Visualizing TIP Projects in Google Earth Web Browser

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Abstract:
SAFETEA-LU mandates that MPOs empower the public by providing them with data and information in a format that they can easily use and understand. This includes publishing transportation plans and transportation improvement plans (TIPS) on the Internet and utilizing visualization techniques to communicate this information.

This paper will describe how PPACG developed a webpage that embedded Google Earth© to display regional information showing environmental, socioeconomic and transportation layers. This includes specific instructions in using for creating the content. The goal is create an easy way for decision-makers, stakeholders and voters to understand how proposed transportation projects interact with the region.

Background:
SAFETEA-LU mandates both that MPOs utilize the internet to publish their long range transportation plans and transportation improvement plans (TIPS), and that they also make use of visualization techniques to communicate this information more effectively. Both of these requirements are designed to empower the public by providing them with data and information in a format that they can easily use and understand.

MPOs shall publish or otherwise make available for public review transportation plans and TIPs “including (to the maximum extent practicable) in electronically accessible formats and means, such as the World Wide Web” 23 U.S.C. 134(i)(6) and 49 U.S.C. 5303(i)(6)

As part of transportation plan and TIP development, MPOs shall employ visualization techniques to the maximum extent practicable. 23 U.S.C. 134(i)(5)(C)(ii) and 49 U.S.C. 5303(i)(5)(C)(ii)

To meet these requirements the Pikes Peak Area Council of Governments (PPACG) MPO continues to revise and expand its use of the virtual globe Google Earth© (GE). Virtual globes combine satellite imagery, aerial photography, digital terrain data, and geospatial information - borders, roads, etc., - into a highly accurate three-dimensional model. While the surfaces shown are typically terrain elevation, they can be modified to show abstract quantities, such as air quality pollutant concentrations, noise propagation, or even demographic variables like population density, per capita income, etc. The goal of this project is to communicate with the public by creating a user-friendly visualization of proposed projects and related information in a very usable format. In addition to overlaying relevant social, economic and ecological information onto the region, 3D models of individual transportation projects were created to depict the likely project location and impact.

As PPACG has matured in its use of GE there came a realization that the next iteration of the system should offer these 3D views without installing software on each machine. The answer is embedding GE into an Internet webpage. Communication can be further enhanced with easy search functions based on location, funding source, project type, etc. Also, preprogrammed
“guided tours” that show the viewer project information from a regional context, to a plan view, to low angle perspectives circling the site, to driver experience views, and finally oblique views of the entire project. Also, “movies” that show how a location is likely to function with and without a proposed project can be created and linked to. In GE, drop down menus allow users to select projects.

This paper will describe how PPACG developed a webpage that embedded Google Earth© to display regional information showing environmental, socioeconomic and transportation layers and describe how other agencies could construct 3D models using Google’s Trimble SketchUp©, and paint programs (Adobe PhotoShop©), and Google Earth©. The goal is create an easy way for decision-makers, stakeholders and voters to understand how proposed transportation projects interact with the region.

**Purpose:**
There is an on-going and increasing emphasis placed on using visualization techniques to enhance public knowledge and involvement. This includes informing the public on individual project locations and relations between transportation projects and community and environmental data. In order to maintain a transparent selection process, information used during scoring should also be available to the public so that they can understand why individual projects were and were not selected. Ideally, all of this information is available in one easily used and understood location.

In order to aid this process PPACG has been utilizing Google Earth to depict projects for both the Regional Transportation Plan (RTP) and Transportation Improvement Program (TIP). Google Earth offers a virtual landscape and site specific models help users see the proposal. However, this use has also presented some challenges. First, it requires users to download software onto their computers. Libraries and citizens are often reluctant to do this. Second, the information is contained in either a kml or kmz file that are downloaded from the PPACG website. This means that information that is old or sensitive is out of control of PPACG. The solution to both of these issues is to embed Google Earth into the PPACG website. Advances in technology have made this solution relatively straight forward and achievable by MPO’s of all sizes.

The web enabled plug-in for Google Earth, with custom models for each project and data set provides a useable and useful visualization. Users can see how new on-ramps connect with existing roads. They understand potential right-of-way requirements. Environmental conflicts become more apparent. The hope is that with better information there is less confusion and more acceptance that can inform decision making.

**Introduction**
There is a plug-in for web browsers readily available that offers custom applications of Google Earth (see Google Earth API site information). Socioeconomic, environmental and transportation
data typically involves GIS layers, requiring ArcGIS skills for symbolizing, and exporting. There are also programs (e.g. Sketch-up, ArcGIS) that can be used to create custom 3D content for Google Earth.

**SketchUp**
Trimble SketchUp creates the content. For example, the City of Colorado Springs submitted a layout for a proposed overpass project. The 2D jpg image overlays the design on an aerial image (Figure 1). A SketchUp tool captures site specific imagery and terrain elevation (Figure 2).

![Figure 1: Image of Proposed Project](image1)

![Figure 2: Location Capture in SketchUp](image2)
The conceptual design is digitized to a 3D drawing with elevated ramps and photo-real surfaces (Figure 3).

Figure 3: SketchUp model of proposed overpass (US 24 & 8th)

The SketchUp process for creating roads requires a basic understanding of the software. Describing the details is beyond the scope of this paper. Readers can view the YouTube.com videos on “Getting Started” or accept that parts of the next few paragraphs may not make complete sense.

The process starts by capturing the terrain and imagery of the proposed road improvement (Add Location Tool). If available, the user can place the site plan image on a polygon as a reference for digitizing. Aligning the imagery is easiest with flat terrain and a semi-transparent site plan image. A toggle switch turns on the terrain elevation. However, make sure the final 3D model is built with the terrain toggle on, showing the topography.

The typical process started with vertical pegs (blue line, 5-10 feet high) placed at regular intervals on one side of the roadway (Figure 4). For undulating terrain these should be located at the high points. The top of the pegs are connected with a line.
Then cross road lines are drawn (ideally in the red or green direction). A triangle is completed by connecting the segments of these two lines. This line is broken with a shorter line segment and then this intermediate point is moved, creating a four sided polygon. Within this polygon, inference can create a perpendicular line segment measured to match the width of the roadway. Then inference can create a parallel line for the other side of the road. Repeat for the next triangle.

It is useful to build the polygons incrementally down the length of the road. This will assure each segment connects to the last, avoiding unsightly gaps. Vertical adjustments usually break the rectangular polygons into triangles (see Materials below). Overpasses use taller vertical pegs (30-50 feet). Access ramps use triangles to align with through sections. Side slopes can be constructed with triangles connecting the roads with the terrain.

Use the Hide tool if the plan polygon obscures the site and the Undo button is your friend. Save often and save important milestones in the design. SketchUp will export the model directly to Google Earth. Perform the export periodically to identify site specific issues (e.g. areas of z-fighting). There are other techniques for digitizing the roadway and each user should experiment to find their best method. The caveat section of this paper contains additional guidance.

**Materials**

SketchUp comes with hundreds of surface textures, called materials. Applying these images to polygons creates a photo-real appearance. SketchUp can import 2d raster images (jpg, png, gif, tif, bmp, psd). Paint programs can generate the raster image with the design based on the ratios cross sectional width (lanes + median + shoulders). Images with dimensions of a couple hundred pixels work best, reducing the rendering demands for video cards.

The road textures were created in Adobe Photoshop, but simpler paint programs work too. A series of textures were created for the projects depicting typical road cross-sections, including 2 lane roads, interchange ramps, and divided highways for highways multi-lane highways (Figure 5). The images could use actual photos of existing roads, although edge mapping inconsistencies may create unnatural, repetitive artifacts.

![Figure 5: Series of typical road cross sections, depicted as simple images.](image)

After placing a material on a polygon, it must be aligned (Figure 6). The image will automatically repeat along the length of the segment. It is useful to square the rectangles (search help on “inference”), so that the textures can be aligned perpendicular to the road alignment. Pushpins set the anchor point (red), scale and alignment (green), while the skew pins are rarely used for roads (blue and yellow). A series of tangential segments usually portray curves. More segments will create a more natural curve, but the time of digitizing increases accordingly.
SketchUp digitizing has some unique challenges:

- The road surfaces must be coplanar, and form a closed loop. It is fairly easy to digitize triangles to depict terrain and road surface. However, the road surface polygon should be a rectangle to facilitate alignment of the Materials image depicting the road cross-section. The polygons should be created as rectangles rather than triangles so that the entire road cross-section can be viewed.

- Proposed road surfaces laying directly on the terrain may flash on and off, known as Z-fighting or stitching. The software cannot determine which layer has display priority because they are so close together. This effect is exaggerated at higher elevations because the relative ratio of height distances becomes less. This effect is minimized by raising the road polygon a few feet above the existing terrain. Raising the road polygon too high makes it appear to float above landscape. Undulating terrain can be problematic and Google Earth does not allow editing of the terrain.

- Moving road surfaces rectangles vertically may cause the polygon to break into a series of triangles losing the alignment of the materials.

**Google Earth**

Final preparation of the model occurs in Google Earth. Although the Google Earth plug-in will display the model in a web browser, organizing and creating its tour involves the use of Google Earth desktop. In the Places directory (left side), users can drag and drop components, rename
them in Properties, and Save Place As with appropriate file names. Google Earth models use a kml or kmz extension (Figure 7).

The file exported from SketchUp is in a SUPreview folder. Plussing up the folder shows the model which is renamed and moved to a new folder (prevents overwriting of future SketchUp exports).

Figure 7 Google Earth displaying 3D model imported from SketchUp (US 24 at Airport/Stewart in Colorado Springs.

PPACG also displays regional data showing environmental, socioeconomic and transportation layers. ESRI ArcGIS can export to Google Earth kmz files, preserving the symbology of the layer. Google Earth Pro can import shapefiles; offering greater control over the symbology and labeling. Buffered street centerline (GIS layers) show resurfacing projects with a transparency applied to the polygon. Trails are digitized directly in Google Earth as lines.

Data Overlays
The Google Earth interface can display typical GIS data overlays. PPACG includes layers on demographics, the environment and transportation. Google Earth Pro is used to import ESRI shapefiles and many other formats. The Pro version also offers customizable templates for managing symbology and selecting label names. Point and line layers are the easiest to symbolize. Using transparency on polygon layers can improve recognition of place context (Figure 8). Clicking on a location displays details about the place.
Enhancements to the data can improve its power to communicate its information. In Figure 9, each polygon was simplified to a rectangle. The size of the rectangle depicts the total population in that Census Block Group. The height of the extruded polygon relates to the percent of households with zero vehicles. This percentage figure is also grouped and symbolized by color.

Figure 9: Extruded Polygons in Google Earth (Census Zero Car Households).
Tour

The tour offers a canned presentation of the proposed project. It frees the novice user from navigating through the landscape. The tour explores the proposed construction, emphasizing essential features and relationships. Think like a movie director; offering context, guiding the viewer through the story, highlighting nuances and then showing a strong conclusion.

A tour follows a series of Placemarks identifying specific views (Figure 10). Each Placemark acts like a frame in a movie storyboard. Google Earth offers a tool which records the route as the viewer flies through the Placemarks. The goal is to take the viewer through continuous series of images illustrating the location and design of the proposed project.

The first frame offers a common starting point (storyboard to the right). In this case we show the entire planning area, Teller and El Paso Counties (Colorado). Then the tour flies through various overhead plan views depicting the site and its vicinity. The viewing frames transition to a more oblique view, always including the horizon. The frames circle the proposed improvements or follow the proposed road alignment. Flying through overpasses provides a dramatic sense of the driving experience. The final slide should show the entire project, focusing on a known reference geography or standard direction. For Pikes Peak Area Council of Governments, the final frame looks toward... Pikes Peak!

A smooth recording of the tour will reduce the potential for users experiencing motion sickness. Presenters should always consider preparing a tour for live demonstrations of Google Earth. This reduces quick movements that usually miss their intended mark. Users can turn off the proposed road model and rerun the tour to see existing conditions at the site. Similar tours can explore socioeconomic, environmental and transportation data.

Figure 10: Storyboard of Google Earth Tour.
Plug-in Web Interface

In addition to the standalone Google Earth application, Google also offers a free web browser based Google Earth Plug-in that includes an open application programming interface (API) written in the javascript programming language. When users install the free Google Earth Plug-in, they can explore the world from their web browser, and the open API allows websites to present a variety of different views and features which tie in with the Google Earth global map data.

Content Integration

With a final list of over 100 TIP Projects as well as multiple dimensions that different users may be interested in accessing this information (by year, sponsor, area, type, funding source), one challenge has been designing a user interface that is simple, flexible, and easy to use.

The approach that has been chosen for this application uses a categorized list of projects and supporting data (demographics, environmental, transportation) that offers users different ways to search and find the information they are most interested in. The list is organized in a hierarchy. Initially, users are presented with a short simple list of choices (see image below on the left). When users click on a link at the first level, it opens up the links of the next level. Users continue to click through the hierarchy, and the final level displays a list of checkboxes and links for each TIP project or type of supporting data (Figure 11).

![Image of web-enabled Google Earth interface](image)

Figure 11: Web-Enabled Google Earth Interface.

When users click one of the links for a TIP project, the Google Earth Plug-in loads and plays an interactive tour of that project’s location. If the user selected the checkbox next to the TIP project link, a 3D model of that project will also be displayed during the interactive tour. The Google Earth Plug-in gives users controls to pause the tour and change the view in the map window to any direction, altitude, or zoom level.
This hierarchical navigational approach gives all users access to all the data in multiple ways, and provides a simple and intuitive way for different users to search for TIP projects based on their specific interest or purpose.

**Application Architecture and Update Process**

The actual project data and interactive tour .kmz files will all be stored in a MySQL database. This has three main benefits: it allows non-technically skilled people to easily input and update the project data, it allows layout and design changes to be accomplished more simply, and it separates all of the programming code from the project data.

A web based data entry form will allow non-technically skilled people to add, edit and delete information about each project that will be presented through the user interface without directly accessing any of the programming code.

When users navigate to the main PPACG TIP Project web page, scripts written in javascript and PHP programming languages will first retrieve the project data from the MySQL database, and then format and output that data to the web page. This allows any layout and design changes to be implemented more simply by making changes to these scripts. When users click on a link for a TIP project, the Google Earth Plug-in loads and plays the chosen interactive tour .kmz file.

Separating the actual project data and interactive tour .kmz files from the programming source code eliminates the possibility that one person making data entries or updates might inadvertently make changes to or overwrite any of the programming source code. It also allows data entries and updates to be made by one group at the same time that another group might be making changes to the programming code by another group.

**Disclaimer**

The models depict a long-range planning level of detail. The final alignments, grades and connections will change as the design process proceeds. Users must recognize the model is approximately right. Spending hundreds of hours digitizing details may create a product that is precisely wrong. Highway design professionals may quibble with inaccuracies, but the purpose is to illustrate the plan rather than create a final design. Finally, remember that the end-user is using a web browser on a typical computer. Complex models require longer upload times, slow video rendering and a lousy user experience.

The web browser contains a disclaimer:

"The information on this page is for long range planning purposes only. No warranties, expressed or implied are provided for the data herein, its use or interpretation. All items are subject to change."
Caveats
Learning SketchUp requires an investment of time to learn the software and methods of creating 3D models. Google Earth has fewer controls, but users still must practice to master navigation and other functions. YouTube SketchUp channel contains excellent video driven tutorials, although the content emphasizes architectural techniques. Adapting the techniques to transportation projects requires some creativity, but hopefully this paper will offer useful guidance. SketchUp is easier to learn and use than most design programs. Still, proficiency in SketchUp requires an investment of time. This paper describes the unique skills and processes used to create this project, without offering details about the interfaces and techniques.

SketchUp can import CAD drawings, but this effort is rarely useful. These design drawings are generated from many, many short line segments with few polygons. CAD drawings might offer location, but its level of detail and vector format limit its value.

Both Google Earth and SketchUp offer free versions with powerful capabilities. These software products are intended for personal use, not commercial use. Both can be purchased (SketchUp Pro and Google Earth Pro) and these upgraded versions offer additional capabilities. Users should read the licensing agreement to determine the limitations of the free versions.

Conclusion
Virtual globes combine satellite imagery, aerial photography, digital terrain data, and geospatial information - borders, roads, etc., - into highly accurate three-dimensional models. With the continued emphasis on communicating with the public, embedding a virtual globe into a webpage creates a relatively secure user-friendly visualization of proposed projects and related information that is achievable by MPO’s of all sizes. In addition to overlaying relevant social, economic and ecological information onto the region, 3D models of individual transportation projects can increase understanding of the likely project location and impact.

This paper described how PPACG developed a webpage that embedded Google Earth© to display regional information showing environmental, socioeconomic and transportation layers and describe how other agencies could construct 3D models using Google’s Trimble SketchUp©, and paint programs (Adobe PhotoShop©), and Google Earth©. The goal is create an easy way for decision-makers, stakeholders and voters to understand how proposed transportation projects interact with the region.
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