イスラーム世界研究　第 6 巻（2013 年 3 月）83–94 頁
Kyoto Bulletin of Islamic Area Studies, 6 (March 2013), pp. 83–94

An Introduction to the Spatial-Temporal GIS 'DiMSIS-Ex' and its Application for the Recovery and Restoration Process after Large Disasters in Düzce City: Construction of the New Residential Area and Traffic Network

YOSHIKAWA Koji[*], KAJITANI Yoshio[†], KAKUMOTO Shigeru[‡], HATAYAMA Michinori[§], USUI Mahito[**]

Abstract

To contribute to the improvement of regional safety, we have developed a spatial-temporal information system under the concept of a risk-adaptive regional management information system (RARMIS). This system can be characterized as follows: (1) Coordination between normal and emergency functions. (2) Integrated database for handling spatial-temporal data. (3) Implicit topological data descriptions.

In this paper, technical matters about spatial-temporal GIS and its applicability for not only disaster prevention but also a broader kind of analyses and the daily tasks of local governments will be explained at first.

Then, the case study of Düzce city will be mentioned as an example of the application of spatial-temporal GIS. Relatively soon after the earthquake, it was decided to develop a new residential area in the suburbs of the city and let 50,000 people emigrate there. However, because the road conditions were not so good, we tried to check whether the traffic capacity of the roads between the new residential area and the city center was adequate. Concretely, we surveyed traffic volumes and found that while no serious traffic jams occurred the trip took about 45 minutes. Accordingly, we suggested a new trunk road was needed and also, using vacant lots in the center of the city, small but numerous parking lots might be constructed. At the time of writing, this work has been completed almost according to our suggestions. Now, both areas are connected by a new 8 km-long trunk road and the trip takes only 6 minutes.

1. INTRODUCTION

In accordance with the purpose of this panel discussion whose title is "*The Importance of Interdisciplinary Research Connecting Historical, Anthropological, Information, and Engineering Sciences of Based on the Case Study of Spacial-Temporal GIS(DiMSIS-EX) Application*", our chief role that should be described in this paper might be regarded as explaining the spatial-temporal GIS to non-technical/engineering based researchers plainly,

* Professor, Osaka Sangyo University.
† Associate Professor, Kyoto University.
‡ Professor, Tokyo Institute of Technology.
§ Associate Professor, Kyoto University.
** Lecturer, Suzuka National College of Technology.

and introducing a good application example to encourage researchers to come up with ideas for its application in their own research fields.

Accordingly, in this paper, the features, advantages and possibility of application for historical and anthropological researches of the spatial-temporal GIS, especially ‘DiMSIS-Ex’ which we introduced and propose to use widely for most research fields, will be shown as a first topic, and then our application for the recovery and restoration process after large disasters in Düzce city will be introduced as a second topic.

2. WHAT IS THE SPATIAL-TEMPORAL GIS ‘DiMSIS-Ex’?

2.1 History and Activities

Spatial-temporal GIS, named DiMSIS-Ex, and its database structure development has mainly focused on its utilization for local government applications to mitigate disaster damage and to contribute to the improvement of regional safety after the great HANSHIN-AWAJI Earthquake occurred in Japan in 1995. A suitable system has been surveyed through case studies to apply the system to Japanese local governments, and Düzce is the 6th target city for our assistance (Fig.1). Through these activities, we could verify the broad applicability of such GIS because countermeasures taken by each local government have been different according to their backgrounds.

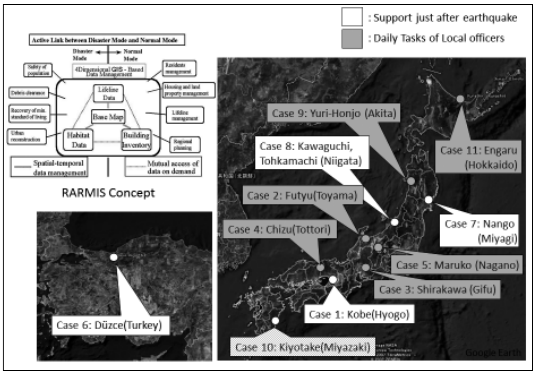


Fig. 1 DiMSIS Activities

RARMIS (Risk-Adaptive Regional Management Information System) concept shown in Fig.1 is the important output of these activities, and it can be said that DiMSIS-Ex has been developed under this concept. This concept shows that the normal condition and the emergent one are inseparably related to each other; that is, such data must be updated continuously and accumulated as only the most recent can be utilized in an emergency phase. Additionally, it shows that, regarding actual operation in the field, we would not be able to use any information system if local officials were not accustomed to using it for daily tasks.

DiMSIS-Ex has advantages regarding the ease of data handling as shown in chapter 2.4, and it can be supplied without much cost because it is not a commercial product but software managed by academic staff. This is why DiMSIS-Ex has an advantage as an administrative GIS and is used for the daily tasks of many local governments.

Our support channel in 1995 was measures for the removal of damaged houses by the local government in Kobe. It was a very disconsolate matter for the victims — they lost houses full of memories — but their removal was very important and essential because without it, they wouldn't have been able to re-construct their lives. Thus we could contribute to the actual tasks they had to deal with just after disaster.

Now we can indicate the typical advantages of GIS through it; that is, by using GIS, officers could get a reliable verification of applicants' locations by finger-pointing, in other words, they could confirm them without using 'vague' addresses, and could order removal works efficiently with area bundling. As officers were not accustomed to such procedures at first, there was always a very long queue, and the waiting time exceeded applicants' patience, but after employing GIS, the maximum efficiency of the reception was achieved and the long queue could be dispersed. In addition, we researchers also got significant information about the distribution of damaged buildings for encouraging restoration planning afterwards, including historical factors as shown in Fig.2.

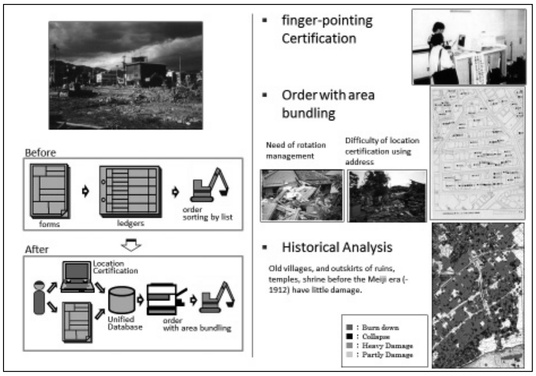


Fig. 2 Supporting for debris removal after Kobe Earthquake

2.2 Conventional GIS and spatial-temporal GIS

Through our activities mentioned above, we got a new understanding that the condition of cities would change both extensively and very rapidly after a disaster (Fig.3). We can say that only spatial-temporal GIS could manage the data at that time. Also, when considering that our cities are changing continuously and ceaselessly even in a normal phase, albeit relatively slowly, it is a certainly a general requirement that accumulating and managing the real time data, along with its time axis, is indispensable.

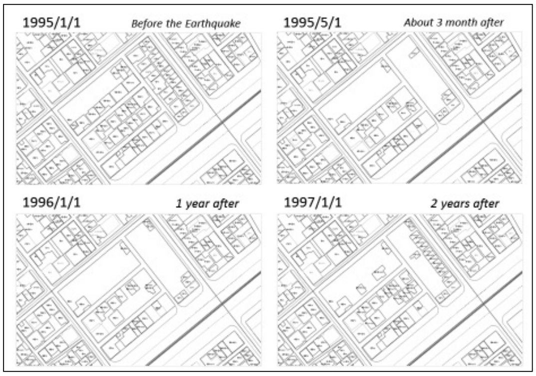


Fig. 3 Examples of Temporal Data

In cases where historical matters have been dealt with using paper maps, such maps as shown in Fig.4 might be used. Conventional GISs, as they were

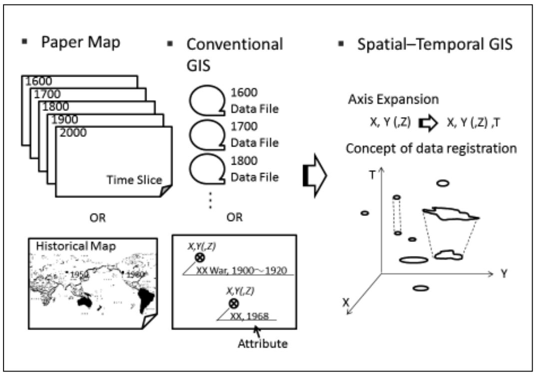


Fig 4. Conventional GIS and Spatial-Temporal GIS

developed to realize digital maps initially, are designed in the same way as paper maps. Many problems will inevitably happen when storing historical data. For example, many files will be needed, and moreover, when you want to update them in a random order or refer to historical events of various eras, you must open many files in turn. It means that we cannot describe, accumulate, or analyze information of the real world effectively using conventional GIS.

On the other hand, each object of spatial-temporal GIS has not only spatial axis but also time axis. Though it might be regarded as only an expansion of dimension technically, its impact is tremendous; that is, we can describe and store data on almost all events in the real world uniformly and by the same simple way, wherever and whenever such an event occurs.

2.3 Implicit Topology Data Description

For handling spatial-temporal data, we employ the implicit topology data description shown in Fig.5. Data description itself is also a technical matter, but, in this case, data registration can be done very easily because the topology definition of each object is not needed.

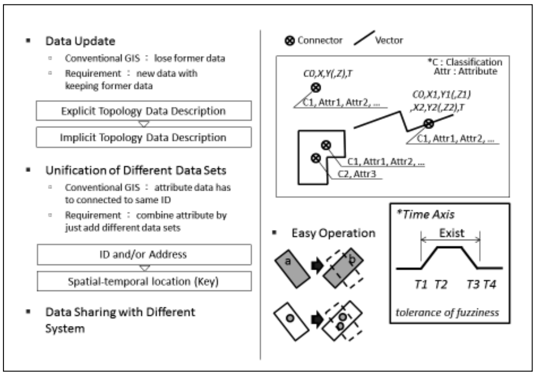


Fig. 5 Implicit Topology Data Description

Concretely, only using the point element named 'connector' and line element named 'vector', you can create and update your data. For registering point data, all you need to do is to set a connector at the appropriate position in the spatial-temporal space. You can set the x,y data by mouse-clicking on the screen and set the attributes and time by key input. Of course, such man-machine interface is easily changeable. Regarding line and area data, you can draw lines and sides in the same way as CAD because topology definitions are not needed. All you need to do is to register the attributes as one or more connectors on the line or inside the area. With respect to the time, 4 time data (*T1, T2, T3, T4*)can be registered in order to tolerate the ambiguity.

Thus, when you need to update the shape of the area such as the enlargement or reconstruction of house, you don't need to define the topology. You should definitely confirm whether the attribute data remains intact after changing, but this is not so difficult. Furthermore, unification of different data sets and data sharing with different systems can be done freely because of such a simple data format.

2.4 Accumulation of Historical Information

Making the most of the advantages of the flexible time data handling mentioned above, historical information can also be accumulated easily. You can register transitions of matters such as territories as well as events and periods as shown in Fig.6. You can easily update whenever you get data on a newly founded territory.

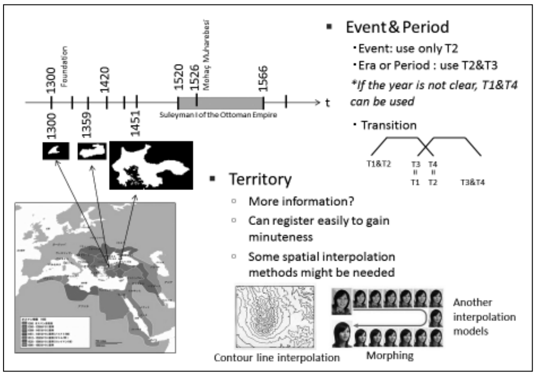


Fig. 6 Accumulation of Historical Information

I wonder if it was due to the limitation of paper maps that historians did not draw more maps by shorter time interval in spite of having more information. Using DiMSIS-Ex, maps for an arbitrary year could be drawn freely. In order to do that, some interpolation functions might be needed for describing territory transitions — for example contour line interpolation and morphing technology would be of use as a reference —, but you can develop such functions and moreover an application suitable for your own use by yourself if you have basic level programming skills, as source codes of not only applications but also the core-program of DiMSIS-Ex are free for academic use. You might indeed comment: 'Do I have to develop this app by myself?'. But in reality, this can be regarded as another advantage of DiMSIS-Ex. It would not be an ideal situation if our ideas of analyses were to be limited or lead by the existing functions of GIS, in which the selection of some functions could only be executed according to what private companies had judged as priorities. In you are using ArcGIS or Google Maps for spatial analysis, even if you request these companies to add on a function you need, in most cases your hopes will not be realized.

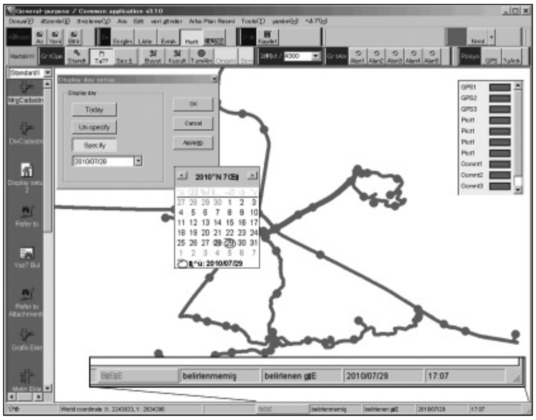
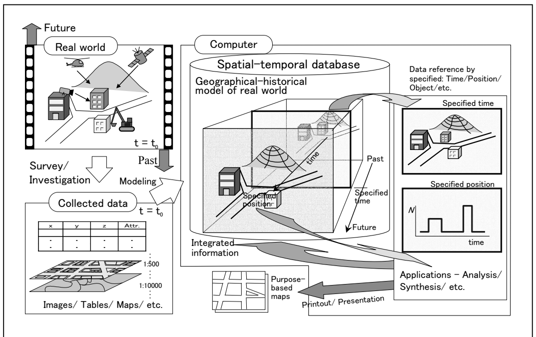


Fig. 7 Time Setting Up Menu for Browsing



Overall concept of spatial-temporal GIS named DiMSIS-EX

Fig. 8 Concept of Spatial-Temporal Database

Fig.7 shows a screen copy of DiMSIS-Ex. When you click a menu button at the bottom of the window, you can choose the time to display. As it is just a matter of man-machine interface, we can change it easily according to the users' request.

Over all, the concept of spatial-temporal GIS can be illustrated as in Fig.8. We want to emphasize again the potential of GIS not only as a means of expression but also as a unified database to improve data accumulation, management of information, analyses, and furthermore, to encourage new discoveries and findings.

3. SUPPORT ACTIVITIES AND ANALYSES IN DÜZCE

3.1 Our Support Activities & Policy

The two earthquakes, which occurred on August 17th and November 12th in the northwestern part of Turkey, resulted in significant loss of life and property damage. Economic losses totaled 16 billion US dollars, which corresponds to 7% of the Turkish GNP. The number of dead was over 17,000 and many more people than this lost their homes.

Düzce city is located about 170km east of Istanbul and close to the epicenter of the second earthquake. Its population is about 75,000, and wood crafts and hazel nut production are the main industries. According to a summary of the property damage caused by the two earthquakes in Düzce city, from among the 11,000 buildings which existed prior to the earthquake about 2,300 buildings were judged as heavily damaged or had collapsed, and about 2,500 were judged as having medium damage. A total of 3,560 households had been living in the heavily damaged or collapsed buildings, and as a result, they were obliged to seek shelter in temporary housing or tents (Fig.9).

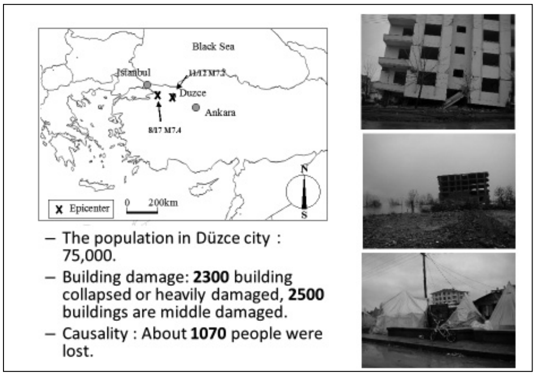


Fig. 9 1999 Turkey Earthquake

Our first visit to Düzce was in December, 1999, just 1 month after the 2nd earthquake had occurred.

In Düzce city, damage factor analysis of housing, and city revival planning based of it were needed. Thus we began to develop the reconstruction monitoring information system using DiMSIS-Ex from January, 2000. Through these activities we received the following requests for such a system from the Düzce authorities:

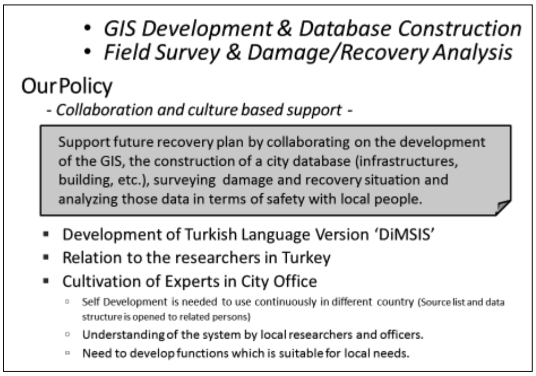


Fig. 10 Our Support Activities and Policy

1) It should be a system that is able to describe the ever-changing regional information.

2) It should be a system in which the application software can be added by Düzce city officers themselves.

3) It should be a system having a database compatible with other GIS/CAD applications.

In satisfying these requests, we have done all our work under a policy of collaboration and culture-based support. In other words, a series of activities were performed according to the needs of the people in Düzce, and by collaborating with Turkish people. Fig.10 shows a policy statement we drafted at the beginning.

3.2 Turkish Version GIS Setup & Spatial-Temporal Database Construction

A building damage survey had already been performed by Düzce city officials when we started to assist, but this was only available in the form of paper maps colored according to the degrees of damage. Our first task was to set up a Turkish version DiMSIS-Ex and to construct a spatial-temporal database of Düzce in order to conduct spatial and temporal analyses.

After the Hanshin-Awaji Earthquake, DiMSIS-Ex was evolved as an internationally adaptable system. Multiple languages can be used in DiMSIS-Ex and functional developing kits are available in Turkish to build local people's own systems according to their preferences or regional cultures. Düzce's case shows that this internationally adaptable concept as well as other system concepts was well received by the local people.

We created a basic database from the paper maps, while the damage and recovery data taken from photographs was assembled by public officers in Düzce.

Thus, we were able to connect the different damage datasets by geographic coordinates and visualize the change in the spatial patterns. We could also compare the damage patterns and photo data, which were taken and attached to the database (Fig.11).

As new residential areas were being planned for development by the Government with assistance from the World Bank, individual map datasets of these areas as well as that of the city area were gathered by vector data. As these three datasets are measured independently with absolute coordinates, matching has been done by using Quickbird image data, and GPS data was also utilized to increase accuracy (Fig.12). Through these procedures, an integrated spatial-temporal database was constructed.

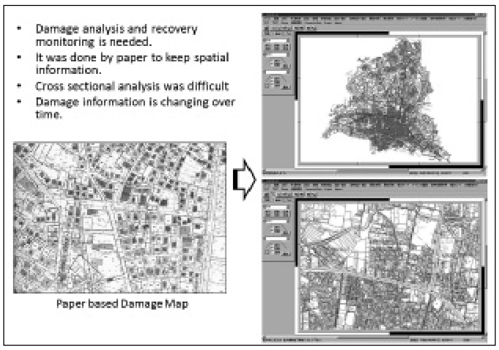


Fig. 11 Spatial Database Construction

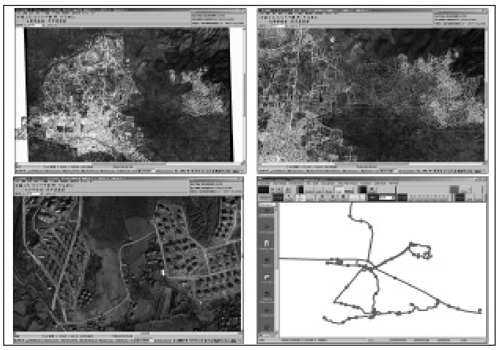


Fig. 12 Satellite Image Overlay (Trukish Version DiMSIS)

3.3 Spatial-Temporal Analyses

1) Spatial Distribution of Damaged Buildings

Fig.13 shows the spatial distribution of damaged buildings. When we zoom in, we can distinguish the damage to each building. Each star indicates the classified damage type. Heavily damaged or collapsed buildings have been indicated by painting over and buildings with medium damage are cross-hatched. Quite a few buildings are classified as having heavy or medium damage. In DiMSIS-Ex, such attributes are stored as these types of marks using the connectors mentioned in chapter 2.3. Basically, we collect, sort, analyze and merge connectors when we need to summarize and analyze the data in an arbitrary spatial scale.

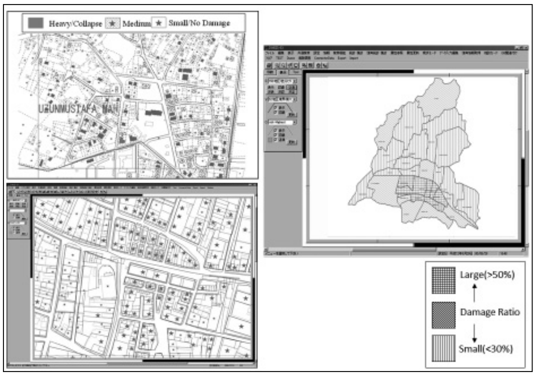


Fig. 13 Spatial Distribution of Damaged Buildings

The right-hand figure shows a map of Düzce city's total damage. The most heavily damaged area is the central part of the city where there are some relatively high reinforced concrete buildings.

2) Damage Classified by Stories

Using damage data, we compared the damage level for each building to the number of floors (Fig.14). We could easily find that the damage level sharply increased in buildings over 5 stories. It can be concluded that the damage degree in the city center was higher due to the existence of many high reinforced concrete buildings there. Actually, the Mayor introduced a policy of removing the upper floors of buildings over 4 stories high. Photos of the buildings from which the upper floors were removed are also shown in Fig.14.

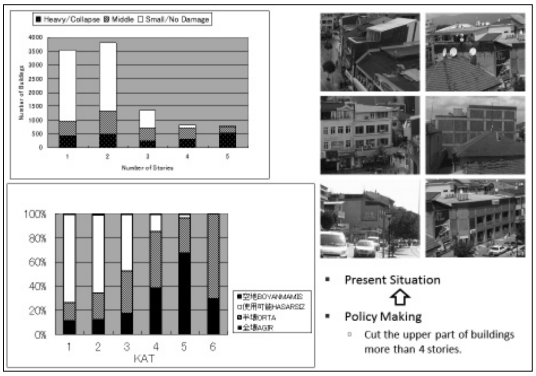


Fig. 14 Damages Classified by Stories

3) Damage by the First and Second Earthquakes

As building damage data was created in a spatial-temporal format, we could investigate further research on the Turkish Earthquakes; for example, we could analyze damage caused by the first earthquake and second earthquake separately. Mapping of the building damage due to the two earthquakes can be done by other GISs, but spatial-temporal GIS has the advantage that we can make such extended analysis and also monitor the recovery process after the disaster. More expansive results are expected by storing the information over time.

Graphs 1 and *2* in Fig.15 show the damage evaluation after the second earthquake to the reinforced concrete buildings which were and were not damaged by the first earthquake. The buildings, which were originally evaluated as having slight or medium damage, tended to have a higher damage rate percentage. *Graph 3* depicts the corresponding degree of damage by the first and the second earthquakes. The buildings which were evaluated as having slight damage from the first earthquake, became heavily damaged or collapsed at a rate of 63.6 % (14/22) from the second earthquake. The buildings with no damage recorded for the first earthquake became heavily damaged or collapsed at the rate of 30.6% (45/147) in the second earthquake.

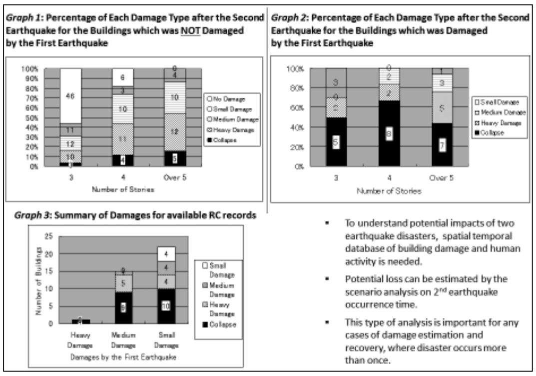


Fig. 15 Building Damage Analysis

Even the buildings which were judged as slightly damaged by the first quake tended to be heavily damaged or collapsed due to the second.

They are therefore quite vulnerable, and because of the likelihood of future disasters, the cost of effectively retrofitting them should be considered. This is the task for future recovery in Düzce city.

4) Traffic Flow Survey between the New Residential Area & the Old City Center

As we briefly mentioned in chapter 3.2, the Turkish government and the World Bank jointly developed two new residential areas with 10,000 apartment houses in a hilly, suburban part of the city which used to be hazel nut orchards. This was analyzed as one of the most stable areas, and 50,000 people were allowed to emigrate there. Considering the orginal population of the city (approximately 120,000) and the condition of the existing roads, there was some concern that not a little inconvenience would arise and severe traffic congestion would occur (Fig.16). Accordingly, we tried to check whether the traffic capacity of the roads between the new residential area

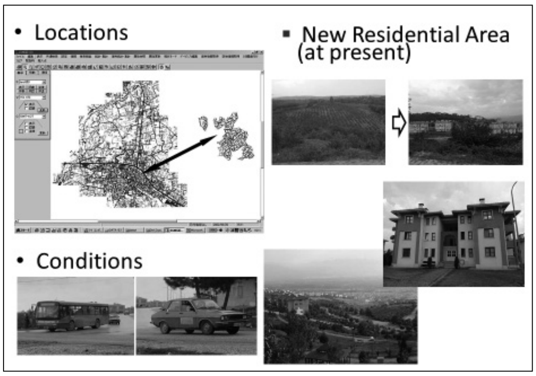


Fig. 16 Locations and Conditions of New Residential Area

and the city center was adequate. We chose 11 traffic survey points shown as from A to J in Fig.17, considering the importance for access. Fig.18 shows the survey results for the road network by handy GPS and traffic volumes.

Also additional analyses such as the difference of traffic volumes according to the time period, and surveys to determine the number of passengers in cars and buses were performed.

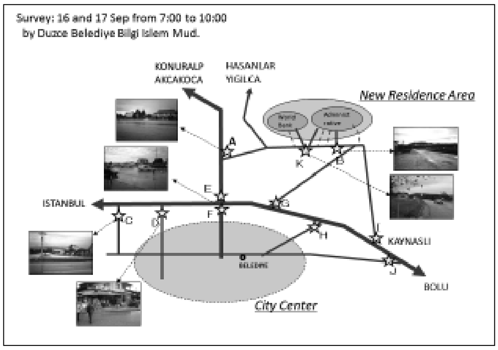


Fig. 17 Traffic Survey Points

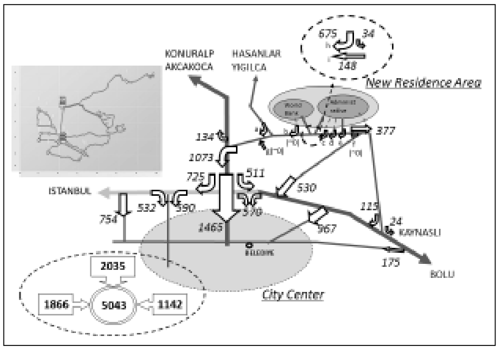
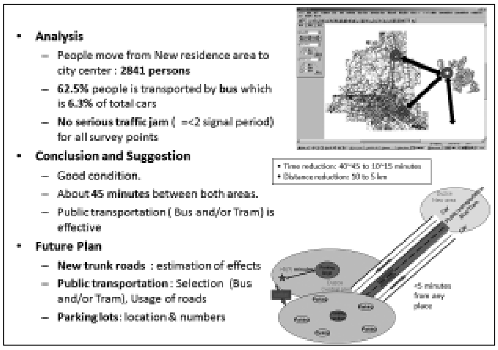


Fig. 18 Traffic Survey Results

As a result of these surveys, we found that generally no serious traffic jams occurred. On the other hand, we found that the trip between both areas took about 45 minutes, so we suggested that a new trunk road was needed and also, by making use of vacant lots in the city center, many small parking lots should be constructed. Moreover, we suggested the construction of a tram line which would be a fundamental solution not only for commuters' convenience but also to provide all of the residents' with mobility, encouraging the revitalization of the city, and promoting an eco-friendly city policy (Fig.19).

At the time of writing, the trunk road and parking lots have been realized almost according to our suggestions. A main road has already been constructed and also ring roads are now in the planning phase as shown in Fig.20. We drove on the trunk road in 2010 and measured the time taken by using the handy GPS. Now both areas are connected by a road which is 8 km long and the trip takes only 6 minutes.



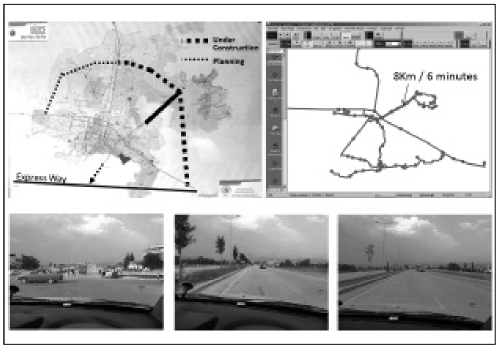


Fig. 19 Analysis and Proposed Future Plan

Fig. 20 Present Plan & Condition (2010/7/26)

4. CONCLUSION AND FURTHER ARGUMENTS

In this paper, we set forth the argument that spatial-temporal GIS is suitable for describing and accumulating information of the real world, and also, through examples of our activities in Turkey, information accumulation through the creation of a spatial-temporal database provides a valuable contribution to practical decision making and planning. In particular, we emphasized that data accumulation by unifying spatial and temporal attributes is essential for advanced analyses and in this regard the spatial-temporal GIS has possibilities for historical and anthropological researches. Also, in the chapter on our activities in Düzce, after referring to our approach in which differences in culture and history are given the maximum consideration and respect, it is shown that practical outcomes for restoration planning which conformed to Turkish culture could be achieved. Additionally, detailed analyses dealing with the impacts of the two earthquakes separately could be made by utilizing the spatial-temporal database. This shows that historical information is also essential for our research on contributing to disaster prevention in the engineering field. We believe that the importance of interdisciplinary research connecting historical, anthropological, information and engineering sciences could be clarified in this paper although this might be somewhat empirical.

The series of our activities can be regarded as a field of comparative study of two countries' cases. We can acquire useful knowledge by an interdisciplinary approach. Differences in building construction systems, restoration processes and residents' refugee activities, — their culture must affect these to a large extent — were confirmed as shown in the upper part of Fig.21.

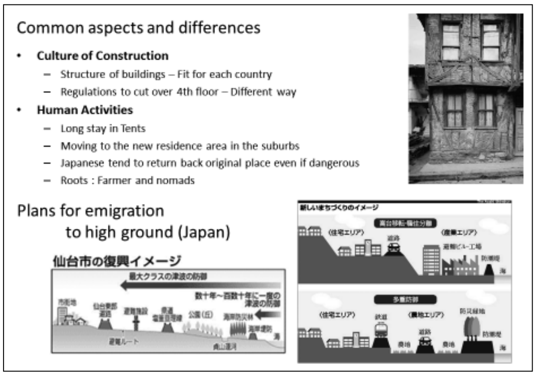


Fig. 21 Turkish and Japanese Cultures

Older wooden houses suffered heavy damage in Kobe but not in Düzce, where new buildings suffered more damage than old wooden houses that were built using experience gained over a long period. The new residential district with new houses has been built in a safer area in the suburban nut orchard area in Düzce. On the other hand, redevelopment schemes in Kobe proceeded to reconstruct most of the city facilities in their previous positions. The Turkish government raised taxes to support the victims and because damage had been caused by an uncontrollable natural force. the people accepted to pay for their fellow citizens' losses.

These facts indicate that suitable survey and measurement procedures were necessarily different. This means that optimum assistance before and after the natural disasters was also different. For realizing meaningful activities in any country, there is no doubt that an integration of historical and anthropological approaches is also essential.

In 2011, the biggest earthquake we have ever experienced struck the eastern part of Japan and we suffered not only quakes but also a tremendous tunami and moreover a nuclear accident. The Japanese government is making plans for emigration to higher ground in the catastrophically devastated areas (see lower part of Fig.21), which is similar to the Turkish government's decision. Frankly speaking, we had a had a sense of incongruity about this policy in the beginning, but now we Japanese are attempting to employ a similar policy even though there are arguments both for and against it. Are such migration policies, and also the victims' acceptance of them, are invariably and strongly tied to each culture, or changeable depending on the type and magnitude of a disaster? Taking this into consideration, there are many subjects to be solved by adopting interdisciplinary researches.

REFERENCES

S. Kakumoto, M. Hatayama, Y. Kajitani, K. Yoshikawa, Y. Kosugi and Halit Ramazan Kubilay. 2004. "Damage Reduction by Culture Based Method Supported by Spatial-Temporal GIS - Collaborative Research with Duzce Municipality Turkey -," XXth ISPRS Congress, International Society for Photogrammetry and Remote Sensing, pp.1209–1215.

Y. Kajitani, S. Kakumoto, K. Yoshikawa, M. Hatayama and Y. Hayashi. 2003. "An Analysis of Damages and Recovery Status in Duzce City after 1999 Turkey Earthquakes employing Spatial-Temporal GIS," 8th International Conference on Computers in Urban Planning and Urban Management (CUPUM'03), CD-ROM.