Using GIS to Document, Visualize, and Interpret Tokyo’s Spatial History

Social science historians bring a wide range of topical interests and methodological skills to the investigation of historical conditions. Those with an interest in the changing distribution and locational relationships of social, demographic, economic, political, cultural, physical, and other phenomena may now be considering the use of geographic information systems (GIS) for historical analysis. As an urban form historian and mapping scientist who uses GIS to document, visualize, and interpret spatial history, I am writing...
this account of my development of a GIS spatial history of Tokyo with the hope that it will convey the benefits and challenges of using GIS for historical research.

Why use GIS for historical research? There is a simple, two-part answer. First, humans are spatial beings. Individuals, groups, and institutions exist and interact in natural and human environments that occupy space over time. Human history necessarily includes a spatial dimension, which historians often overlook. Second, geographic information systems are designed to record spatial features and related information, display them, and analyze their conditions and spatial relationships. These capacities enable spatial historical research and extend its analytical reach.

Historical spatial information is often hard to deal with. It is found in a diverse range of sources, such as maps (with various scales, cartographic styles, levels of detail, degrees of accuracy), urban plans, photographs (aerial and ground-level), and census, economic, institutional, and voting records. Comparing spatial information from one of these sources with information from another, or with information from the same type of source but a different time period, can be complicated and difficult, especially for historians who are not familiar with spatial sources or the specialized cartographic techniques that enable one to glean the most from visual spatial information. Patterns in social statistical data, however, are often hard to grasp unless the data can be explicitly mapped to the corresponding spatial areas. By linking historical spatial information to corresponding geographic features in a computerized cartographic database, geographic information systems make it possible to record, display, and evaluate relationships between types of information that were in hard-to-compare formats or spread over many sequential historical maps.

Many aspects of the history of an urban region’s form can be recorded to produce an integrated spatial database. For example, the GIS can include changes in visible spatial features such as land cover, transportation networks, and physical geography. Changes in abstract spatial features such as political units and boundaries, socioeconomic patterns, and demographic data from censuses and other sources can also be incorporated. Temporal events or other information can often be linked to spatial features, such as linking corporate events and business performance statistics to the geographic locations
of different branches and customers, or linking organizational events in the history of a railroad company to the rail lines, stations, and service areas affected by mergers and acquisitions.

Integration of this diverse information allows analysis of relationships that might not otherwise have been considered. For example, a GIS can be used to display at a similar scale the urban patterns seen in various historical maps and aerial photographs and recorded from census data, as well as rail network growth patterns recorded from maps and rail company chronologies. Such overlay comparisons are possible using conventional, non-computer mapping techniques with acetate film, but a GIS greatly facilitates coordination of display scales and selective display of different components for easy comparison. Another use would be to compare an urban plan with mapped data on conditions in existence at the time the plan was made, then at various times after it was implemented.

Research on spatial history using GIS can take a variety of approaches. Some researchers may be interested in a specific set of questions and hypotheses, so they may need to map and evaluate only certain types of historical spatial features (e.g., county boundaries and census data). Other researchers may be more interested in developing a multifaceted spatial database that can be used to record and analyze a wider range of spatial features, both physical and human.

As a mapping scientist interested in urban form history, I have intentionally used the latter, multifaceted approach to develop methods of recording and analyzing many different types of spatial phenomena and their changes over time. This is a “data-driven” approach that starts with questions about what existed, where it existed, how it changed, and how such information can be accurately and efficiently mapped using a new technology. Once the geographic features are mapped and the associated information is recorded, the researcher can then begin to evaluate the broader historical questions (“why” things existed and changed). My approach is thus an inductive one that relies on a logical progression from description to visualization and interpretation. What a researcher chooses to describe is influenced by his or her interests, but, as I will convey in this article, there are inherent relationships between mapped phenomena that require the researcher also, and perhaps first, to map things he or she may not be specifically interested in. To develop a multi-
faceted spatial history database, I thus intentionally strove for thematic, data-
source, and mapping-method variety, to ensure that a variety of technical
issues would be addressed.

This multifaceted GIS spatial information resource could be given vari-
ous names, such as “spatial history database” or “temporal GIS database.” I
have chosen to refer to it as simply a “GIS spatial history.” The term GIS in-
dicates the technology used and can be omitted when not required (as in “the
spatial history of Tokyo”). The term spatial is abstract enough to encompass
geography, planning, demography, urban design, and architecture as well as
other, less visible phenomena, yet it is concrete enough to evoke images of
actual places. And the term history is generic enough to include changes in all
sorts of temporal phenomena, from natural and built environments to chang-
ing social, economic, and political conditions and events, virtually all of which
have some connection to place.

I selected the greater Tokyo area as the geographic area for development
of the GIS spatial history for personal reasons. I was born in Tokyo, grew
up there, and revisited it often while working elsewhere in Japan and then
in America. Personal knowledge and interest in the geographic area being
studied help motivate the researcher when faced with the substantial chal-
lenges and effort needed to create a multifaceted GIS spatial history of an
entire region.

As an urban area, Tokyo offers potential for new research and integration
of existing research, as evidenced by the many works dealing with its history.
Specifically, it has a rich premodern history of urban development as Edo,
the capital of the shoguns’ centralized, feudal government from the 1600s to
1868, and a modern history as the core city of one of the world’s largest and
most efficiently functioning urban regions. There is thus a long and diverse
spatial history to map. Another reason for choosing the Tokyo area is that
it has abundant historical spatial data records, including frequent historical
maps and census records.

In summary, this research integrates three areas of interest (see Figure 1):
the history of urban and regional form and planning (my thematic focus),
Japanese spatial studies (my geographic focus), and GIS and remote sensing
as tools for documenting, visualizing, and interpreting historical changes (my
methodological focus). The result is a rich computerized resource of informa-
tion documented from historical maps, historical census records, transporta-
Figure 1  Overlapping areas of interest forming basis of the GIS spatial history

tion system records, and other sources. Individually or together, these can be used to visualize and interpret the spatial history of Tokyo and its surrounding areas.

I first reported on this project in my dissertation (Siebert 1997) in urban design and planning. In this summary article, I describe the documentation methods used and provide examples of some of the visualization and interpretation results.

Background and Sources of Inspiration

This research is fundamentally about the production of a historical atlas—a powerful, flexible electronic atlas that can be queried and used for analysis. Currently, it is being used for my own research; in the future, portions or all of the database might be made available for viewing and perhaps querying via the Internet. The project’s precomputer predecessors include printed his-
torical thematic atlases of Tokyo (Masai 1986) and Japan (Collcutt et al. 1988; Kodama 1989; Ikegami et al. 1993), as well as geographic and place-name dictionaries, which often include some maps (Papinot 1972 [1910]; Yoshida 1937–40; Kadokawa and Takeuchi 1978; Shogakukan 1996).

An early inspiration was John Reps’s use of bird’s-eye views to depict and interpret urban history (e.g., *The Making of Urban America*, 1965). I wanted to develop computerized methods for using similar historical views of Tokyo. However, I soon realized it would be better to start with modern maps because they are more accurately surveyed, and then to work back in time to the bird’s-eye views and maps of the Edo era (1600s to mid-1800s).

Further inspiration came from a visual history of Vancouver (McDonald 1992), which includes decade-by-decade maps of land use and other urban patterns for the 1900s, and from a similar time-series work on the transformation of Yokohama from an early fishing village into one of Japan’s leading ports (Yokohama Planning and Coordination Bureau 1981). Neither of these atlases used GIS, though McDonald relied on desktop publishing. Both facilitate comparisons by using consistent scales and map formats so one can readily see how the city changed over time. Although more a socioeconomic study than a historical atlas, an analysis of the emergence and growth of metropolitan Detroit (Doxiadis 1966) also inspired me by its consistent mapping of various social and economic factors.

Another major source of motivation was my dissatisfaction with many of the works I have read on urban history. While they offer interesting hypotheses and explanations, many lack the maps that would easily and clearly depict the relationships that the authors so carefully argue in words. Similarly, my fascination with rail systems was usually met with disappointment when I read a rail history but found few or no maps showing development of the system and its relationships to other geographic features. This was true even in books that attempt to show how railroads helped build an area (Crump 1962; Hilton and Due 1960; Warner 1978). In some cases the absence of maps reflects the personal focus of the author; as rail buffs, some were more interested in rolling stock than in geography (Wing 1988). However, other important factors may have been the difficulty and cost of manual production of extensive map series, the lack of sufficient historical records, or the author’s lack of geographic or cartographic training. My goal thus became to develop
By this time, GIS software had become widely available and was being used in various institutional and academic fields. The same was true for image processing, used for analysis of aerial photographs and satellite images. There also was extensive conceptual work on how to handle time in GIS databases (Langran 1992), a conference on GIS and temporal data (Barrera et al. 1990), and over 350 papers on spatiotemporal data by almost 300 researchers (Al-Taha et al. 1994). Other work dealt with underlying concepts and techniques of time and geography (Thrift 1977), visualization of geographic time-series data (Monmonier 1990), and treatment of time as a variable on maps (Vasiliev 1990). GIS was also being used in archaeological analysis (Gamble 1987; Allen et al. 1990), showing its potential for historical research.

At the time I began this project in 1993, few projects using GIS for actual historical analysis had been reported in the literature. Most of the GIS work was more theoretical in nature, as discussed in various articles about database design issues for temporal analysis in GIS, such as those cited above. During the years I spent constructing my GIS spatial history of Tokyo, other researchers were working on similar GIS projects for other cities. For example, work on San Francisco (Acevedo et al. 1996; Bell et al. 1996) and the Baltimore-Washington region (DeCola 1997) produced a series of temporal maps of urban growth, based on interpretation of urbanized extent from historical maps and current satellite imagery and including animations of historical change.

Research on Japanese land use and urban history using GIS or manual mapping includes several major projects: (1) manual mapping of Edo/Tokyo history (Masai 1986, 1990), (2) a nationwide GIS mapping of historical land use on a 2 km grid (Himiyama 1992, 1994), (3) urban infrastructure and land use mapping on a 500 m grid (Todokoro 1993), (4) various projects on computer mapping applications (Kubo 1991), and (5) development of computer animation techniques using gridcell population data of Tokyo as the sample dataset (Okazaki 1993). Recent Japanese GIS and mapping activities can now be searched on the Internet using a computer resource guide (Pollard 1996).

To this expanding body of projects dealing with manual and computerized mapping of spatial phenomena, I have added my computerized GIS spa-
tial history of Tokyo. My aim has been to increase the spatial resolution and geographic scope, to include a wider variety of geographic features, and to map changes at a higher frequency than in prior projects.

**Software, Sources, Input, and Time Requirements**

When deciding whether to use GIS for historical research, one must consider certain technical issues, including GIS software selection, source map availability and quality, map input and storage, and time requirements. I will summarize these issues here based on my experience in creating a GIS spatial history of Tokyo. Details of these and other technical issues are given in the dissertation on which this article is based (Siebert 1997).

**GIS Software Selection**

The choice of which software to use for a historical project is crucial. There are two basic issues. First, does the software have the necessary features for documenting, visualizing, and interpreting the types of historical information of interest? Second, does the researcher have ongoing access to the software?

Let me address the second, simpler question first. Use of a GIS for historical research involves much effort in project and database design, location of suitable historical map and data sources, input of map and other data, and visualization and analysis. The researcher thus needs to have regular and long-term access to the specific GIS program(s) with which the spatial history database is created. Although most GIS programs can import from and export to the proprietary map formats of other GIS programs, doing so is not always simple or error-free.

As a student at the time this project began, I wanted to have round-the-clock access to a GIS program on my own computer rather than compete with other students for computer lab time. I also wanted to produce my spatial history database using software that could go with me when I finished the dissertation and worked elsewhere. Cost and availability thus became important considerations for software selection. For small projects, a historical researcher could now probably meet most software needs for under $1,000, and perhaps even under $500 if scanning and georeferencing are done elsewhere.
Now back to the first issue—software functionality. The general procedures and associated software requirements for a project like this one are:

- Initial map input, usually by scanning or digitizing (tracing desired features);
- Georeferencing—that is, designating where the map is in geographic space by recording its latitude and longitude (or similar coordinate values) so it can be correctly displayed with other GIS geographic layers;
- Creation of geographic features in the GIS;
- Linking of historical information to those geographic features via the database component of the GIS software;
- Performing various analysis functions, depending on the data and questions being investigated; and
- Visualization—that is, generation of maps and other views of the information for display and interpretation on-screen and via printouts.

There are several types of GIS and related software. In vector GIS, geographic features are mapped as $x$-$y$ coordinates of points, lines, or areas (called polygons). In raster (or gridcell) GIS, geographic features are mapped on a matrix of equal-sized cells. A point is thus recorded as one gridcell, a line as a string of gridcells, and an area as a group of gridcells. A related type of program is image-processing software, used for analyzing aerial photographs and satellite images and also for preparing scanned historical maps for use in the computer.

I needed all three types of software for my project. Preparing the scanned maps and georeferencing them required image processing, though more recent GIS programs now have such capabilities themselves. Raster GIS operations would be useful for interpreting the scanned maps and aerial photos, especially to map land cover and land use. Recording other features, especially linear and point features such as rail lines and stations, as well as administrative boundaries, census boundaries, and other areal features that have distinct edges, would be more efficient with a vector GIS.

Having one software program that could handle all three types of data—vector GIS, gridcell GIS, and raster images—seemed the best, so I selected TNTmips from MicroImages (Lincoln, Nebraska). However, I soon discovered that its vector functions were not suitable for recording rail lines and stations. When two rail line segments cross each other between stations (very
common in Tokyo, especially in the subway network), I needed to keep them separate so I could maintain the correct linkages of historical information to the station-to-station segments. TN'Tmips, ArcInfo, and most other vector GIS programs break and join crossing line segments, in effect creating a transfer point where no station exists. In contrast, Maptitude, a vector GIS program from Caliper (Newton, Massachusetts), which specializes in transportation GIS, correctly handles crossing lines. Also, only Maptitude allowed me to assign information to endpoints of line segments. Because the endpoints would be the rail stations, I needed to link specific historical information to them. Another factor in Maptitude's favor was ease of digitizing—quite important, considering how much would be needed.

As a result, most of the work of creating this GIS spatial history of Tokyo has been done with Maptitude, an inexpensive yet reasonably powerful vector GIS program. Researchers who are thinking of creating a GIS spatial history of another region should evaluate their own specific data types and information needs and the corresponding software capabilities as thoroughly as possible before beginning data entry—and should expect that unforeseen circumstances may make changes necessary.

Source Map Availability and Quality

For the historical researcher who wants to use GIS, one of the critical initial issues is the availability of suitable source maps. One should determine at the outset whether sufficient historical maps exist for the features of interest and whether they are available in digital, computerized form. For many historical questions and locations, the answer to the first question is maybe and to the second question is no. Although government mapping agencies are now supplying digital map products for use in GIS, these are primarily current maps. The historian must find other sources for digital historical maps or must convert paper maps into digital form for his or her own project.

In my case, I needed to obtain paper reproductions of historical maps and produce my own digital versions. In fall 1993, I went to Japan to evaluate map availability and order reproductions of a series of present-day and historical topographic maps of Tokyo and surrounding areas. Figure 2 shows the coverage area and frequencies of the selected maps at scales of 1:200,000 and 1:50,000. I chose current (1990s) topographic maps for all areas shown, and
Tokyo’s Spatial History

<table>
<thead>
<tr>
<th>Location in Japan</th>
<th>Nine 1:200,000 Map Sheets Covering Tokyo and Surrounding Prefectures in Kanto Region</th>
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<td><img src="image" alt="Map of Japan showing Kanto Region" /></td>
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Maps Used in GIS

<table>
<thead>
<tr>
<th>Sixteen 1:50,000 Map Sheets Covering Tokyo, Yokohama, and Suburban Cities</th>
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<tbody>
<tr>
<td><img src="image" alt="Map of Tokyo, Yokohama, and Suburban Cities" /></td>
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</table>

1:200,000 maps:
- Once per decade in 1900s for Tokyo (outlined in bold)
- Current (1990s) maps for eight surrounding sheets

1:50,000 maps:
- Once per decade in 1900s for six sheets (outlined in bold) covering Tokyo city and its western suburbs
- Current (1990s) maps for ten surrounding sheets

Number of Mapped Years in Each Decade for Sixteen 1:50,000 Maps

<table>
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<tr>
<th>1900s</th>
<th>1910s</th>
<th>1920s</th>
<th>1930s</th>
<th>1940s</th>
<th>1950s</th>
<th>1960s</th>
<th>1970s</th>
<th>1980s</th>
<th>1990-3</th>
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<td>1</td>
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</tbody>
</table>

Figure 2  Spatial and temporal coverage of maps
once-per-decade coverage for the rest of the twentieth century for specific 
areas covering Tokyo itself (GSI-J1900s-1990s).

The Geographical Survey Institute of Japan and its predecessor agen-
cies have produced many maps and updates since modern surveying began, 
in the late nineteenth century (GSI-J 1984, 1990). The table at the bottom of 
Figure 2 shows the number of times in each decade that each 1:50,000 Tokyo-
area map was updated. For example, in the 1920s, most maps were updated 
two times, and some were updated three or four times. The nature of the up-
dates varied, of course, with the regular addition of new rail lines and stations 
and less frequent changes in land use and in basic survey data. Thus, there 
were often several maps to choose from in each decade. I chose a set as evenly 
spaced in time from decade to decade as possible. I inspected the maps at the 
agency’s Tokyo map room and ordered full-size black-and-white xerographic 
reproductions of historical maps (about $5 each), along with color current 
maps, totaling about 80. In 1998, I returned to Japan and obtained about 300 
more historical maps and 200 aerial photographs, which I am now beginning 
to add to the GIS spatial history of Tokyo to expand its spatial and temporal 
coverage.

When using historical maps, aerial photographs, and other visual 
Sources, it is important to have high-quality reproductions or, better yet, 
originals. My scanned reproductions are generally quite readable, even 
though most are second- or later-generation copies. Figure 3 is a reproduc-
tion of the scanned 1953 Ome topographic map, with the full map area shown 
at top and an actual-scale inset at bottom. Working from originals or first-
generation copies would probably have simplified the location and digitizing 
of some features, especially with the 1:200,000 maps. I initially also planned 
to use reproductions of historical aerial photographs but decided to wait until 
I had more time to carefully select the desired images and could afford good 
reproductions.

Map Input and Storage

Information from historical maps can be entered into the computer in several 
ways. The traditional method is to mount the map on a “digitizing tablet” and 
trace the desired features. A newer method, made possible by better scanners 
and computers with more memory and storage capacity, is to scan the entire
Figure 3  Example of scanned map (Ome area west of Tokyo)
Source: 1953 topographic map of Ome, Geographical Survey Institute of Japan (200 dpi scan of monochrome
copy, reproduced by permission)
map into the computer as an image. After the image is georeferenced (i.e., located in correct geographic space), the desired spatial features are “digitized” (traced) while one views the map on the computer screen. This enables one to zoom in to see the area being worked on; it is also easy to redisplay the map to input other features, or to show it as a “backdrop” to existing GIS data layers. For example, I use the scanned maps to show topography and land use features that I have not had time to digitize yet.

Before scanning, one needs to determine the spatial resolution (dots per inch) and spectral resolution (number of colors or grayscale levels) that will best replicate the desired map features (e.g., administrative boundaries and land use shading). It is also important to consider the total number of maps to be scanned and the required storage space. I found 200 dpi and 256 shades of gray or 256 colors to be adequate; the resulting maps (scanned from 13-by-20-inch originals) are each about 10 megabytes in size. With 80 scanned maps, many vector GIS data layers, and many associated data tables, the total current size of the GIS database of Tokyo’s spatial history reaches about one gigabyte. The newly obtained additional maps and historical aerial photographs are being scanned at higher resolution, now that hard drive capacity is much greater and CD recordable media are available for off-line storage of scanned maps.

Time Requirements

Creation of the four major components (shorelines/rivers, administrative areas, population, and rail network) of my GIS spatial history of Tokyo took at least six months each—all told, I spent more than two solid years creating the geographic layers, inputting the attribute data, and linking the two through carefully designed coding systems. The input work was preceded by about a year of planning, acquiring data (including a research trip to Japan), experimenting with input methods and GIS programs, and scanning and georeferencing the historical topographic maps. Display and interpretation took much less time than creation of the GIS database itself.

The amount of time required to construct a historical GIS depends, of course, on the complexity and magnitude of the historical sources and the database designed to record the information. I now have recorded the histories of over 150 rail companies; 200 rail lines; 2,000 rail line segments; 2,000
rail stations; numerous administrative boundary, name, and status changes (totaling over 1,000 events); many population changes; and many shoreline/river changes. The historical changes are recorded at a decade, half-decade, or precise-date interval, covering all decades of the twentieth century as well as some changes (railroads, administrative annexations) for the last three decades of the nineteenth century.

**Documenting Tokyo’s Spatial History**

I set out to design and develop an integrated, multilayered GIS spatial history of Tokyo that could be used for documenting, visualizing, and interpreting historical patterns and relationships. By “documenting” I mean recording actual historical conditions and changes in the GIS spatial database. In a GIS, this means designing the spatial database, creating the geometric shapes used to represent actual spatial features, then linking each one to a database record that gives its type, name, and other associated information. The previous section covered some of the technical issues. Here I will introduce the nature of the features I chose to document, and the next section will discuss their use. Table 1 lists the types of information to be included in the GIS spatial history of Tokyo, the major data sources for each, and the current status of their spatial and temporal coverage in the database.

Individually or together, these themes of Tokyo’s spatial history deal with different related aspects of its urban form. For example, shoreline changes and land reclamation can be mapped to explore their effects on the amount of developable land and on the city’s overall form and potential transportation linkages. Rail network growth can be compared with various indicators of urbanization, such as political status (village, town, city, ward), extent of “built-up area” interpreted from land use or topographic maps, or population patterns mapped from census data.

The decision of what to document should be based on the researcher’s interests but must also consider the nature of the data and mapping methods used. A researcher who is interested in changes in human geography may find that some changes in physical geography need to be mapped as well. For example, a physical feature such as a shoreline or river may also serve as a political boundary, requiring decisions on how to record such shared features, especially when they change over time. Furthermore, shoreline changes
Table 1 Components of GIS spatial history of Tokyo

<table>
<thead>
<tr>
<th>Category</th>
<th>Map features</th>
<th>Major data sources (scale)</th>
<th>Mapping status</th>
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<tr>
<td></td>
<td></td>
<td>Spatial</td>
<td>Temporal</td>
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<tr>
<td>Physical</td>
<td>Shorelines</td>
<td>Topo maps (50K and 200K)</td>
<td>Tokyo Bay</td>
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<td></td>
<td>Land reclamation</td>
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<td></td>
<td>Physical</td>
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<td></td>
<td>Rivers, channels,</td>
<td>Topo maps (50K and 200K)</td>
<td>All in Tokyo</td>
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<td></td>
<td>and canals</td>
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<td>Most in Kanto</td>
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<td></td>
<td>Lakes and other water bodies</td>
<td>Topo maps (50K and 200K)</td>
<td>Most in Tokyo</td>
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<td></td>
<td>Topography</td>
<td>Contours, DEMs</td>
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<tr>
<td>Political, social,</td>
<td>Province/prefecture boundaries</td>
<td>Topo maps Historical atlases</td>
<td>Kanto region</td>
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<tr>
<td>economic</td>
<td>Administrative units/boundaries</td>
<td>Topo maps (50K and 200K)</td>
<td>Tokyo</td>
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<td></td>
<td>(villages, towns,</td>
<td>Census maps</td>
<td>Kanagawa</td>
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<td>cities, city wards)</td>
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<td>Saitama</td>
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<td>Population</td>
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<td>Economic conditions</td>
<td>Censuses</td>
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<td>Commercial and industrial</td>
<td>Land use maps (25K and 200K)</td>
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<td>activities</td>
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<td>Transportation</td>
<td>Rail network development</td>
<td>Corp. histories</td>
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<td></td>
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<td>Topo maps</td>
<td>Tokyo</td>
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<td>Road network development</td>
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<td>(some)</td>
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<td>Landscape</td>
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<td></td>
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<td>Land use</td>
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<td>Topo maps</td>
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and land reclamation may affect the area of political or census units, so it is necessary to map them accurately if the intended analysis will require area-based calculations such as population density. Geographic information systems thus not only allow integration of different spatial information, they may also require it.

My decision of which features to record was based on personal interest in the feature (e.g., rail history and land cover/land use), the availability of suitable historical data sources, the nature of data-recording methods for geographic features and associated information in the GIS, and my desire to experiment with a variety of features to develop effective methods of computerizing them and of recording various types of information about their historical changes.

In addition, I decided to record geographic features and events over a wide geographic area and long time period so as to discover many different types of historical conditions and events that might require unique treatment in the GIS. Spatial database design is easy for conditions that follow simple patterns and rules. It becomes quite complex and challenging to handle the exceptions. For example, the spatial conditions at railroad transfer stations (of which Tokyo has many) are quite complex due to scale and generalization issues. Should a transfer station be treated as one point in a network of lines, or should each company’s or each line’s station be mapped at its exact location, thus forming a group of stations that together constitute the transfer “point”? Such relationships are further complicated by changing owner-

Table 1  Continued

<table>
<thead>
<tr>
<th>Category</th>
<th>Map features</th>
<th>Major data sources (scale)</th>
<th>Mapping status</th>
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<td>Historic urban, transportation, and</td>
<td>Plan reports and maps</td>
<td>(Not started</td>
</tr>
<tr>
<td>planning</td>
<td>other plans</td>
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<td>Block creation</td>
<td>Topo maps</td>
<td>Blocks of Ome</td>
</tr>
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<td>Land rationalization</td>
<td>Planning records</td>
<td>1900s by area</td>
</tr>
<tr>
<td></td>
<td>Ownership parcels</td>
<td>Agency records</td>
<td>decade</td>
</tr>
</tbody>
</table>

(Not started yet)
ship or rerouting of lines. Devising suitable means for recording the geographic configuration of such junctions and linking the applicable historical data records was very complicated.

Because of my interest in Tokyo's railroads, the first component I worked on was the rail network. I used the GIS to record company establishment and merger dates, line opening dates, electrification dates, multiple-tracking dates, station opening dates, and other data from historical maps and published sources, such as a centennial history of Japanese railroads (Tetsudo 1972), a history of lines and stations in the Japan Railways system (JRR et al. 1991), and many rail-company system guidebooks.

Next, I planned to record land cover and land use changes from topographic maps to compare them with rail growth. However, I first needed a shoreline layer to indicate what was land and what was water (the most basic land cover distinction). Because of the extensive changes in Tokyo Bay in the 1900s, this became a major, detailed project of interpreting changes from topographic maps of varying quality. In Tokyo, many changes have also occurred in river channels and canals, especially in the delta lands at the head of the bay, and these changes affected political boundaries. Experimenting with how to map these and other water features was a natural outgrowth of shoreline mapping, because it extended the concept of “land versus water” into inland areas. However, it required different forms of mapping in the GIS because, depending on the mapping scale, rivers and canals are represented either as lines or as long, slender areas (“polygons” in GIS).

Once the shoreline and river/canal layers were done, I had to choose whether to proceed to map the land cover and land use (from which I could interpret urbanization extent) or to use some other indicator of urbanization, such as the generalized extent of urban areas already interpreted by other researchers (e.g., Masai 1986). I wanted, however, to base my GIS spatial history on a common series of topographic maps for as many features as possible, rather than using the results of other researchers’ work, for which I might not be able to determine the data source, mapping methods, or decision rules. After I complete my own mapping of changes in urban extent from the topographic map series, I will be able to compare it with similar maps produced by other researchers. There also are questions about how consistent the government mapping agencies were in depicting urbanized areas from decade to decade on topographic maps. Accordingly, an ongoing part of the project is
to compare the topographic maps with aerial photography for as many time periods as possible.

To explore other types of historical changes, I then mapped the historical boundaries and changing names of administrative areas (villages, towns, cities, wards) from topographic maps and annexation chronologies (Ota 1995). Doing so would also allow me to relate administrative areas and their contemporary population, thus creating the means for mapping census data (Bureau of Statistics 1950–95; Research Publications 1973) and for roughly interpreting the extent of urbanization based on the population and density of these administrative areas. A more detailed delineation would require population data broken down for subareas within villages, towns, cities, and wards, which is available only for more recent decades.

As a result of these incremental decisions on what features to map, I now have four components in my GIS spatial history of Tokyo: (1) shorelines and rivers, (2) administrative units, (3) population, and (4) rail network. Together, these four represent diverse aspects of Tokyo’s physical setting, political relationships, intensity of settlement, and interconnectedness. These four components also required use of various data sources: historical maps for shoreline and river changes; historical maps, administrative chronologies, and census data for administrative boundary, name, and status changes; census data for population changes; and historical maps and rail-company system guidebooks for rail network development.

Finally, these components required different methods for recording their spatial location in the computer and linking the associated historical information. Shorelines, administrative areas, and census units are all areal features and are thus treated as “polygons” in the GIS. Rivers and rail networks are linear features and are thus treated as line segments in the GIS, but with different patterns (river systems have a branching structure, and rail systems have a network structure). Wider rivers are also mapped as long, slender polygons. Rail stations are points but are treated as line endpoints rather than as stand-alone points. Although other types of features could have been selected as the initial components of the GIS spatial history, these four represent a useful mix of thematic, data-source, and data-recording types. They are thus a suitable set for experimentation and evaluation of how well geographic information systems can be used to map historical conditions and relationships in an urban region.
Visualizing and Interpreting
Tokyo’s Spatial History

In the previous section, I described how I selected the features to document in my GIS spatial history of Tokyo. In this section, I summarize their uses and purposes for visualizing and interpreting Tokyo’s history. By “visualize” I mean to display and reveal, usually in map form, but also in tabular form when appropriate. By “interpret” I mean to analyze, evaluate, explain, and synthesize. As in many GIS projects, much of the work is in the documenting stage—data acquisition, database design, and data input. Once the information has been documented, the visualizing and interpreting stages are often much quicker and easier.

The power of GIS is that it is an interactive tool for all three stages—often in iterative fashion, which is hard to show in a sequential essay. In fact, visualization and interpretation can follow so quickly, one upon the other, that it is difficult to say which comes first or to differentiate them. Thus, I treat them in the same section here. Furthermore, by connecting the visual display of spatial data with the underlying information recorded in a structured, database format, GIS programs allow the researcher to use both qualitative and quantitative methods. My initial use has been primarily qualitative, though it can often be easily expanded to quantitative.

The dissertation on which this article is based (Siebert 1997) contains a wide variety of mapping and visualization examples (many in full color). Separate articles are being written to expand on specific topics. In one article, I look at the relationship between rail company, line, and station names and the conversion from provinces to prefectures, showing how the province names lived on long after provinces were replaced by prefectures in the late nineteenth century (Siebert 2000). In another article, I analyze and interpret the sequence of conversion from village, to town, to city, and then to ward status in Tokyo and Kanagawa prefectures, showing alternating zones of sequential and nonsequential urbanization (Siebert forthcoming). Other articles in preparation will look at topics such as the annexation processes of villages, towns, cities, and wards (in more detail than presented here); the province-to-prefecture transition process (showing the interlocking historical relationships of different sets of prefectures in the Kanto region around Tokyo); the sequence and geographic patterns of growth in the Kanto re-
region's railroad network; and the relationship between early formation of railroad stations and current prominence of the stations as express stops.

In the remainder of this summary article, I will use four simplified examples from the project to illustrate the components and use of the GIS spatial history. The static monochrome maps shown here can only hint at the complexity and detail of interactive, on-screen, full-color visualization and analysis, and the accompanying explanations reveal only some of the analysis and interpretation that can be done.

In the physical category, I have recorded twentieth-century shoreline changes and land reclamation from topographic maps for each decade. One way I used this data was to show the spatial and temporal patterns of expansion of land area and harbor areas in Tokyo Bay. Figure 4 depicts the generalized stages of completion of Tokyo's inner and outer harbors by the creation of breakwaters and landfill islands. Although the GIS spatial database has values for each decade, here the data are aggregated into three broad periods for mapping in monochrome. Downtown Tokyo is in the upper-left map area. In the 1910s through 1930s, new islands were created to the south and southeast of the urbanized area. By the end of the 1930s, a southwest-to-northeast series of breakwaters had been completed to enclose the inner harbor. Very little island expansion occurred during World War II and the recovery years of the 1940s and 1950s. Many new islands were created outside the breakwater in the 1960s, creating some protection for the many channels between them. The largest expansion occurred in the last three decades of the twentieth century, when new outer breakwaters were built, linking new, large outlying islands to form several outer harbor areas.

When the landfill and harbor-enclosure patterns are mapped by decade for the entire Tokyo Bay area (extending beyond the area shown here), the overall pattern revealed is predominantly southward growth from Tokyo along the bay shore to Kawasaki and Yokohama, followed later by eastward growth toward Chiba. These land expansion patterns correspond quite well with growth of urban areas on the mainland itself. It was natural that urbanization extended southward from Tokyo into Kanagawa prefecture along Japan's most important transportation corridor—the Tokaido highway and railroad—before it extended eastward from Tokyo into Chiba prefecture. Industrialization on landfill islands paralleled the urbanization on the mainland,
and along with formation of new islands came the creation of new breakwaters to enclose wider harbor areas.

The GIS layer for rivers and canals was used to identify different river regions in Tokyo prefecture and to show how major rivers have been rerouted, especially in Tokyo Bay’s delta lands. I investigated how the rerouting of these rivers impacted administrative boundaries and location of trans-
portation routes. Recording these changes from topographic maps and other records was quite difficult due to the complexity of the rechannelization and its impact on village, town, city, and ward boundaries. Having recorded the shifting geography of water and land, I will in future research be able to analyze population movements within and out of the delta area with greater precision, such as the large changes that occurred as a result of the Great Kanto Earthquake of 1923.

Topography is an important component of physical geography and of spatial history. It should, in principle, be included as one of the initial data layers of the GIS spatial history. However, generating it by hand (as gridded digital elevation models or as linear contour maps) is very time-consuming, so I have postponed the use of topographic data until I can afford to purchase digital topographic data from Japan. For now, the topography can be seen by displaying the scanned contour maps as backdrop images.

In the political, social, and economic category, the GIS spatial history includes changes in major and minor administrative areas and their population. I recorded the late-1800s change from provinces to prefectures to show the gradual political expansion of Tokyo. I also recorded changes of minor administrative areas (villages, towns, cities, and city wards) and have analyzed many historical and geographic patterns of the urbanization process. As an example of the many aspects of the spatial history of administrative areas, Figure 5 shows annexation and merger patterns in Tokyo and Kanagawa prefectures. (Mergers followed by dissolutions or reconfigurations are shown by lines that cross each other.) Some of the variety and complexity of annexation histories can be seen in the numbered examples in the map:

1. No consolidation (same spatial extent throughout the village-to-town-to-city urbanization process)
2. Simple “single star” merger of surrounding areas around one core
3. “Dual star” mergers around two cores, which then later merged
4. Linkages of interconnected stars, where some villages split and joined two adjacent cities, thus intertwining their annexation histories
5. Complex linked and overlapping patterns, as where villages and towns were split by river channelization (5a), or by mergers into single wards or cities, followed later by splits into separate wards (5b).

Close inspection of the distribution of these and other annexation pat-
terns in this map reveals that in general, Tokyo prefecture’s cities had much more regular, simple annexation histories, whereas Kanagawa prefecture’s cities and towns had much greater complexity. A partial explanation may be that Tokyo city itself had only a few stages of annexation (a major expansion in 1932 and a small expansion in 1936), whereas the two major cities of Kanagawa prefecture—Yokohama and Kawasaki—had many separate annexation periods in the early 1900s, followed by later divisions and reorganizations into wards. As the largest city of the country as well as its capital, Tokyo was able to annex a large area all at once, whereas Yokohama and Kawasaki grew more gradually and only later obtained special city status and were divided into wards.
Mapping of administrative areas and their changes over time also makes it possible to use historical census data to reveal population changes, such as the large population shifts in Tokyo prefecture during World War II (Figure 6). The two maps reveal striking patterns. The top map shows significant growth in the outer wards of Tokyo city itself and in the suburban areas in the middle of Tokyo prefecture during the early and middle years of the war (1940 to 1944). In the last year of the war, shown in the bottom map, the city suffered dramatic population loss, especially in its inner, older wards and in some suburbs, while mountain-edge zones and mountain villages, towns, and cities experienced substantial growth. These patterns reflect the construction boom in suburban areas as war plants and dormitories were built in the middle years of the war, and the deaths and out-migration due to bombing of the city of Tokyo and suburban areas as the Western Allies targeted the capital of Japan in 1944 and 1945.

These two population maps show percentage change, not total population gain or loss (which could also easily be mapped from the GIS data). By showing percentage change rather than total change, the maps reveal the impact of change. Thus, although a circle showing 75% decline in an inner ward represents much greater total change than a similar-size circle showing 75% growth in a mountain village, the impact on the mountain village might have been as significant. Overall, there appears in this percentage view to be a rough visual balance between amounts of loss and gain, but there actually was much greater loss. Tokyo prefecture’s population went from about 7.35 million in 1940 to 7.27 million in 1944 to 3.45 million in 1945, and Tokyo city’s population went from about 6.78 million in 1940 to 6.58 million in 1944 to 2.78 million in 1945. A comparison with population changes for other prefectures would probably reveal where many, but not all, of these people went. Of course, one might question the accuracy of wartime census data.

In the transportation category, the GIS database covers the rail network in the Kanto region around Tokyo, starting with Japan’s first rail line, opened between Tokyo and Yokohama in 1872. The rail line layer records openings (and suspensions/closures due to war, earthquakes, and construction), name histories, reroutings (due to river channelization, company acquisitions, and grade changes), multiple-tracking, electrification, and interline through-service to downtown Tokyo. The rail station layer records openings (and suspensions or closures), name histories, rankings of current service levels,
Figure 6  Wartime population change in Tokyo prefecture
Note: Mapping units are villages, towns, cities, or city wards.
and development of “in-fill” stations on existing lines. The database also covers the extensive establishment, merger, and renaming histories of rail companies.

I am using the rail network component with other GIS layers to evaluate the relationship between new stations and changes in the administrative status and population growth of adjacent areas. I also have used the database to evaluate the effect of old province names on railroad company, line, and station names (Siebert 2000) and to assess the popularity of certain types of rail station names that reflect an image of residential neighborhood type.

As an example of how the rail and other components can be used in a descriptive, qualitative manner to document and visualize the spatial history of place names, Figure 7 shows the relationships between rail station construction and urbanization along the Ome rail line in the western part of Tokyo prefecture. The area shown is a large portion of the Ome 1:50,000 map-sheet area (compare with Figure 3), with multiple GIS layers and associated data. The thin lines are roads and village edges. The large areas with few roads in the west of the map are low hills. All historical rail lines and stations are shown; stations on the Ome line are numbered. Administrative boundaries of villages, towns, and cities as of 1995 are shown by thick black lines.

The text boxes list station opening and urbanization sequences of the five administrative areas (shaded gray) through which the Ome rail line passes on its route from Tachikawa to Ome. In most cases, the temporal sequence was formation of the village (V), opening of a rail station (S), later conversion to town status (T), then conversion to city status (C). Ome is an exception because it was already a town in 1875, almost 20 years before the Ome line was built in 1894. Most of the other, unlabeled administrative areas had similar village-station-town-city historical sequences.

The table at the bottom of Figure 7 compares the spatial and temporal history of the Ome line’s stations and adjacent administrative areas: spatial order (#, starting from the terminus Tachikawa as “0”), station name, station opening year, temporal order (Time), and the name of the administrative area in which each station is located. The first stations were Tachikawa in the village of Tachikawa, Haijima in the village of Haijima, Fussa in Fussa village, Hamura and Ozaku in Nishi-Tama village, and Ome in Ome town. These all have a time rank of “1” for 1894 (though Tachikawa is listed as “0”
### Stations and Administrative Areas along Ome Line

<table>
<thead>
<tr>
<th>#</th>
<th>Station Name</th>
<th>Year</th>
<th>Time</th>
<th>Location: Village Era</th>
<th>Town Era</th>
<th>City Era</th>
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<tr>
<td>0</td>
<td>Tachikawa</td>
<td>1889</td>
<td>0</td>
<td>Tachikawa (1889)</td>
<td>Tachikawa (1923)</td>
<td>Tachikawa (1940)</td>
</tr>
<tr>
<td>1</td>
<td>W Tachikawa</td>
<td>1930</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>E Nakagami</td>
<td>1942</td>
<td>7</td>
<td>Fukushima (1928)</td>
<td>Showa (1941)</td>
<td>Akishima (1954)</td>
</tr>
<tr>
<td>5</td>
<td>Haijima</td>
<td>1894</td>
<td>1</td>
<td>Haijima (1889)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ushihama</td>
<td>1944</td>
<td>8</td>
<td>Fussea (1889)</td>
<td>Fussea (1940)</td>
<td>Fussea (1970)</td>
</tr>
<tr>
<td>7</td>
<td>Fussea</td>
<td>1894</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Ozakura</td>
<td>1894</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>10</td>
<td>Kabe</td>
<td>1927</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>E Ome</td>
<td>1932</td>
<td>5</td>
<td></td>
<td>Ome (1875)</td>
<td>Ome (1951)</td>
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<td>12</td>
<td>Ome</td>
<td>1894</td>
<td>1</td>
<td></td>
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</table>

**Figure 7** Stations and administrative areas along Ome line
based on its earlier date of 1889 on the Chuo rail line). Of these six original stations, four have the same name as the administrative area in which they were located when they opened (Tachikawa, Haijima, Fussa, and Ome). The remaining two, Hamura and Ozaku, did not reflect the name of their administrative unit, Nishi-Tama village. Many years later, in 1956, when Nishi-Tama village finally had grown large enough to become a town, it changed its name to match the station name: Hamura. This marked a shift from the settlement focus along the Tama River in the western part of the area to the newer, Hamura area around Hamura station in the uplands away from the river.

Several of the later, in-fill stations took their names from the administrative area itself (Nakagami in 1908 from Nakagami village) or as “West” or “East” directional variants of the administrative area (Nishi-Tachikawa in 1930, Higashi-Ome in 1932). Although it might appear that Higashi-Nakagami station is similar, it actually has a more complicated derivation. By the time the station opened in 1942, Nakagami village no longer existed. Furthermore, the station is not even in the former area of Nakagami village. The station thus derives its name from its position east of Nakagami station.

The place-name history of Haijima and Akishima is more complex. Haijima station opened in 1894 on the western edge of Haijima village; it became a junction for the Itsukaichi line in 1925, the Hachiko line in 1931, and the Haijima line in 1968. In 1928, several small villages east of Haijima village merged to form Showa village, adopting the reign-era name of the Showa Emperor (Hirohito). In 1938, a new station called Showa-mae (“in front of Showa”) was opened to serve a new military base named Showa. In 1941, Showa village became Showa town, and in 1954 Showa town and Haijima village merged to form Akishima city. The name was formed by combining the Japanese pronunciation of one Chinese character from each of the two names: “Aki” from the “Sho” of Showa, and “shima” as a variant of the “jima” of Haijima (Shogakukan 1996). Finally, in 1959 Showa-mae station was renamed Akishima. Although it is not the major station in the city of Akishima (the junction station Haijima is more important), it is located closer to the center of the city whose name it took. Haijima and Akishima thus have a mixed set of historical relationships: an initial station named after a village remained the most important station in the area, whereas a newer station that now uses the name of the city is less important.
Most of these station name histories follow the typical Japanese pattern of naming stations after the administrative area or subarea in which the station exists. However, some variation did occur, as for Hamura, Háiijíma, and Akishíma. By recording the histories of administrative area and station names (including some station names that changed as many as five times), the GIS spatial database enables a comparative analysis of which types of names were common or fashionable in different eras and areas, revealing variety in the region’s historical geography.

Figure 7 also shows historical landscape units in the Ome area west of Tokyo. The thin lines on the map provide a cumulative view of all roads on 1:50,000 topographic maps in the twentieth century, as well as the edges between settled areas and forested hill lands. The resulting polygons thus depict division of the landscape into units that correspond in most places to city blocks or built-up village edges. The changing land cover/land use in each of these blocks will be recorded for each decade from the historical topographic maps. (Unlike U.S. Geological Survey topographic maps, those produced by the Geographical Survey Institute of Japan include detailed land cover categories.)

With the current status of mapping in the database, the distribution, size, and shape of these landscape units could be analyzed to characterize different zones. For example, the “blocks” appear to be smaller along the Ome railroad line than they are along the three other rail lines that link to it at Háiijíma (station 5). This reflects the greater age and higher density of development along the Ome line. By also displaying the topographic maps, the river layer, and/or the population data for different administrative units at different time periods, this combined map could be used to explore other relationships, such as that between rectilinear blocks in newer areas on the flat uplands along which the Ome line runs versus more varied blocks in the older settlement areas closer to the rivers or along the edges of the hill areas.

Many different spatial features can be incorporated as components of a GIS spatial history of Tokyo, to help analyze aspects of its urban form history. The features I have developed so far in the project create a balance of thematic type, data sources, and mapping methods, serving as a good set for evaluating the effectiveness of using a geographic information system for documenting, visualizing, and interpreting the history of urban changes. The brief examples included in this summary article have been chosen to illustrate the thematic
variety and different types of descriptive and interpretive visualization that are possible. More in-depth coverage of these and other examples of qualitative and quantitative use of the GIS spatial history of Tokyo are included in the dissertation and in separate articles now in preparation or forthcoming.

**Some Advantages and Disadvantages of Using GIS for Historical Research**

Gathering historical records of the past serves to set us apart as humans. This need for connection to the past includes a connection to past environments—the places where we live and work. Planners and architects often attempt to re-create aspects of past environments or design styles, yet that is often impractical in the face of the economic and social demands of a growing society. As a result, most past environments are preserved only as history—as memories. Because geographic information systems allow documenting, visualizing, and interpreting information that has some connection to place, they are an ideal tool for maintaining a collective memory of past environments.

GIS programs are, in essence, data-integration engines (Nyerges 1995). What better tool could exist for integrating information and views of an urban area’s historical form?

GIS programs have another key feature that makes them ideal for historical research: they are very unforgiving of inconsistency and incompleteness. Although this might be viewed as a disadvantage, it is really one of the primary advantages of GIS, for it compels the researcher to maintain high standards and to account for the quality of the data and analysis at every step. For example, a date field can normally take only one date. If different sources record different dates for the same event, one must resolve the discrepancy to enter an unambiguous value. In addition, once the database structure is defined and the historical data is recorded, incompleteness of the historical record can easily be seen when database fields remain empty, when linkages do not work as expected, or when gaps appear in the map. My experiences with inconsistencies and incompleteness in the rail company records made this clear. When creating a sequential chronology for inclusion as an appendix in the company’s system guidebook, the authors or editors did not have any structural requirement of consistency or completeness. In contrast, when I took the same information and input it into my rail database tables and at-
tempted to link it to geographic rail features in the spatial database, inconsistencies and omissions in the data soon became obvious, and I had to resolve them.

Another advantage of using GIS programs for historical research is that they make it easier for the researcher to record metadata—data about the sources and quality of the underlying data. This can be done for the geographic layer and database as a whole, or on a record-by-record and even field-by-field basis. For example, for certain types of information in my rail database, I coded the source and quality for each data entry, such as the type and number of sources used. These codes can be used to reveal on-screen which parts of the visualization and interpretation are based on confirmed, reliable source data and which use data about which I am less confident. Such recording and display of metadata is considerably more complex and often impossible in traditional tabular and map products (e.g., attempting to record the source of each mapped object on a paper map).

The major disadvantage of using a GIS for historical research is the same as the disadvantage of using GIS for any research: data input is usually the most costly and time-consuming part of the project. In the case of historical research, the problem is compounded by the great amount of information that must be entered (assuming that a frequent time sequence of data is available and desired) and by the varying quality of the information. Wherever possible, existing digital data should be considered for use. However, it is unlikely that the historical researcher will find such data for anything but the recent past.

Because of these time requirements, the historian who wishes to use a GIS for analyzing an urban region must carefully consider whether the desired result could be obtained more efficiently by noncomputer methods. For example, arranging a set of historical paper maps in time sequence, then viewing each to assess the condition of a feature of interest, might be more effective for some purposes. However, when the relationships of diverse features at various points in time need to be systematically documented and analyzed, the GIS becomes a powerful tool. All of the time and effort that it takes to create a GIS spatial history of an area then start to pay off. In other words, the combined advantages of data integration, data consistency, data comprehensiveness, metadata recording, and iterative analytical mapping can outweigh the great effort needed to produce them. It is important not to let the GIS be
the only tool. In my project, I attempted in various ways to augment the GIS information by including data tables (e.g., chronologies of administrative and corporate changes) and verbal descriptions of other related factors that may not be amenable to recording in a spatial database.

Finally, geographic information systems have many features facilitating comparison and analysis of data, but they are, in general, “hard-line” tools that cannot replicate the flexibility, generalization, and synthesis capabilities of the human brain. It is thus often useful to step back and “squint” at the data to see general patterns. But this is also an advantage, because the interactive nature of computers makes them more powerful than simple maps to be viewed. The GIS can easily be queried interactively to produce new combinations of display of underlying data and their relationships, to be “squinted at” and interpreted by the human analyst.

Map Notes and Sources

The maps were all produced with Maptitude, the GIS program used to create my GIS spatial history of Tokyo. I could have produced higher-quality map output with better control of fill patterns, labels, and legend elements by exporting the map data to a more sophisticated cartography or illustration program (such as CorelDraw, Adobe Photoshop, or Adobe Illustrator). However, I chose to keep all map generation within Maptitude itself for two reasons. First, this article is about the use of GIS, so I wanted to convey what GIS can do, not what more sophisticated cartographic programs can do. Second, by keeping the cartographic output within the GIS, I am able to display changes immediately, since the map really is an interactive view into the database. That linkage would be lost if other programs were used to modify the map’s elements for publication.

Maps produced in GIS software combine multiple layers of geographic information to visualize the desired geographic phenomena. For a multifaceted, comprehensive GIS spatial history database such as this, describing the “sources” for each map thus becomes quite involved and lengthy. This is especially true for maps that show cumulative conditions, since they combine many decades of historical source data, input and confirmed from various types of sources. The following notes characterize the general nature of the multiple layers of historical information that went into the database components shown in each map.

Figure 2 Spatial and temporal coverage of maps

Inset map of Japan was extracted from a digital map of the world supplied as part of the Maptitude software package, produced by Caliper Corporation. Maps of Kanto area prefectures and smaller administrative units were digitized from boundary lines in 1:50,000 and 1:200,000 topographic maps produced by the Geographical Survey Institute.
of Japan (GSI-J 1900s–1990s). Tabulation of the number of mapped years was produced from individual map listings in the map catalogs at the archives of the Geographical Survey Institute of Japan.

Figure 3 Example of scanned map (Ome area west of Tokyo)
Reproduced with permission from 1953 1:50,000 topographic map of Ome, Geographical Survey Institute of Japan.

Figure 4 Development of Tokyo harbor areas
Shoreline and island boundaries and dates were digitized and recorded from once-per-decade 1:50,000 topographic maps produced by the Geographical Survey Institute of Japan (GSI-J 1900s–1990s).

Figure 5 Annexation patterns in Tokyo and Kanagawa
Administrative boundaries were digitized from once-per-decade 1:50,000 and 1:200,000 topographic maps produced by the Geographical Survey Institute of Japan (GSI-J 1900s–1990s). Annexation and merger patterns were interpreted from those same maps, from tabular and text descriptions in 1903–95 census data (Research Publications 1973; Bureau of Statistics 1950–95), and from flowcharts and tables in historical atlases and chronologies (Ota 1995; Masai 1986; TMG Planning Bureau 1989).

Figure 6 Wartime population change in Tokyo prefecture
Administrative boundaries were digitized from 1940s 1:50,000 and 1:200,000 topographic maps produced by the Geographical Survey Institute of Japan (GSI-J 1900s–1990s). Population data were input from 1940, 1944, and 1945 census data (Research Publications 1973).

Figure 7 Stations and administrative areas along Ome line
Administrative boundaries, railroad lines, railroad stations, and roads were digitized from once-per-decade 1:50,000 topographic maps of Ome produced by the Geographical Survey Institute of Japan (GSI-J 1900s–1990s). Station opening dates were input from rail station chronologies (JRR et al. 1991; Japan Travel Bureau 1985; Chuo Shoin 1995). Some now abandoned lines and stations were located from a history of Japanese railroads (Tetsudo 1972).

Notes
Loren Siebert is a lifelong map and train lover who grew up in Japan and worked there many years as a technical editor and writer. He has a Ph.D. in urban design and planning from the University of Washington (1997), a master’s in urban planning from the University of Washington (1991), and a B.A. in East Asian studies from Western Washington University (1976).
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Siebert’s Ph.D. dissertation committee consisted of John Hancock (chair), Frank Westerlund, George Kakiuchi, Timothy Nyerges, and Anne Vernez-Moudon.

References

Some organizational authors are alphabetized under their short form as used in the text, followed by their full names. Works in Japanese are given with transliterated title first, followed by either the official English title (after a forward slash) or my translation (in parentheses).


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