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EVALUATION OF THE BAY AREA SPATIAL INFORMATION SYSTEM (BASIS) FOLLOWING THE LOMA PRIETA EARTHQUAKE

Abstract: A GIS called BASIS has been used since 1975 for earthquake mitigation projects in the San Francisco region. The October 1989 Loma Prieta earthquake provided an opportunity to evaluate both technical and institutional aspects of the system. The BASIS experience illustrates the factors that determine the effectiveness of GIS technology.

INTRODUCTION

BASIS (the Bay Area Spatial Information System) was created in 1975 as a multipurpose geographic information system covering the 7000-square mile San Francisco Bay region. It was developed by the Association of Bay Area Governments (ABAG), a regional planning agency, to support regional and local planning applications.

Over the past 16 years, BASIS has been utilized by governmental agencies at all levels as well as numerous private consulting firms. Applications include evaluation of sites for hazardous solid wastes, building a directory of industrial site data, calculating impacts of airport noise, providing data for market feasibility studies, mapping socioeconomic data, and building a capability for local environmental assessments.

Since ABAG has long supported a major earthquake mitigation program, BASIS has also been used for many projects related to seismic safety. The October 1989 Loma Prieta earthquake provided an excellent, if unwelcome, opportunity to test these applications.

This paper describes several earthquake-related studies conducted within the BASIS framework. Beyond the technical aspects of the applications, these studies illustrate some of the institutional issues that determine the effectiveness of GIS technology. The paper begins with an overview of the BASIS system structure, and then looks at several of the earthquake-related projects. It concludes with an evaluation of the system in both technical and institutional terms.

SYSTEM STRUCTURE

Over its 16-year history, BASIS has evolved along with the computer industry. The hardware environment has changed from a midsize minicomputer to a network of desktop workstations to standard PCs. This evolution has not only increased the speed of projects while reducing costs; it has also made the system more manageable. By making GIS technology accessible to planners working on individual projects, this setup should result in dramatic improvements in how systems are used.

The BASIS data structure has also changed as new applications have required different types of data and enhanced capabilities. Much of the data base is represented as one-hectare grid cells. (Coverage of the region at this scale requires about 2.1 million cells.) A hectare cell structure was selected originally as a compromise between level of detail and ease of implementation; cells work particularly well for operations such as overlay models.

The continuing need for new analytical capabilities and the increasing availability of digital map data have resulted in the use of more complex data structures. Current projects often combine cell data with vector or polygon files, particularly for display purposes. Employing DIME/TIGER files for address matching have also become more important.

It seems clear that the ability to mix data structures is critical. The capacity to maintain a regional overview, and to capture local detail where necessary, is important: it makes regional and local applications possible within the same system framework.

BASIS AND EARTHQUAKES

BASIS has been used over the years for many earthquake mitigation projects. The overall purpose of these efforts is to reduce damage by not building, or building more intelligently, in areas that are most susceptible to earthquake hazards.

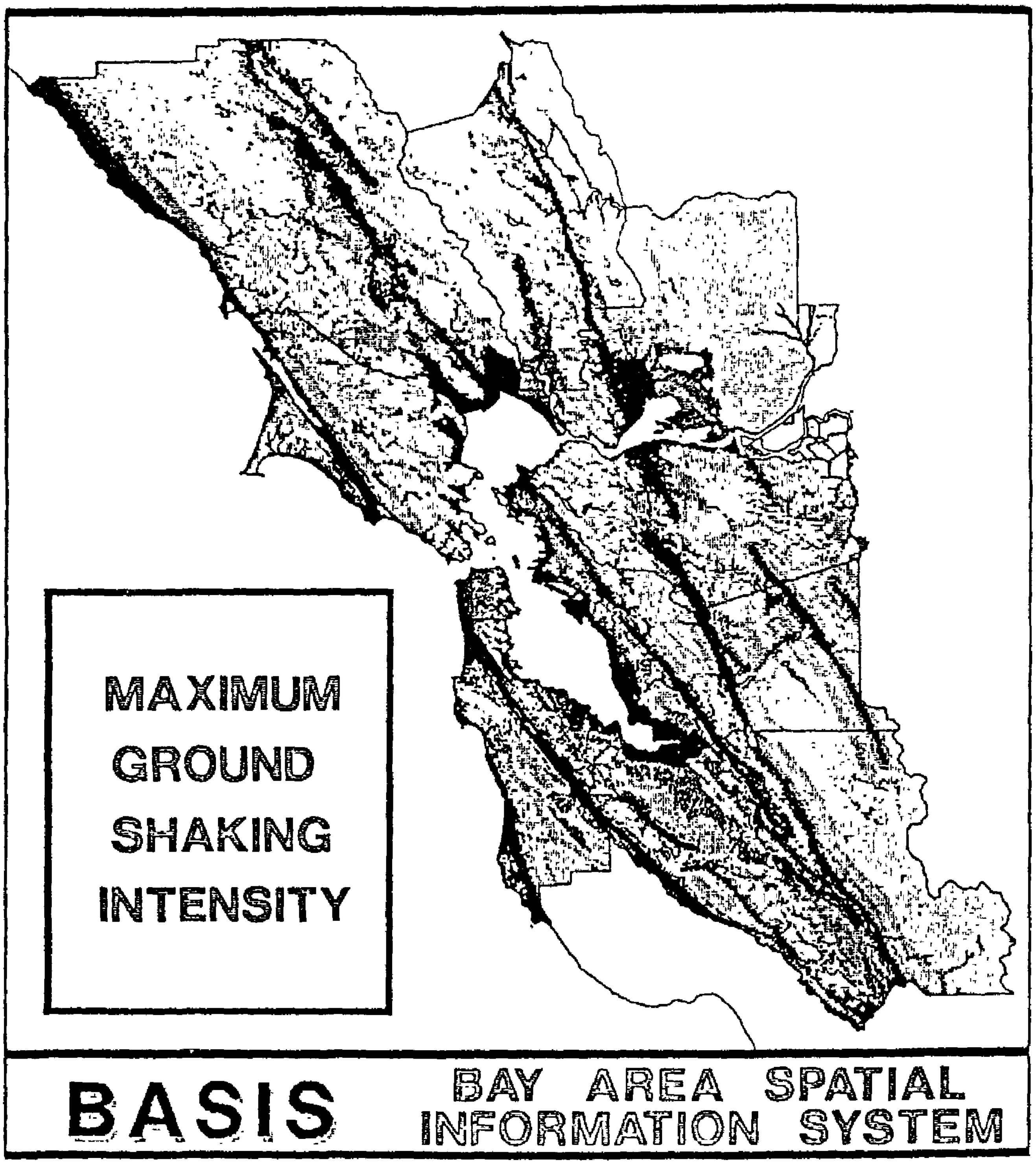
Groundshaking

Several earthquake mapping projects have included the preparation of complex models showing likely groundshaking intensity. Based on models and data from U.S. Geologic Survey staff and other researchers, they rely on concepts of attenuation of shaking with distance from faults and the varying response of different geological materials.

Fault lines are digitized, and distance from each active fault is calculated. The resulting distance bands (which vary depending on the expected maximum event on each fault) are overlayed on a file of geologic materials to derive a groundshaking factor. Each hectare cell is assigned a value depending on its geology and proximity to faults. The output of these models is mapped for use in mitigation planning.

These intensity models have been run for many different scenarios, including expected earthquakes on each major fault in the region. A composite of these scenarios results in a map (data file) showing the maximum expected intensity of groundshaking from any event for each cell (FIGURE 1).

FIGURE 1



MAXIMUM
GROUND
SHAKING
INTENSITY
BASIS
BAY AREA SPATIAL
INFORMATION SYSTEM

Related models focus on economic risk for each major building type, based on the intensity models described above and expected frequency of earthquakes.

Secondary effects of seismic activity (liquefaction of soils, tsunamis, flooding resulting from dam failure, earthquake-induced landslides) have also been analyzed and mapped using similar techniques.

Lifelines

The groundshaking models described above look at seismic activity on the surface. Taking this process one step further, the model output can be overlayed on other data sets to predict the effect of earthquakes in human and property terms. For example, one project used population data to estimate numbers of people at risk under different scenarios. This data gives emergency service agencies a set of numbers for planning purposes.

The most extensive project of this nature was an analysis of the impact of earthquakes on lifelines, public and private facilities important in maintaining public safety and economic activity. These include highways, bridges, railways, rapid transit lines, power lines and substations, and petroleum pipelines. The project objective was to overlay these lifelines on data sets containing projections of groundshaking intensity. The intensity data was stored in the hectare grid cell base. The lifelines were represented as points and vectors and then overlayed on the cell data. This procedure determined both an average level of risk for each entity (such as a freeway segment) and the specific parts of a network most vulnerable to damage. FIGURE 2 is typical output, showing expected levels of risk for a BART station.

FIGURE 2
EXAMPLE OF HAZARDS TABULATION

BART: GLEN PARK STATION	
Surface Rupture Fault Zone	OUT OF ZONE
Maximum Earthquake Intensity	C
Risk of Damage: wood frame	29
Risk of Damage: concrete/steel	46
Risk of Damage: tilt-up	76
Liquefaction Potential	1
Earthquake-Induced Landslide Susceptibility	3
Rainfall-Induced Landslide Susceptibility	2
Dam Failure Inundation	NO
Tsunami Inundation	NO

Unreinforced Masonry Buildings

The Bay Area has several thousand unreinforced masonry buildings, many of them in San Francisco. These buildings, because of their construction type and style, are the most susceptible to severe earthquake damage. A survey In San Francisco had produced detailed lists of the buildings by street address, but there was no straightforward way to relate the location of each building to expected risk factors (geologic unit shaking susceptibility, maximum groundshaking intensity, risk of groundshaking damage, liquefaction susceptibility). BASIS was used to assign a coordinate to each surveyed building by matching its street address and then extract data from several data base layers to provide more information about risk to each structure.

ASSESSING THE IMPACT

One of the difficulties in evaluating GIS systems is that benefits are often long-term. Although the relative longevity (in GIS terms) of BASIS provides some ways to assess the system from a perspective of several years, the real impact of applications like earthquake mitigation is more illusive . The Loma Prieta earthquake has provided an opportunity to more realistically assess the system's impact.

In evaluating the system, it is useful to look at both technical quality and effectiveness.

Technical Results

From a technical standpoint, the BASIS data base and analytical models performed very well. Comparison of the actual damage pattern in Loma Prieta to previous models of groundshaking intensity shows a high degree of consistency. These earlier models used theoretical earthquakes on two segments of the San Andreas fault. To further test the underlying assumptions, another model run was made using the actual segment of the fault that probably ruptured during Loma Prieta. Again, the correlation with actual damage was very high; locations such as the Marina district in San Francisco and the Cypress structure in Oakland show up as being particularly susceptible to groundshaking.

The tangible output of the system has clearly been high. Reports and maps have been distributed to local governments, land developers, engineering consultants, and other interested parties for several years.

Many of the theoretical benefits attributed to GIS have been borne out. The massive amount of data and complexity of the models required to study seismic hazards means that BASIS maps and tabulations provide much more data than would otherwise be possible. The data is also presented in a more usable form; maps of the region enables one to look for patterns, while the ability to extract and enlarge a specific area provides more useful data to a local planner.

Another GIS benefit is the ability to provide a common framework for diverse data sets. Data about hazards exists in different forms, so it is difficult to manually summarize and compare risks for a set of sites (such as the lifeline facilities described above). Use of a common data base makes it possible to more readily access information. (And this advantage becomes even more important in a multipurpose system, where hazard data can then be used in conjunction with demographic or land use data.)

It is safe to say that many of applications described above would not have been attempted without the availability of the system. Further, some projects have yielded more useful results because of the ability to try alternative assumptions with little additional cost - an option normally not possible in a manual system.

Effectiveness

In evaluating a system, however, we must keep in mind the difference between technical results and effectiveness. The fact that data bases have been built and maps have been plotted does not mean that the effort has been worthwhile. Looking beyond the technical factors, can we say that BASIS saved lives or prevented damage in the Loma Prieta earthquake?

Assessing the true impact is difficult. There is no single event or decision that can be pointed to as a direct connection between the system and its impact on mitigation.
Overall, it is likely that BASIS - in combination with hundreds of other sources of data and analysis - provided information that helped to reduce or avoid damage. And although benefits may be impossible to quantify, one can argue that the system is justified if it contributes information that avoids the destruction of one building in an earthquake.

Potential v. Reality

Looking at the system's performance also generates comparisons of potential and reality - what a GIS can do as opposed to what a GIS actually did. Could BASIS have provided more or better data, and could it have been utilized more effectively?

Improvements in the technology are certainly possible. Changes in GIS hardware and software technology, as well as the growing availability of digital cartographic data, will make the system more powerful and more accessible - and therefore more capable in a technical sense. Improvements in design of output, as well as the utilization of other media, will improve accessibility of data.

Much of a system's potential depends on reaching people who make decisions about land use. A regional planning agency like ABAG, which has influence but no direct authority over these decisions, must operate indirectly through local governments. BASIS products have been oriented primarily to this local government audience. Since Loma Prieta, the level of interest among other user groups (builders, facility managers, and individual homeowners) has increased dramatically; delivering information to these audiences should be a future priority.

CONCLUSIONS

In looking at BASIS after Loma Prieta, it is clear that a GIS can provide useful information that can help avoid hazards. Many of the expected advantages of GIS technology have been confirmed by our experience.

The advantages of a multipurpose system are clear. Keeping BASIS alive has meant a constant struggle for funding, and the ability to serve other applications has increased the funding base. Optimal use of any system, however, will require a constant stream of support for update and maintenance. BASIS has relied primarily on grant and contract money, which is directed more to research than applications; getting a broader funding base is a key factor.

Institutional factors go beyond funding support. To be truly effective, a system must provide information to the right people. The focus for BASIS has been, and will continue to be, local government officials, who have a primary role in land use control. As GIS technology evolves, however, it will be easier to get information to businesses and individuals, who ultimately make decisions about land use.