Formulation of an Urban and Regional Planning System Based on a Geographical Information System and its Application - A Case Study of the Ishikawa Prefecture Area of Japan -

Mitsuhiko Kawakami and Zhenjiang Shen
Department of Civil Engineering
Faculty of Engineering
Kanazawa University
Japan

ABSTRACT

An Urban and Regional Planning System based on a geographical information system was developed using four sub-systems consisting of a digital map system, a database system, an analysis and forecast system, and a planning system. In this case ARCVIEW GIS software was used as a development tool. The digital map system is formulated by the planar orthogonal coordinate system. The data is converted from digital maps issued by the Geographical Survey Institute of Japan (GSI). The database system has layers of data sets, which consist of statistical data, attribute data of geographical points and characteristics of natural features and the built environment. Several sets of principal census data have been converted to mesh data. These kinds of data sets are also utilized to this system. LANDSAT TM data is converted into vector data and linked to the same coordinate system. The analysis and forecast system consists of statistical or mathematical analysis, forecasts, and visual presentations of the results. The planning system consists of some planning models and reviewing techniques to evaluate alternatives. As an example, this paper examines the relationship between land use and the temperature on the ground level in built-up areas.

1 PURPOSE AND RESEARCH METHODOLOGY

In Japan the central government, local governments and private companies have formulated many kinds of spatial data to be used by computer systems. Besides these kinds of spatial data, statistical data such as population, regional areas, land use, types of industry and employee numbers, relating to a particular spatial location, are also collected and collated. If these kinds of statistical data could be integrated with the spatial data as a geographical information system, spatial analysis and presentations would be easily produced using this system.

In order to formulate this kind of system for urban and regional planning, it is a
great theme to introduce these spatial data to geographical information system. In this paper we will formulate a data base system for urban and regional planning, which utilizes existing spatial data provided by the central and local governments, and examines the methodology for integration and management of the data. We will in the future continue to further develop an effective planning system, which could be used for information presentation, regional analysis, future forecasting and evaluating alternatives. This paper outlines a formulation methodology for a data base system for urban and regional planning and a method for information presentation as a case study involving system utilization. Although this study is not necessarily original or in its final stage, it verifies the proposed system’s effectiveness for urban and regional planning. Actually the study was done as follows. Concerning the preservation of the natural environment, the structure of land use distribution such as forest, building area and other characteristics are analyzed at a macro level, and a spatial relationship between land use distribution and temperatures at ground level are analyzed at a micro level. In order to do this analysis, data from remote sensing data is introduced besides of the data prepared by the central and local government.

2 FORMULATION OF DATABASE FOR URBAN AND REGIONAL PLANNING

In this paper Ishikawa Prefecture area is used as a region and Kanazawa City area is used as an urban area. Table-1 shows the details of the software and hardware of the computer system used for this study. Figure-1 shows the component structure of the database formulated using ARCVIEW 3.2 of ESRI Corporation, which utilized spatial data prepared by the central and regional governments. Actually those kinds of data are utilized as follows, the vector type digital map prepared by each local government (1997.7), aerial photographs used to draw the digital map (1997.6), data from the basic study for urban planning (2002.2), the digital national land information prepared by the central government, LANDSAT TM data as remote sensing data (1997.4,), which is described as TM data in this paper. Figure-2 shows an interface image on CRT of this system.

Table 1: Conditions of Computer System

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Endeavor Pro-600L (CPU Pentium III) 1 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>Microsoft Windows Me</td>
</tr>
<tr>
<td>Software</td>
<td>ARCVIEW Ver.3.2 ESRI production</td>
</tr>
</tbody>
</table>
2.1 Integration of Regional Space Data Prepared by the Central Government

The National Information Provision Project of the central government has provided the digital national land information. This data was originally prepared for national level regional planning such as the Comprehensive National Development Plan and the National Land Use Plan. The data was distributed to the government organizations, local governments and other public institutions such as universities free of charge on request. Recently the government decided to distribute the data through the Internet for free. The URL for the home page of the Ministry of Land, Infrastructure and Transport of Japan is http://www.nla.go.jp/ksj/index.html.

The digital national land information is described as text data with a code number using the Standardized Mesh Code System of Japan. The text data can be converted to spatial point data according to the code number and plotted in the plane rectangular co-ordinates.

Then the attribute data of the point data are written down as attribute data for the third mesh polygon or fourth mesh polygon using the extension function of ArcView3.2.
2.2 Integration of Spatial Data Prepared by the Local Government

2.2.1 Vector type Digital map and Basic Survey for Urban Planning
The vector type digital map prepared by Kanazawa City is formulated on the seventh plane rectangular co-ordinates using ARCVIEW, and contains data such as road lines, building locations, district lines, location of public facilities and other relevant data. The basic survey for urban planning is recorded as attribute data on this map. The base map used for urban planning in Japan is a map of 1/2500, which has a printout scale of 800mm×600mm 2km×1.5km and three km² in real scale.

2.2.2 Integration of Aerial Photographs as Background Scene
Aerial photographs of Kanazawa City were taken according to each mesh area based on the plane rectangular co-ordinates. In other words, photographs were taken by focusing on the center of each mesh area and covering some of the adjacent area. Referring to aerial photographs, we could get actual clear images of the ground such as buildings, roads, rivers, and forest without any omission and with an amplified
image. In order to integrate aerial photographs, names of each aerial photographs and
the four corner points of each corresponding mesh are recorded on a management file
of the system as shown in figure-4, because an image registration function had not
been set as standard equipment in ARCVIEW 3.2.

Figure 3: Introduction of the Digital National Land Information to Mesh System

The House Map shows designated lines of land use zoning, upper limit of building
coverage ratio and building floor ratio and lot line, which are not recorded on the
vector type digital map. Also we could get information about the land use for each
building and lot, which could be used for detailed district planning. The image data of
the House Map issued by Kankoh Ltd. in 1998 was used for the system.

2.3 Integration of Remote Sensing Data by Conversion to Vector Data

LANDSAT TM data, which is a kind of remote sensing data, is converted to vector
type data as shown in figure-5.

First, using ERDAS as GIS software, coordinate values of the longitude and
latitude of each pixel and its Band values were transformed into a text type format.
Then, utilizing one of functions of ARCVIEW, point data are created from the
longitude and latitude data and polygon data, which corresponds to each pixel, these
are then formulated using the Avenue script programming. In order to attain the
unification of coordination, longitude and latitude coordinates of TM data are
transformed to the seventh plane rectangular coordinates. Through this transformation
a pixel of TM data is converted to a polygon, which has a scale of 27.8 \times 34.4m.
As described previously, several types of data prepared by the central and local governments are integrated into the database for urban and regional planning using ARCVIEW. In order to support planning, it is important to present every planning information theme by manipulating relating data. As shown in figure 6, EXEL developed by MICROSOFT Corporation and AMOS developed by SMALL WATERS are unified into this system as analytical tools using script programming.
Figure-7 shows an interface image on CRT. In this paper an analysis on spatial information is conducted as a utilization example of this system.

First, the digital national land information distribution of land use such as built-up area and forest in a part of Ishikawa Prefecture is analyzed. Second, the relationship between ground temperature and land use distribution in the central area of Kanazawa City is also analyzed using the basic survey for urban planning and remote sensing data from a viewpoint of environmental preservation. This analysis is done to study the effectiveness of the system because relating theories have not yet been fully reviewed.

Object model using Arcview system

Urban and regional planning system -Project-

Script  DocGUI  Document

Theme map  Analysis tools  Spatial search

EXCEL  AMOS  SPSS

Data edit  cause-and-effect  Statistics analysis

Graph  model  Factor

Figure 6: Unification of Statistical Analysis Software for the System

Figure 7: An Example of Interface Image on CRT Using SPSS
3.1 Application Examples One; Spatial Distribution of Land Use

As an example of analysis this paper studied a part of Ishikawa Prefecture, which consists of 1,014 meshes. In order to analyze spatial land use distribution, data from the third mesh relating three time points were analyzed using statistical methods such as the Cluster Analysis and the Principal Component Analysis, in which seven factors shown in Table 2 were used as variables. In this study a number for clustering was conditioned as six and analysis was proceeded. Through interpretation of each principal component, analysis revealed some characteristics of land use distribution using the Principal Component Analysis. SPSS Ver.6.1.3 was used for this analysis as the statistical analysis method.

Table 2: Land Use Categories on The Third Mesh from the Digital National Land Information

<table>
<thead>
<tr>
<th>Source data (ASC II data)</th>
<th>Contents</th>
<th>Data type</th>
<th>Data range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration district data</td>
<td>Administration district</td>
<td>Vector data</td>
<td>Ishikawa prefecture</td>
</tr>
<tr>
<td>Land use survey</td>
<td>Attribute data for roads, buildings, farm land, forest, rivers lakes and the seaside</td>
<td>Standard mesh data (Polygon)</td>
<td></td>
</tr>
<tr>
<td>Commercial survey</td>
<td>Attribute data for commercial statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry survey</td>
<td>Attribute data for industry statistics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An analysis is done referring to the results of the Principal Component Analysis and the Cluster Analysis. Figure 8 shows an example of land use distribution grouped as six clusters. Figure 9 also shows mesh score distribution categorized into six groups on orthogonal axes of the first principal component and the second principal component.

Analysis reveals that the first principle component is interpreted as showing a “distribution tendency of forest area” and a “land use tendency of built-up area”, and the second principle component is interpreted as showing a “distribution tendency of paddy field” and a “land use distribution of built-up area”. Referring to plot distribution in figure 8, it is evident that meshes of class one are distributed relatively evenly, meshes of class two and three are distributed mainly in the area of plain and meshes of class four are distributed mainly in the coastal area. Distribution of the meshes of class six are concentrated in the central area of Kanazawa City.

As shown in figure 9, a built-up tendency is evident on the right-hand side of the
first principle component and upper-side of the second principle component. Meshes of class six have the strongest tendency towards the built-up area, which are mainly located in the built-up area of Kanazawa City as shown in figure 8.

Figure 8: Mesh Distribution Grouped by Cluster Analysis

Figure 9: Score Distribution of Meshes Using Results of SPSS
3.2 Application Example Two; Relationship between Ground Temperature and Land Use Distribution in the City Central Area

The relationship between the ground temperature and land use is analyzed using data from the basic survey for urban planning and TM data in the central area of Kanazawa City, where meshes of class six are located. Ground temperature can be estimated using the Band value \(^{(1)}\). The distribution of five rank of ground temperature is shown in Figure 10. This study uses TM data at 12:38pm on the 25\(^{th}\) April in 1997. The range between the highest temperature and the lowest temperature is about seven degrees centigrade. Each of the values corresponds to land use categories in a mesh, which have the same shape and location as a cell of remote sensing data. These are estimated using a spatial analysis function of ARCVIEW and registered to the data base system as one of the attributes of the mesh. Land use categories are blocks, building area, forest and water area, bare land and greenery area. Figure 11 shows an example of maps, which represent the distribution of forest and water area. Area ratios of each cell, which correspond to a pixel of TM data, such as built-up area, streets, parking sites, forest, water area and bare land, are used as analysis indices. The water area is counted in the same category as it decreases the ground temperature, although there is not so much water area in the study area.

![Figure 10: Distribution of Ground Temperature](image-url)
Designated land use zoning is also registered as an attribute of each cell, which is categorized as residential, non-residential and scenic. Figure 12 shows the distribution of land use as a rank of five levels of temperature. These tendencies are recognized as follows. Forest and water area is placed in the higher rank of one and two, having a lower temperature and is generally in the lower ratings from rank one to five.

On the contrary, the built-up area gains a higher rating from rank one to rank five. It is especially higher at rank three, four and five. Although bare land is higher at rank three, it is distributed at other ranks at a certain level. Greenery area is higher at rank...
one and it is distributed at other ranks. Parking area is lower at rank one and two. Street area is distributed relatively evenly between ranks.

The relationship between ground temperature and land use is analyzed using the Covariance Structure Analysis of AMOS as the analytical method. Using this method, the relationship structure between ground temperatures is formulated and an analysis is done. Figure 13 shows the result of an analysis of covariance structure. In the case of non-residential zoning, indices relating to the built-up area become higher and indices relating to the natural environment become lower. These relationships increase ground temperature.

![Figure 13: Relation Structure between Ground Temperature and Land Use using AMOS](image)

4 CONCLUSION

In this study we tried to formulate a database system for urban and regional planning by utilizing existing information, such as the digital national land information and the basic survey for urban planning. This information was prepared by the central and local governments of the area and provided the data to analyze spatial structure. Actually the study was done as follows. First, the process and methodology for introduction of data to the GIS system and treatment of attribute data were explained. Second, a supporting system for urban and regional planning was formulated by unifying existing statistical analysis tools. Third, an interface system was designed in
order to allow easy manipulation of the system for users.

As an application of this system, an experimental study was conducted in the area of Ishikawa Prefecture and Kanazawa City. An analysis was done on land use distribution using the digital national land information. It shows effectiveness of this system for supporting planning, although it was still at the analysis stage.

By unifying the variant scale of spatial data, it became possible to compare different districts, which had been relatively difficult using the former method. This system could be developed to support planning systems such as spatial distribution analysis of land use, the time series variation and other such planning subjects, which utilize spatial data and statistical information produced by this method.

5 NOTES

Temperature of surface land (T) can be calculated by using LANDSAT TM data as follows.

\[
T = 1.7651 \times 10^{-2} \pm \sqrt{0.017651 \times 10^{-7} \times 5.1292 \times 10^{-9} (1.6023 - R)} - 273.15
\]

R is a CCT value of band six of LANDSAT TM data, which shows an absolute radiation luminance.

6 REFERENCES


