 3**.

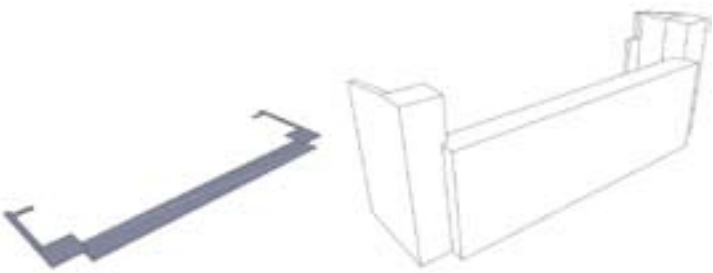

Figure 3 – 3-D models created by specifying heights to each region

Colors and textures, or materials, were added to model faces. **Figure 4** shows wing wall models with and without stone material applied. **Figure 5** shows a material in a transparent type of safety fence using a Portable Network Graphic (PNG) image.

Figure 4 – Wing wall models with and without stone material applied

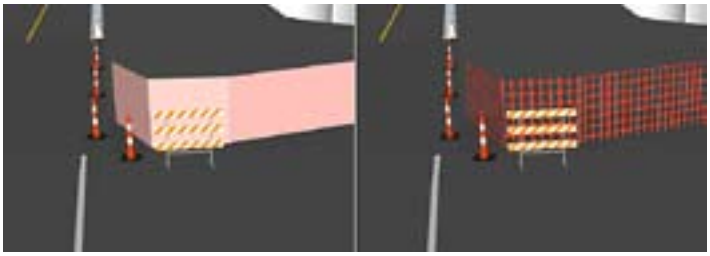

Figure 5 – Material in a transparent type of safety fence using a portable network graphic (PNG) image

The level of detail of the project-specific models can be varied depending on the purpose. Since the highway work zone was the main purpose in this research, some details such as crown slopes were omitted.

Library models

The 3-D library models were created separately from the project-based models. The library models are defined as 3-D models reusable for any project. Most of the objects in the 3-D library are traffic signs and temporary traffic control devices. The library was also saved for reuse. **Figure 6** shows examples of 3-D library models created and used in this research. From left to right are: tabular marker, electronic sign (chevron sign), barricade, and flagger. *Note: these icons are not to scale, but would be at-scale when incorporated into a visualization program.*

Figure 6 – Examples of 3-D library models created and used in this research

These library models were imported directly into the work zone visualization and set at locations according to traffic-management layout drawings as shown in **Figure 7**.

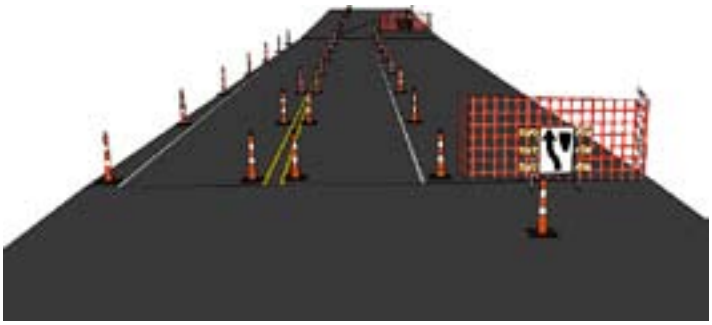

Figure 7 – Library models imported directly into the work zone visualization model

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Scheduling data

For the highway construction schedule, in addition to the typical construction schedule, tasks were grouped into stages for traffic control. Instead of using start and end dates for separate tasks, start and end dates of traffic work zone stages were used. Each stage schedule is linked to a 3-D model representing the work zone configuration under that stage of construction. A time navigation tool is used to control the time function in Google Earth. The actual work zone configuration for the final stage of construction is shown in **Figure 8**.

Figure 8 – Actual work zone configuration for the final stage of construction

Future applications

Potential future applications of Google visualization involve the examination of queue lengths, wait times, turning movements, blind spots, and many other types of work zone analysis prior to the start of construction. Since traffic data is similar in nature to schedule data, the visualization could be modified to incorporate a realistic traffic mix and flow, providing major benefits for both large and small-scale construction projects.

Future development of Google visualization will improve the accuracy and dimensional scale of the models. If the highway construction design process moves from 2-D to 3-D design, the 3-D models will be available without recreating them. The work zone visualizations are easily posted to project Web sites and provide a low-cost, useful tool for communicating with stakeholders regarding current and future traffic work zones.

*[**Note**: Over 50 studies and evaluations have been completed since the inception of the SWZDI and are presented online at **www.ctre.iastate.edu/smartwz/index.cfm.**]*

About the authors

Kelly Strong earned his bachelor of arts degree in civil engineering from Iowa State University, a master of business administration degree from the University of St. Thomas, and a doctorate in strategy and organization management from the University of Colorado.

Dr. Strong is currently an associate professor of civil and construction engineering at Iowa State University, and associate director for construction management and technology research at the Center for Transportation Research and Education (CTRE).

Daniel Sprengeler earned his bachelor of arts degree in civil engineering from Iowa State University in 1983. Sprengeler is currently the work zone traffic control engineer for the Iowa DOT. In addition to his work zone safety responsibilities, Sprengeler serves as the department's project coordinator for the Smart Work Zone Deployment Initiative pooled-fund study and oversees contract administration for all of the pooled-fund's research projects.

Sprengeler has been employed by the Iowa DOT since 1984 and is a registered professional engineer in the State of Iowa.

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