Understanding Threatened Urban View Corridors with LIDAR Data

Presented at the 2006 ESRI International User Conference

By: Paul Cote
Lecturer in Urban Planning and Design
Harvard University Graduate School of Design

June 30 2006

Paper Abstract

In 2002 the city of Boston built a charismatic new bridge--the cable-stayed Leonard Zakim Bridge. Many places that were previously undistinguished now have new value because of views or potential to create views of this new icon for the city. Likewise, some of these windfall view corridors may be threatened because of view-seeking development that may happen in between.

Also in 2002, the Commonwealth (MassGIS) flew a LIDAR survey of the metropolitan area. We have several applications of this LIDAR survey that investigate potential urban view corridors from existing and unbuilt windows and considering build-out conditions. We explore techniques and applications of fine-scale topographic data for understanding and potentially protecting the visual quality of the city.

Introduction:

This paper is concerned with a new form of geographic data – namely broad-scale three dimensional models of cities collected by airborne laser scanners -- and how this new form of information can lead to new and improved ways of understanding urban design or policy scenarios and their impacts on the visual connectivity across broad areas.

The connectivity of places within a city in terms of distant views to familiar landmarks is very important to how we understand, navigate, and feel about places within a city, and how comfortable we feel about a city as a whole. (Lynch 1960; Hillier, 1996; Hillier and Hanson, 1984). Urban designers and entities responsible for urban design review are therefore interested in methods for evaluating the impacts specific design and policy proposals with regard to their impact on the visual connectedness of places. Developers may add value to their projects by taking advantage of views of important landmarks, and in so doing may block the views from pre-existing developments or public areas. It is common practice for proposals to be evaluated in their immediate context using three dimensional models of in physical and digital form. Consideration of broad-scale impacts and opportunities of proposals in a city-wide sense has been much less common owing to the difficulty of building, sharing, and experimenting with very broad-scale urban models.

Recent innovations in data collection – namely airborne 3d scans of cities using Laser Detection and Ranging (LIDAR) are yielding expansive information about the geometry of urban areas. These wholesale 3d city models are making their way into flexibly managed geographic information systems (GIS) infrastructures. And these GIS infrastructures are providing a framework that can provide a framework for facilitating and integratng the work performed with the, more locally detailed, computer aided design and modeling tools that designers use (Cote, 2006). This paper provides some examples of how the convergence of wholesale 3D city models, GIS and CAD will lead to new ways to understand the visual connectivity that will lead to cities that are more easily navigable, more comfortable and more beautiful.

The Case of Boston and the Big Dig

The Boston Metropolitan Area provides an excellent laboratory for exploring visual connectivity. Boston is a visually rich city with many landmarks and vistas. Boston is also a city that has had many recent changes with regard to near and distant views, with many more anticipated. In addition to these reasons to be interested in studying the city, Boston also is endowed with very good data. In 2002 the Geographic Information Systems Agency for the Commonwealth of Massachusetts (MassGIS) engaged in a pilot project with the U.S. Homeland Security Agency to develop a LIDAR-Based 3d Model of the metropolitan area.

Our case study involves one of the largest urban design projects in the United States, the Central Artery/Tunnel project (CA/T) in which 4 miles of elevated freeway through urban core of Boston were replaced by an underground tunnel. This project has been nicknamed “The Big Dig.” The Big Dig project has also resulted in the construction of a new bridge – the Leonard Zakim/Bunker Hill Bridge, which is noted internationally as the widest cable-stayed bridge in the world, with a 90-meter tall double-tower design that is highly visible from many distant locations (Mass Turnpike Authority, 2006).

Figure 1. Leonard Zakim Memorial Bridge

The resulting removal of the iron elevated highway structure, originally built in the late 1950’s clears away a major visual disruption from the center of the city, creating many new view prospects that have not been possible for 55 years. These new views are noted for the restoration of visual connections between parts of the city that had been obscured by the elevated central artery: such as between Government center and the eastern waterfront; and between Haymarket Square and the North End. In addition to these restored connections, the Zakim Bridge presents a new landmark that extends the visual impact of the Big Dig to widely dispersed areas of the city. These immediate impacts on visual quality present many new opportunities with real value, aesthetically and monetarily for sites that have gained spectacular new views as a windfall of this project.

The immediate windfalls described above in themselves pose a worthwhile reason to study visual impacts, but moving forward we note that the project has opened up approximately 60 acres of new land (23 parcels) for development of new buildings and open spaces (Mass Turnpike Authority, 2006). In the next decade or more there will be many proposals made for the big-dig parcels which will each have their own visual possibilities and impacts. This field of possibilities gives us a rich set of examples that will help us illustrate the following general concepts and perspectives. We will discuss a breakdown of these perspectives.

Data Resources. The information we used to represent the landscape and buildings in Boston are provided by the MassGIS. They include two raster elevation models. The first is a photogrmmetrically generated model of the terrain surface with 5 meter postings. This provides a fairly good representation of the ground surface without trees or buildings. We also have a raster terrain model, derived from the LIDAR survey, that includes the heights of everything on the ground including trees and buildings. The postings of this dataset are at one meter. Third, we have a representation of buildings as extruded roofprint (or massing) polygons. This layer was derived by applying elevation information from the LIDAR raster to polygonal building footprints. The building roofprints layer provides decent representations of buildings for eye-level view studies.

Some Terminology for Discussing View Analyses

In developing the examples for this presentation we have found it useful to consider divide analytical view studies into functional categories according to distinct topological classes, temporal dimensions, and perspectival viewpoint. We have also found it useful to divide the different perspectives of viewshed analysis into subjective and objective cases. Because we feel that these terms are useful for discussing view analyses, we define these terms in the next few paragraphs

Topological Classes of View Impact Studies: Designers of specific projects will likely be interested in design with views in mind (some of these being regarding ***views from the project***, or ***views of the project***, and in all cases, reviewers may be interested in understanding the impacts of ***views across each project***.)

Temporal Dimensions of View Impact Studies: In time, it is worth considering that a project that has good views either as a windfall or by design, may end up having its view blocked by a subsequent project on another site. So, while we have brought up the desirability of understanding ***current views*** existing on the landscape; or of understanding ***specific proposed view impacts*** that would result from the geometry of specific design proposals, that describe future physical scenarios; we also anticipate the utility of studying ***implicit regulatory view impacts*** vis-à-vis existing or proposed design regulations.

Perspectives of View Impact Studies: In our exploration of view studies we have found it useful to distinguish between two different physical perspectives that may be taken.

These are manifest in terms of the point of view of the simulation of impacts. On the first hand we use an ***eye-level perspective*** within which we simulate what a person would actually see when viewing a particular scenario from the ground. We also consider a ***cartographic perspective*** that allows us to evaluate the visual connectivity of a particular place or set of places with all other places across the landscape. The cartographic perspective is limited in terms of its ability to deal with vertical features of cities, since viewed from above, these features are invisible. This is limiting indeed since within cities, vertical walls and windows are quite important. Therefore, we have developed a truly three dimensional class of view study we call the **optical perspective.**

The Cartographic and Optical perspectives have an aspect of reciprocity to them that allows us to consider that the same sort of analytical procedure might be used to ask the question “from where can a particular object be seen” and “Where are the places that can see a particular object.” Our examples will show why it is important to distinguish between these two cases. We will call the former the **Objective Case,** and the latter the **Subjective** Case of the Cartographic or Optical perspective.

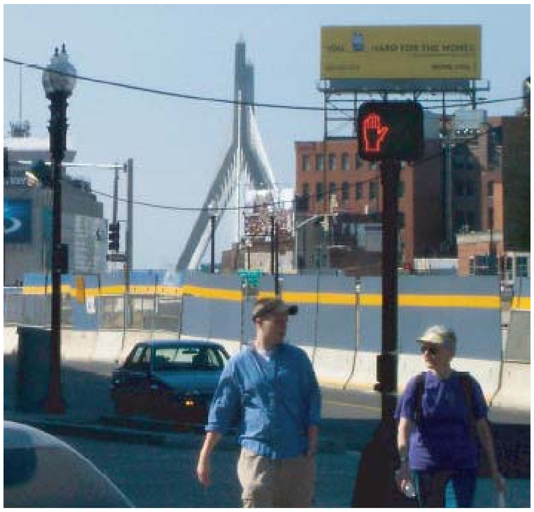
Examples of View Analyses

We set out, in the next section to demonstrate several ways that a broad scale three dimensional model might help to answer questions about the form of the city which would be very difficult to answer without such a model. We take the approach of asking some simple questions about views of the Zakim Bridge, and we then evaluate answers to these questions using the various topographic, temporal, and perspectival dimensions discussed in the introduction.

Example 1:
Eye Level Perspectives: What is the View from a particular place?

This question is best answered by simply going outside and having a look, and taking a photograph as illustrated in figure 2, a photo of Zakim Bridge taken from near the Haymarket just after the elevated viaduct has been taken down. Understanding a Current View with a photograph is a realistic approach. However, to understand the Proposed View Impacts Across a 50 meter tall building project proposed for a parcel on the former artery would difficult to assess without a broad scale 3d model. Figures 3 and 4 show a simulation of this view from approximately the same location as the photograph was taken. These simulations demonstrate a view study from an Eye-Level perspective Across a proposed project. The software used for this example is ArcGlobe by ESRI software.

This eye-level perspective can help to inform regulatory actions that may be desireable for protecting views. In this case, the Redevelopment Authority migh permit transfers of development rights from one part of the development site to another in order to protect the valuable view of boston’t trademark bridge from Haymarket square.



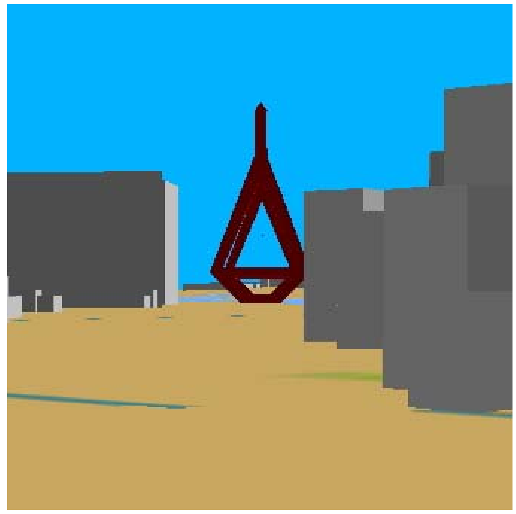


Figure 2: View from Haymarket Sq. **Figure 3: Haymarket View in Model**

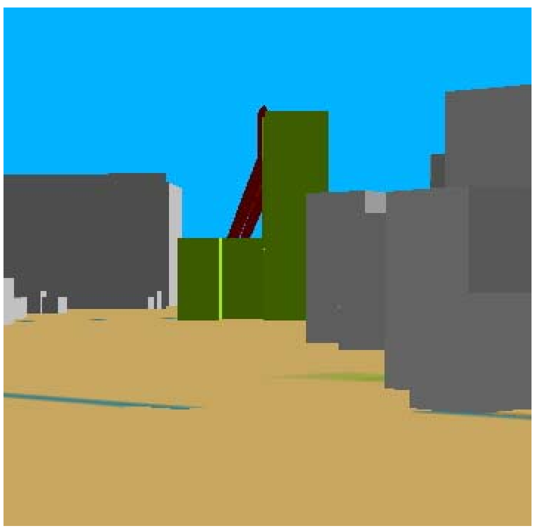
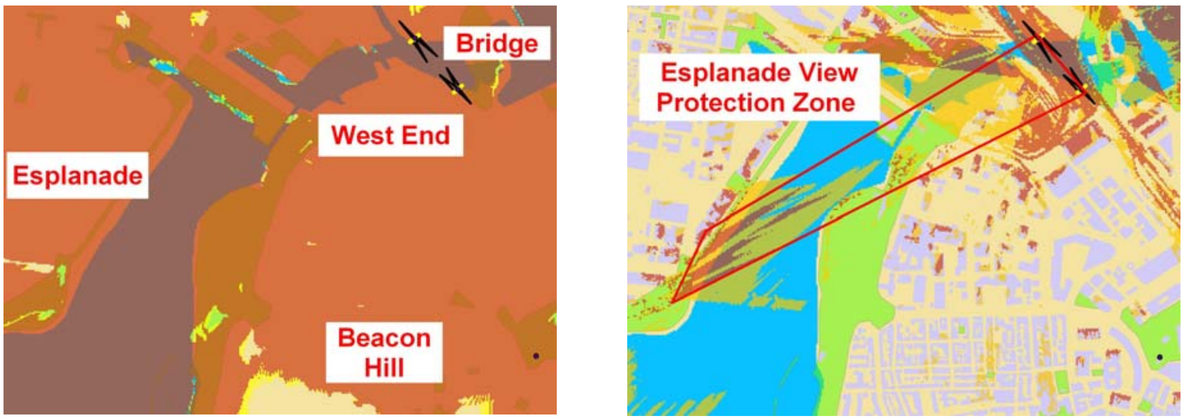


Figure 4: View Across Proposed Site

Example 2:
Objective Cartographic Perspectives: From Where can the Bridge Be Seen?

Eye-Level perspective studies use an intuitive metaphor for understanding views. Yet a 3d model in a geographic information system affords us another useful perspective. Some geographic information system (GIS) tools are capable of analyzing a terrain model to understand what places on a surface are visible from a point or set of points. This procedure is known as a Viewshed Analysis. The viewshed is a map of all of the areas on a surface that have an unobstructed view of the viewpoint (and vice-versa). The map in Figure 4 shows what points on the terrain surface of central Boston, are visible from points half-way up the towers of the Zakim Bridge. Putting the viewpoints on the Object of viewing makes this an **Objective Case** of the viewshed analysis. Areas shaded in red are where a person 2 meters tall can see the top half of both towers, areas shaded in yellow are locations where only one of the towers can be seen. Figure 5 is somewhat unrealistic because the terrain model used does not include buildings or trees. However, this unrealistic view can be useful from a planning perspective because it shows us the **Potential Viewshed**, i.e. where we could potentially make views by removing obstructions. Figure 5 shows the result of the viewshed analysis taken with the same points and parameters using the LIDAR elevation model, which shows the **Obstructed Viewshed**. These analyses are performed with ArcMap Spatial Analyst by ESRI .



Figures 5 & 6 Objective Cartographic Perspectives

Comparing figures 4 and 5 helps us to understand that the entire north side of Beacon Hill has good potential views of the bridge. But the tall buildings built in Boston’s West End in the 1970’s Urban Renewal era are blocking the view of both towers except in a few locations. Because the LIDAR elevation raster shows us the highest elevation for any given location, the yellow streaks on the Beacon Hill map show us where one tower of the bridge may be seen from the roofs of buildings (and not at all from ground level). This is useful information, which in fact would be quite difficult to ascertain without permission of all of the homeowners on the hill, yet this not-quite three dimensional view (considered two-and-a-half-dimensional) does not tell us if we must be on the roof or if perhaps a strip of windows on lower floors also have very valuable views of the bridge.

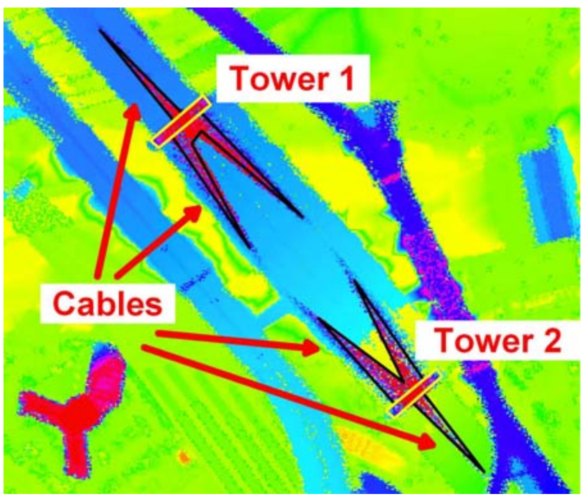
This cartographic perspective would allow us to explore scenarios in the temporal dimension, such as the potential impacts on certain Beacon Hill proerty values of replacing one of the tall towers in the West End with a shorter building. If the impacts were strong enough, we might persuade the wealthy owners on the hill to purchase development rights on particular parcels on the West End.

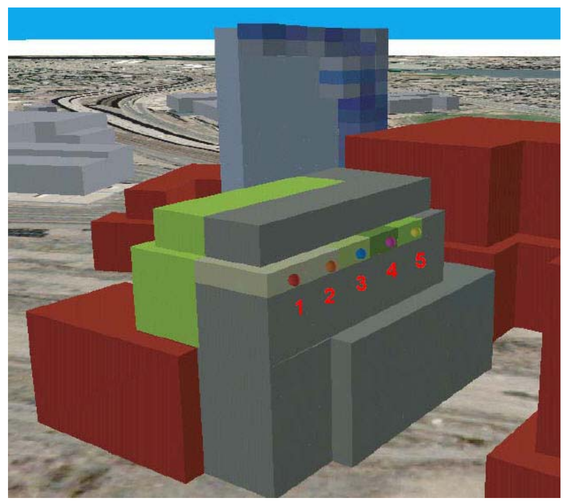
The cartographic perspective in Figure 6 informs us of how a spot along the Cambridge side of the Charles River Esplanade has a very good view of both bridge, and also illustrates that if this important view is to be preserved, city planners may want to consider a special review of new projects being proposed in the intervening areas on the Boston side.

Example 3:
Subjective Cartographic Studies: How Good is the View from Specific Places?

If we place our viewpoints for a cartographic viewshed study at the viewpoint of a particular subject, rather than upon the object viewed, we create a **Subjective Case Cartographic View Analysis**. In this way we can understand what areas on an elevation surface are visible from a particular spot on the ground window. If we have another map that denotes the view-value of specific places, then we can use raster GIS zonal overlay techniques to determine the intersection of the subjective viewshed of a particular spot with the view-value map to establish and compare the relative view values inherent at different places in our model.

In this example we consider the development of a proposed complex of residential buildings to the west of the Zakim Bridge. We consider that units with good views of the bridge will command higher rents and therefore we seek to be able to evaluate the quality of the bridge view from each window. We begin by developing a model of bridge view quality. We decide that having a view of both towers of the bridge is optimal, while being able to see just one tower is good, especially if a substantial amount of the cable supports are also visible. In order to quantify this, we divide our bridge landscape into zones denoting view quality. See figure 7.

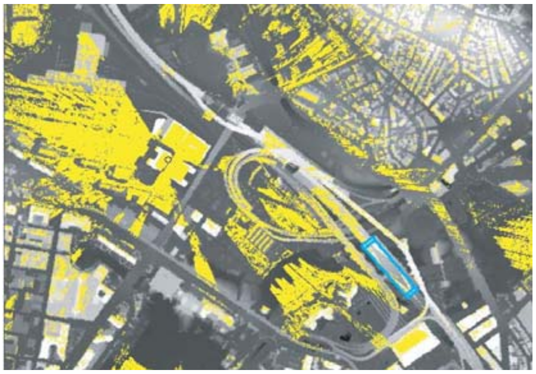


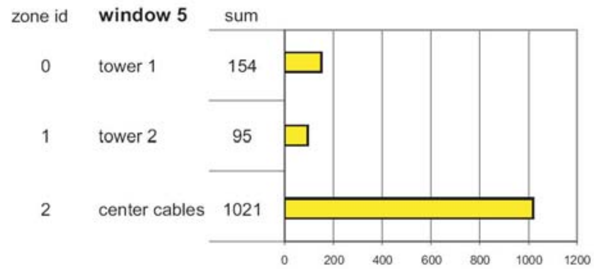


Figures 7 & 8: Bridge View Quality Zones and Window View Points

We design a rough massing model of the building complex in GIS and place viewpoints where the windows will be. See figure 8.

By calculating the viewshed for each window point (figure 9) and then using a raster overlay function to calculate the sum of bridge view quality cells within each viewshed (figure 10,) We build a view quality measure for each window, which can be summed for each apartment in the building



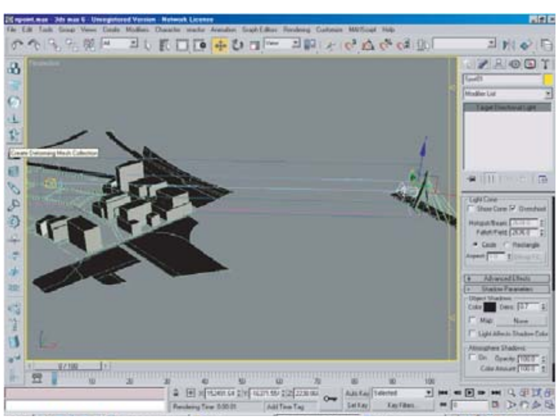


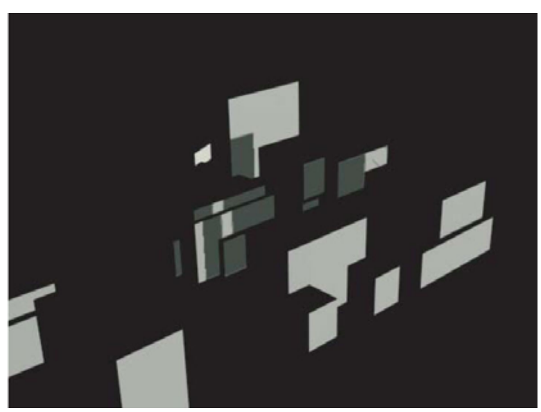
Figures 9 and 10: Subjective Viewshed and View Quality Summary for Window 5

Example 4:
An Optical Perspective View Analysis

Example 3 shows us how we can learn the view potential of particular windows using a subjective cartographic view analysis, but this must be done one window at a time. We are limited by the fact that our elevation data do not represent vertical surfaces, only the highest elevation for any given planimetric point. This is a limitation of 2-D gis, which is why we say that we are limited only to two-and-a-half-dimensional analysis. In this example, we stretch viewshed analysis into the third dimension using an **Optical Metaphor**

We begin by taking our model into a three dimensional modeling package that allows us to model light sources and shadows. In this case we use 3D Studio Max, a product of AutoDesk. Figure 11 shows how our buildings and bridge have been exported from the GIS into the light modeling tool and directional lights placed on the bridge. Then the model is illuminated with these lights. In this rendering we can see variations of light and shadow on our building that tell us what parts of the vertical face have views of the bridge





Figures 11 & 12: Optical View Analysis

Acknowledgements:

Tanya Chiranakhon and Antonio Medieros are credited for carrying out the Optical view analysis as an assignment.

Pontus Lindbergh took the photograph of the bridge from Haymarket Square.

Notes:

Mass Turnpike Authority 2006 http://www.masspike.com/bigdig/background/index.html

Hillier, Bill (1996) *Space is the Machine*, Cambridge: Cambridge University Press.

Hillier, W. R. G. and Hanson, J. (1984) *The Social Logic of Space*, Cambridge: Cambridge University Press.

Lynch, Kevin (1960) *The Image of the City*, Cambridge, Massachusetts: MIT Press.