Better, Stronger, Faster: How Oblique Aerial Imagery is changing the Face of Transportation Planning

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Abstract

This research was preformed to study how oblique aerial imagery is being used in transportation planning applications and to attempt to determine the resulting effects of that use. A list of possible users was generated and subsequent interviews were held either in person or through phone or web conferencing. An interview tool was used that allowed for free-form discussion of the technology; its current uses and the benefits of that use. Challenges to using the technology and future applications and capabilities were also discussed.

As the technology is only recently implemented for transportation applications, the findings show a range of uses for oblique imagery, and qualitatively positive impact on extending staff time, resources, data accuracy and safety, but quantifiable impact could not be established.

"Oblique photographs are not widely used, primarily because the drastic changes in scale that occur from foreground to background prevent convenient measurement of distances, areas, and elevations (1)."

This problem is now resolved.

INTRODUCTION

This paper will give a brief history and explanation of the uses of imagery in transportation planning. It will then discuss low altitude oblique digital photography in the context of examples of current uses in transportation planning. The aim is to increase the general body of knowledge among the current users, spark the imaginations of those who have access to the technology but are not yet using it and inform the rest of us of the technological development of this aspect of remotely sensed imagery.

Remote Sensing is the practice of deriving information about the earth's surface using images acquired from an overhead perspective, using electromagnetic radiation reflected or emitted from the earth's surface (1).

Transportation planners have been using remotely sensed imagery data since at least 1927, when aerial photography was used to survey highway traffic between Baltimore, MD and Washington, DC (2). Each new generation of technology in imagery data collection has improved the state of the art and the state of the practice in transportation planning. Remotely captured low altitude oblique digital photography is a recent innovation in aerial photography that is currently improving the work of the transportation planners that have access to it.

From photography being used from a balloon to capture aerial views of the earth's surface in 1858, to Wilbur Wright's flight over Centocelli in 1909, to the coining of the term "remote sensing" in the 1960s, a great distance has been traversed in the technology of remotely sensed imagery (1). Advances in computing power have increased the capabilities of both the collection and use of remotely sensed data. Digital oblique aerial imagery combined with intelligent interpretive software is one of the newest additions to the family of remotely sensed data.

Oblique aerial imagery is distinct from more traditional and widely available orthophotos, in that orthophotos present a plan view of the covered area. Further, each pixel is ortho-rectified so that each appears to be the nadir of the view for measurement purposes. Orthophoto views are top-down, straight angle views, and it is generally agreed that some training and expertise are required to interpret them. Oblique imagery is angled view imagery in which four directions are captured so that feature faces and the represented area can be seen from north, south, east and west (Figure 1). Oblique imagery provides, essentially, a three-dimensional view, and with the development of interpretive software, is used for a wide variety of transportation planning applications. For some of these, orthophotos have traditionally been used and the introduction of oblique imagery data improves the application. For others orthophotos are inadequate and so oblique imagery renders them possible as new transportation planning applications.

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FIGURE 1: The Difference between Orthophotos and Oblique Imagery; A) Orthophoto of Transamerica Building, San Francisco, CA, B) Oblique Image of Transamerica Building, San Francisco, CA

The interpretive software programs are not geographical information systems (GIS) as they are understood today. Instead, they are information systems that allow for navigation and prolific use of both orthophotos and oblique images. The software programs also incorporate the use of GIS layers and data and multiple measurement and viewing capabilities. GIS data can also be created within the software using oblique imagery or orthophotos as an internal reference, but higher end GIS functions such as spatial queries have not been duplicated. While the software programs are reportedly easy to use, GIS professionals interviewed would like to be able to use oblique imagery more directly in their GIS environment.

Benefits of Oblique Imagery

The Federal Government has long recognized the value and potential benefits of acquiring and analyzing remote sensed data. The Transportation Equity Act for the 21st Century's (TEA-21) authority to carry out a Commercial Remote Sensing Products and Spatial Information Technologies Program in cooperation with NASA in 1998 (3) is a comparatively recent act in the long history of governmental support for developing and using remote sensing technology. Since the 1920s, there has been federal support across several agencies for developing remote sensing. The Department of Agriculture together with the Tennessee Valley Authority initiated the institutionalization of the use of aerial photography in government by their use of it for environmental and economic planning during the 1930s. Naturally, the Department of Defense utilized remote sensing heavily starting with World War II and continues to do so presently (1).

Today, the US Department of Transportation's Federal Highway Administration (FHWA) acknowledges that imagery is an important data source for planners at State Departments of Transportation (SDOTs) and Metropolitan Planning Organizations (MPOs). The National Highway Institute offers training in remote sensing (4). The newly formed Research Innovation and Technology Administration's (RITA) Transportation Science and Technology Office (SCITECH) maintains the Remote Sensing and Spatial Information Applications pages (3). In recent history, the now defunct Research and Special Programs Administration together with several universities and commercial partners, implemented the National Consortia on Remote Sensing in Transportation (5). In short, support for remote sensing applications in transportation runs long and deep. Interpretable oblique imagery, however, is too new to have history. It has only been around for about five years and is only now beginning to have any significant impact.

In order to determine if one is interested in a particular technology it is useful to know how the technology may improve the current situation. Some benefits discovered in interviews with users of low altitude oblique digital photography are that it:

Saves labor, time and money,
Reduces travel expense,
Reduces or eliminates field visits,
Provides increased accuracy for data verification and data collection,
Requires less interpretation by users, and
Is an excellent tool for public processes, in that it increases problem understanding by the public and decision makers alike.

These benefits apply across many planning areas including planning analysis, safety and communication.

METHODOLOGY

Availability and use

While there are many providers of oblique aerial imagery, there are relatively few providers of oblique imagery and interpretive software suitable for planning applications.

One firm sells a product developed in 2003 that offers a combined orthophoto and oblique view and can, with a desktop application, interpret and show measurements on any oblique photograph. A second firm offers a product that also integrates vertical and oblique aerial photos into a single site file, enabling viewers to navigate and measure locations within the file. This product also can interpret any aerial photograph. A third firm produces an information system that combines high resolution, digital orthogonal and oblique images with an interpretive software system. The product does not analyze third party photographs (6) (7) (8).

It is an admitted shortcoming of this paper that a wide array of varied data is not available to analyze. Customer information is naturally proprietary, and the field is relatively young. These obstacles make data collection difficult. Data was requested from all three vendors but at the time the research was undertaken data was available only from the co-author's firm, who provided a comprehensive customer list of counties that have acquired the technology and have it in house. The list included 140 counties and cities; from the vendor's first sale in 2001 to Arlington County, Virginia, to their most recent customers such as the Pima Association of Governments whose data were delivered July 15, 2005.

It was decided to interview or survey MPOs that had the technology covering more than 50% of their land area or population. Ultimately, as a result of some interviews where it was recommended that other agencies be interviewed, certain state agencies and cities were contacted as well.

A spatial analysis was performed to determine how many counties fell within an MPO area, and what percentage of each MPO's land area and population was covered by the customer county. Fifty-eight MPOs were represented by 108 of the 140 counties. For some MPOs, coverage was quite irrelevant. In the cases of the Denver Regional Council of Governments and the Houston Galveston Area Council, for example, a single client county in each MPO represents less than eight percent of the total MPO population. Of the 58 MPOs, 43 have coverage over greater than 50% of their land or population, 34 have coverage over greater than 50% of their land area and population and 26 have 100% coverage over both (either every county in the MPO has the technology, or the MPO is comprised of only one county that has the technology). Eight had at least 50% population coverage over less than 50% of land, and the Cleveland, Ohio MPO, the Northeast Ohio Area-wide Coordinating Agency, has 56% of land covered, but only 28% of its population.

After eliminating MPOs with less than 50% of population and land area covered, 36 transportation planners, modelers and GIS professionals from 28 MPOs were interviewed or surveyed in person or by telephone about their use of oblique imagery for transportation planning purposes. Additionally, nine planners, engineers and GIS specialists were interviewed at the Massachusetts Highway Department, Massachusetts Department of Conservation and Recreation (DCR) and the City of Rockville, MD.

Assumptions about access of the technology between the counties and the MPOs are based on knowledge of licensing agreements between the purchasers and the vendor. The data can be licensed by a County, a State or the Federal Government. When an entity agrees to a license, they are allowed to distribute and use the data and software within any of the departments within that entity. Since MPOs are generally geographically aligned with counties, they fall under the licensing terms of the purchasing county. For counties with the technology, all county agencies, cities, and governmental subdivisions can obtain and use the data with unlimited seats of the software and copies of the data.

Despite the wide inter-agency availability of the technology there was some lack of awareness and use of the technology. This can be attributable to various causes; delivery dates may have been too recent, staff may be unaware of licensing terms allowing them to share, entrenched views may make personnel on one end of the transaction uninterested in using or disseminating new technology. For these reasons, at 31 agencies where the technology is ostensibly available, 17 are utilizing oblique imagery to varying degrees for transportation planning purposes, and at four more agencies either the GIS group or planners are aware but not using the technology. Planners at twelve agencies had no idea the technology was available and it is not utilized.

CURRENT APPLICATIONS

Entirely new transportation applications afforded by the interpreted oblique images are not numerous but they do introduce valuable data and capabilities. Below are examples of applications currently in use by planners interviewed for this research for which orthophotos and un-interpretable oblique imagery are insufficient. Because a planner is executing these applications in a manner previously inconceivable, they are referred to as new applications.

Transportation planners, from their office desks, are now:

Allocating floor space by area type. This information is necessary for increased accuracy in travel demand modeling; the technology gives the ability to view not just the number of buildings in a given Traffic Analysis Zone (TAZ), but also to measure the height, count the stories and acquire an idea of building condition.

Clearly seeing views not available from the ground. It is commonly understood that having an overall scope or view of an area aids in the visualization of and solution to a problem. While it is cost prohibitive to put a team of planners, engineers and architects on a plane and fly them over an area, oblique imagery allows this to take place virtually from an office or a laptop in the field. The concept of taking a "virtual tour" can be used by land use planners and developers as well. Parcel data can be overlaid on oblique images allowing for comparisons of tracts of land as well as surrounding infrastructure.

Collecting increased and improved data. Oblique imagery may allow users to see assets too small to recognize in orthogonal photography such as sidewalks, traffic control devices, pavement markings, etc.

Identifying Vertical Code Violations. Oblique imagery gives the ability to measure vertical surfaces such as fences or brush lines and the offset of those surfaces from the pavement edge.

Additionally, there is a general consensus (and supporting history outside of transportation usage) that the more this new technology is implemented, the more additional uses will be discovered and invented.

Planning and analysis

An FHWA planner neatly summed: "Most local planning agencies are really strapped for funds. There is never enough money for staff, for travel and it's difficult for staff to get out in the field. If visualization can be cost effective it would help them with the road condition data, adjacent land use, trip generation, pedestrian travel condition information without having to go into the field. Most of the small agencies I have experience with, did not have the staff to support land use or travel models. Having an inventory that would allow them to access the imagery without having to send someone out in the field would allow for better decision making. Most of the MPOs I worked with had only one staff person doing the planning. They need a tool to improve quality and efficiency by providing a comprehensive inventory."

Infrastructure Inventory

The single most frequently mentioned use of oblique imagery for transportation planning is conducting and maintaining infrastructure inventory. In road inventory everything can be seen, counted or measured, including number of lanes, turning lanes, pavement markings, traffic control devices etc. In cases where identification is not possible, a site visit is called for. However, as a rule, site visits decrease dramatically with the implementation of oblique imagery and software. Numerous sidewalk and crosswalk inventories for pedestrian safety are currently being undertaken with oblique imagery. Theoretically, a billboard inventory both for obstructions and to see who was using them could be performed.

Identify centroid connectors – TAZ Validation

Oblique imagery has a variety of uses for modelers, most of which aim to improve model accuracy. The above-mentioned ability to allocate square footage by area type has the benefit of improving data for both trip generation and distribution. An Atlanta Regional Commission project to visually identify centroid connectors for TAZ validation is an innovative use of oblique imagery that should help to increase model accuracy in the Atlanta region. Other applications are the ability to disaggregate to a smaller study area if desired, and the ability to better determine TAZ density.

Estimate Walk Access to Transit

Orthogonal imagery presents problems for sidewalk inventory in projects to estimate walk access to transit. Portland Metro, in Oregon, discovered that insufficient contrast orthogonal imagery flown at one-foot resolution and leaf coverage concealing sidewalks and paths made interpretation to the detail desired impossible. Additional field visits for data collection were necessary to complete the project (3). Atlanta Regional Commission, in a similar project, is using comparatively higher resolution oblique imagery and is successfully completing their access to transit project in a relatively short time-frame.

Land Use Classification

In keeping with the USGS 1976 land use and land cover classification scheme, oblique imagery is excellent for second and third level classification identification. Third level classifications, those that are subjective and must be determined by planners, of urban or built-up land relevant to transportation and land use planning are increasingly accurate with this technology. It is easily possible to distinguish among the level two classifications to obtain and refine detailed, accurate, local knowledge.

Safety

Public safety officials spearheaded the use of oblique digital imagery and have advanced the technology as they have embraced it. One of the more distinct advancements is the recognition and response to transportation issues. Transportation planners also must employ safety conscious planning principles. Whether the issue is a common daily planning requirement, as pedestrian safety, or one we must plan for but hope never happens, as evacuation planning in the event of terrorist attack, oblique imagery puts a recognizable face on the transportation component of the event. Some current applications found utilized in the field today include:

Dignitary Safety/Event Planning

Oblique imagery is used in preparation for and during transportation interruptions, such as presidential visits and marathon planning. In these cases, major transportation corridors are closed to traffic and plans must be in place to allow that to happen smoothly, reconstruct traffic patterns during the shutdown period, allow for safety precautions and contingency plans and at the conclusion reopen the corridors to traffic.

Emergency Preparedness

Emergency Preparedness includes a predefined plan that allows for a uniform and concise response that will ultimately reduce fatalities. A major factor of preparedness planning is knowledge of incident locations and their surrounding areas. Having an archive of interpretable oblique imagery is unquestionably a perfect complement to asset and inventory management, link volume and capacity information, terrain considerations and even hazardous plume modeling. Furthermore, a preparedness plan can be disseminated to individuals with an untrained eye for GIS or orthophotos and will be readily understood and acted upon.

Pedestrian Safety

The layout of current infrastructure and assets can be captured, overlaid and viewed on oblique imagery. Plans can be derived for areas that need improvement and areas in question can be visually surveyed.

In this example from the city of Rockville, MD (Figure 2) oblique imagery was used to plan, design and display pedestrian safety improvements.

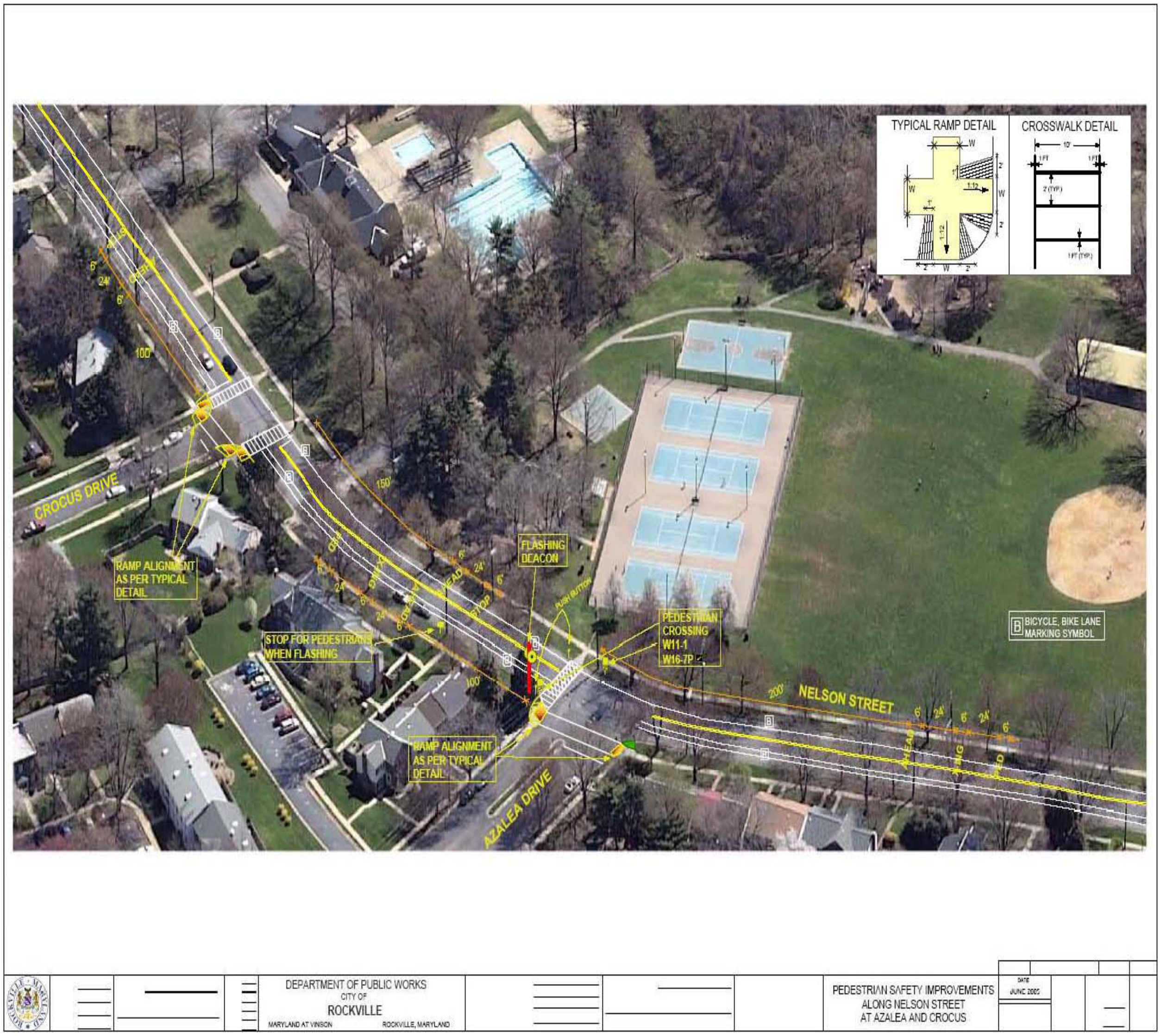

FIGURE 2: Pedestrian Safety Improvements Plan, City of Rockville, MD

Emergency Response

States are responsible for coordinating and obtaining remote sensing to support their own disaster response operations. To effectively exercise that responsibility, States are highly encouraged to identify potential state (e.g., National Guard), local, and commercial remote sensing providers in their region, determine their capabilities and availability, and develop/establish appropriate contingency support agreements (9)

Digital oblique imagery has been used in disaster response situations of all kinds. In some instances the imagery was already available, in other cases it was acquired specifically for the disaster and in yet other cases one set of imagery was available and a second set was captured after the event (before and after images) such as was the case with Hurricane Charlie (Figure 3).

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FIGURE 3: Before and after disaster imagery; A) Before Hurricane Charlie; B) After Hurricane Charlie

Accident Reporting / Analysis

Law enforcement officials can accurately locate an accident site using oblique imagery in the field. Accident data can be reconstructed in a digital format directly on an image of the area. The cumulative data can be used for safety planning, crash hot spot detection and analysis of roads and intersections. Crash causing obstacles not detectable with orthophoto imagery, such as obstructing walls or foliage, can easily be identified with oblique imagery

Snow Removal Planning

Oblique imagery is generally captured during “leaf off” conditions with no snow. Assets that will be hidden during snow coverage times can easily be viewed and located. By overlaying corresponding data, such as school bus routes and critical crosswalks, with snow removal routes, flaws in plans that may have been derived without knowledge of the aforementioned data sets are readily apparent and easily repaired.

Search and Rescue / Fire Control

The software used with oblique imagery allows for input of coordinates and addresses. In such cases as cellular 911 calls this technology is imperative for saving lives. Emergency responders report that oblique imagery provides a qualitative increase in ease of access and mental preparation for response.

In search and rescue events, a grid can be overlaid on the imagery and coordinates can be radioed in from the searchers to the command center and plotted. The search area will be, therefore, well defined resulting in a systematic and more thorough search, which allows for more accurate time and resource estimations.

Roads are frequently used as fire breaks in the event of brush or wild fires. For planning purposes, canopy on these roads can be checked for overgrowth routinely, ahead of an event, using oblique imagery. Along the same lines, natural "chimneys" can be located with the visible terrain model in oblique imagery.

Communication

Transportation planners are faced with increasing responsibilities of educating decision makers on major infrastructure investments, effectively participating in public involvement and resolving conflicts that arise in the planning process, and they must use every tool in their collective arsenal to do so.

Public Meetings

Probably the most easily recognized attribute of oblique imagery is its "wow" factor. Once that is past, oblique imagery is still excellent in public meetings. Planners say there is no processing time for the public to recognize what it is that they are seeing. For this reason, comprehension and agreement follow more easily. Oblique imagery can be used in a pure form to show current area features or the output can be modified with GIS to show future development. Planners agree that oblique imagery increases understanding of difficult engineering concepts. FHWA is exploring the possibility of using it as a background layer for micro-simulation.

In long range planning and meetings with developers oblique imagery has been used to identify where right-of-way must not be sacrificed, as it impacts future projects already on the books.

Address Complaints Expediently

The ability to see obstructions and also to measure them and their offsets from a planner's desk has resulted in time savings for planners. When a complaint is made it can often be resolved within the time frame of the original phone call. Planners report that they can pull up the locality in question, view the problem, measure, analyze and assess it and often recommend a solution on the spot. Oblique imagery has been used to immediately resolve public complaints from insufficient lighting, to whether or where noise barriers should be located, to whether a traffic island was a public park or not.

Other

Many other uses that cannot be neatly categorized were identified over the course of this research. Oblique imagery is being used to develop a training tool for the Georgia DOT. The DOT required that visual imagery of every type of turn configuration be available to train new personnel. Finding the intersections and producing high quality visuals was a simple process, saving planners hours of fieldwork. One MPO, typically strapped for time and staff, simply sacrificed site visits related to planning roadway projects and developing their Transportation Improvement Program. At Massachusetts DCR the technology was used to discover where an individual had taken the initiative to dam a public waterway, and to develop a dam dismantling plan with the Dam Maintenance Program personnel. (Figure 4) FIGURE 4: The hatched area is land outside DCR's authority. The blue lines are a threatened road and trail within the forest (the road runs below the dam). Some of the logs that make up this illegal dam are 3' - 4' in diameter. Massachusetts Department of Conservation and Recreation.

Barriers to Implementation

As with all new technologies, there are challenges to implementation. Little time and less money make it difficult to purchase technology and train staff. Some individuals are resistant to change, visionaries are few and far between, and there are some practical problems as well:

Storage space required for the imagery can be massive depending upon the size of the area that is covered.

Implementation of the data and software to hundreds of users can be a challenge.

Strong perception that the cost to capture and implement the technology of oblique imagery is prohibitive. Frequently the data is purchased by a county and shared with the MPO or vice versa. When the use of the data is distributed widely, the cost is not as prohibitive.

- Lack of cross agency communication or interest. Relationships among agencies, overworked staff, understaffed agencies, lack of mechanisms in place to share new technology and information, all contribute to a poor communications. Eleven out of 28 MPO transportation planners interviewed were unaware that they had coverage and access to oblique imagery, in at least three of the eleven cases the GIS group was aware of coverage and access.

Lack of competition in the industry makes for little choice among vendors.

Proof of value is only acknowledged slowly.

FUTURE USES

Barrier/Retaining Wall Inventory

An FHWA planner familiar with the needs of the Bureau of Land Management suggested that, since the software included with the oblique imagery allows measurement of heights and widths, views of facade and vertical areas and offset from the road and elevations can be determined, the structural state of retaining walls can be recognized and a preliminary evaluation of conditions can be made. All without field visits.

Slope Identification

The oblique imagery viewed in all of the interviews during this study incorporated the existing elevation models for that area. The unique capability is to be able to determine and visualize elevation, difference in elevation from point to point, angle of slope and percent rise-to-run on the imagery. The tool set in the software allows the user to choose if the distance should follow the elevation model (terrain – as a ball would roll) or measure the distance virtually (flat screen – as a crow would fly).

Change Analysis

Change analysis allows a user to view an older image next to a new image. Images can be viewed side by side (see Figure 3, above) or in a half overlay mode. Change analysis is used to detect changes in land use, road networks and road markings. Generating before and after project images are another use for change analysis.

Future developments in technology

Interview subjects who are currently using oblique imagery were plainly asked how they would improve the technology. They suggested that the technology would be vastly improved if it were operable within, or as, a GIS.

It seems simple, conceptually, to be able to use oblique imagery in a standard GIS package. Taking this concept to reality is not simple by any means.

First we must understand the hurdles. The oblique imagery software uses a dynamic (non-recto-linear) grid, it also completes an indexed search on a coordinate that retrieves all of the images that represent the selected point, and the software is designed to be image centric. Comparing that to a standard GIS platform that uses a recto-linear grid, processes entirely in layers and revolves around geographic entities, the grid exchange is not at all insignificant. It is labor intensive and of limited value to build north, east, south and west facing layers of data, and it is difficult, at best, to attempt to mosaic oblique images.

In the meantime there are interim steps that have proven very useful:

Coordinate Pass – Code is given to anyone who requests it that allows the user to create a tool that passes a coordinate from the users' GIS software to the oblique imagery software.

An Active X Control – Allows for a "light" version of the software to be used on an Internet application. (New technology is currently under development that will launch the

Active X from a desktop GIS).

Conclusion

Because it is so new, data on how oblique imagery impacts transportation planning is fairly limited. One MPO received their data set a mere two weeks before their interview, but still had a number of ideas on possible uses. Quantitative information is needed on questions of interest such as:

How many or what percent fewer site visits is an agency conducting?

How much faster is public understanding; are public meetings shorter with this technology?

What percentage of greater accuracy is achieved in model results?

How improved is the land use model?

How many seconds are emergency responders saving?

By what percentage are fatalities decreased?

Today we have to be satisfied with qualitative analysis. As time passes and the technology becomes more universally available, data will be collected, quantification will occur. Despite the lack of data for quantitative analysis, qualitative analysis indeed indicates that interpretable oblique imagery is changing the face of transportation planning for the better. One day we will know how much.

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