L.I.S. DEVELOPMENT FOR THE REGISTRATION AND CLASSIFICATION OF THE 1999 ATHENS EARTHQUAKE DAMAGES. APPLICATION ON THRAKOMACEDONES COMMUNITY.

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Abstract:

On September 7th 1999, a 5.9 R earthquake occurred in Athens, SW of Mount Parnitha. During the next days, over 1000 post-quakes were recorded, 143 people were found dead and hundreds injured, more than 40 buildings collapsed, whilst the most severe damages were reported from the Southern and Western suburbs of Athens.

The State's reaction was immediate, putting into effect financial benefits (loan subsidies, gratuities, etc), supplying free assistance from the State and establishing special services for everyone in the Region of Attica with a building damaged from the earthquake.

The occasion of the quake raised the need for the evolvement of a project aiming to the easier, quicker and more accurate registration and management of the resultant situation from the relevant organizations. This project involved the development of various L.I.S. in the mostly damaged areas (Thrakomacedones, Menidi, Kamatero and Liossia), with a common architecture and compatible to each other.

It was structured under Pc ArcView 3.1, due to the software's ability to manage and develop data from ArcInfo, AutoCad, shapefiles, etc. to support multimedia and to link to dBase or other (via SQL connection) databases.

Part of the graphic data was supplied by the Local Authority in AutoCad drawing (.dwg) format, and another part was digitized from local organizations printed maps, providing city blocks, property boundaries, street planning and other layers of information. The descriptive tables were filled in with data captured from Autopsies and Demolition Protocols (for dangerous buildings) given by the Municipality, containing: owner's name and address, characterization of the building's condition (green, yellow, red), possible professional use, number of floors, construction year and type of damages.

Multimedia included in the project, contained pictures of damaged buildings, videos of their demolition procedure and aerial photos of the areas hurt before and right after the earthquake.

The outmost objective of the whole project is to provide accurate and integrated information on the situation that turned up after the quake, for the most efficient confrontation of the problems.

1. SEISMIC DATA FOR GREECE

Greece lays over the limit of contact and convergence of the African and the Eurasian lithospheric plates. The African plate immersing under Greece at the speed of 5cm per year causes the crushing of the Oceanic plate. These movements result to the compression of the Aegean Sea, as the Turkish plate (part of Eurasian plate) pushed by the Arabic plate depresses the Aegean Sea, lengthening it in a NE – SW direction. Thus, the active tectonic in this area is intense, as we can see by the great seismic activity, the deformity of the geological zones and the volcanic phenomena.

The released seismic energy in Greece derives from the approximately 800 active seismic focuses, representing 50% of the released seismic energy in Europe and 2% worldwide. The most impressive geomorphological features of tectonic origin in this area are the following:

- ✓ *The Greek Arc*, connects the Dynaric Alps to the Turkish Taurus Mt, through the Hellenian mountain ranges, the Ionian Islands, and the islands of Crete and Rhodes.
- ✓ *The Greek Abyss*, consists of a number of sea basins whose depth reaches 5 Km, lays parallel to the Greek Arc and contains smaller linear abysses (Plinio's abyss, Stravon's abyss and the Ionian Sea abyss)
- ✓ *The Volcanic Arc*, consists of various volcanic islands, active volcanoes (Methana, Santorini, Nisyros) and sulphuric sources. Between the sedimentary and the volcanic arc, lays the Cretan Sea basin (South Aegean Sea basin) with a depth of almost 2000m.
- ✓ *The north Aegean Sea abyss*, with a depth of up to 1500m, probably extending to the small Marmara Sea Basins.
- ✓ *The Anatolia fault*, which according to a theory, crosses the North Aegean Sea and ends intersecting the Greek arc, which is created by the African and the Arabic plate. As the Arabic plate moves north towards Eurasia, it pushes Anatolia from the west, causing earthquakes along the North Anatolia fault, while the African plate is sinking under the Anatolia plate.

The surface earthquakes (less than a 60 km deep) epicentres' allocation defines the boundaries of various seismic zones. The most important one lies along the outer side of the Greek Arc, meaning the coasts of Western Greece, Ionian islands, S.W. Peloponnese, Southern Crete, Karpathos and Rhodes. Other important zones have an East to West direction, like the ones of the North Aegean Sea, Thessaly – Sporades, Patraic – Korinthian Bay etc.

Analysing the observations on earthquakes, we reach the conclusion that in Greece there is an average of 50 earthquakes a month, 11 earthquakes over 5.0 degrees of the Richter scale almost 8 earthquakes over 6.0 R every 5 years, 12 earthquakes over 7.0 R every 50 years and 3 or 4 earthquakes over 8.0 R every 100 years.

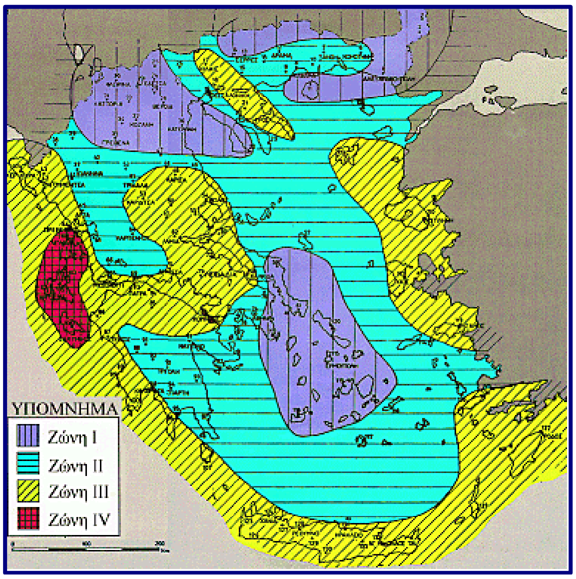
1.1. Greek Seismic Code

The Greek Seismic Code (GSC 2000) is a review of the New Greek Seismic Code (NGSC). The GSC 2000 includes amendments and additions to the NGSC a) determined after important remarks, comments and scientific opinions reported during the implementation of the NGSC, b) in order to be adapted to the relevant EuroCodes EC8 (anti-seismic) EC7 (on foundations). The GSC 2000 will be applied for the first year of implementation parallel to the NGSC.

The New Greek Seismic Code divides Greece into 4 zones according to seismic danger (they are presented in the following picture) and into 4 soil categories. (A, B, C, D), according to their structure.

2. THE ATHENS EARTHQUAKE (7/9/1999)

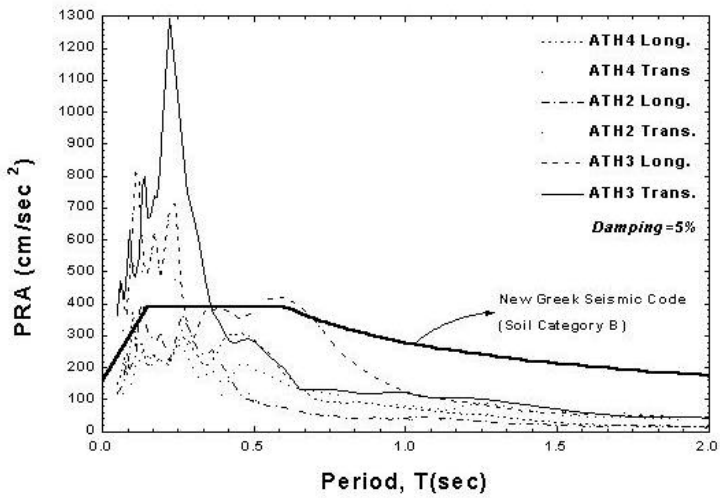
The effects of a severe (strong) earthquake in Athens have many aspects, since Athens is the centre of the economic, political and cultural life of Greece. The earthquake of the 7th September 1999, was one of the most severe which have hit Athens in the last years with surface magnitude 5.9 of the Richter scale, epicentral distance approximately 18 km northwest from Athens in the area southwest of Parnitha and a focal depth of almost 11 km.



Seismic venturousness zones

The strongest of the 1000 (and more) post-quakes that occurred in the first 5 days, took place on the 7th and 8th of September with a surface magnitude Ms=4.7. More than 40 buildings collapsed, 143 people were found dead and thousands injured. Over 6500, were only reported in Ano Liossia municipality.

The peak ground acceleration (PHGA) for the mainshock reached 0.30 with a 0.25 sec period and was recorded by the analogue accelerograph, settled in the area of Kallithea (ATH03), by the Institute of Engineering Seismology and Earthquake Engineering (ITSAK).



In the next picture we can see the acceleration response spectra (horizontal components) for a 5% damping, of the September 07, 1999 main quake, recorded by the permanent strong motion array of ITSAK in comparison to the elastic design spectra of the new Greek Seismic Code (soil category B).

The most serious damages were reported from the western suburbs of Athens, which are close to the epicentre, and especially from Ano Liossia, Menidi, Metamorphosi, Thrakomakedones etc. In these areas, the ITSAC accelerographs recorded almost double highest rates of ground acceleration, than at the places the devices were settled. Most of the buildings that suffered damages were constructed according to the old seismic code. Generally, compared to the most disastrous quakes of the last years in Athens, this one was especially severe for the rigid constructions.

3. THE STATE'S REACTION TO THE EARTHQUAKE

The intermediate time between the disastrous consequences of the quake and the reconstruction and reorganisation of urban areas, was divided into 4 main periods:

a) *Emergency Period:* during which, the State faced the immediate problems caused by the destruction, including the casualties, the injuries, the missing and the homeless.
b) *Reconstruction Period:* including the reconstruction of the entire infrastructure - houses and buildings that can be rebuilt- as well as the restoration of the normal social and economic conditions.
c) *Reorganisation Period I*: during which the city capital reserves and the economic activities, reach levels equal or higher than the ones existing before the earthquake.
d) *Reorganisation Period II*: including works for improving the infrastructure as well as long-term developing programs.

In the Athens earthquake case, the reaction of the State was immediate. Research started immediately for the people confined in 28 buildings, by Greek Rescue Teams, and medical help was provided by the National Emergencies Center. Rescue teams arrived from Cyprus, France, Germany, Israel, Hungary, Switzerland and Turkey in order to locate, assist and rescue the survivors. At the same time a number of urgent actions took place, as the adequacy inspections for the public utilities buildings (in order to help the people), the distribution of tents, water and food, the first aid supply etc. The day after the earthquake, groups of two engineers each, begun 1st degree inspections of the buildings, qualifying them with colors according to the damage they had suffered. Buildings unsafe to use were marked red, temporarily uninhabitable were marked yellow and safe to use were marked green. During this procedure, almost 151.000 buildings were inspected since September 22nd, 9.550 of which were considered unsafe to use and 44.860 were considered temporarily uninhabitable. Besides that, the assistance to the homeless turned out to be a major operation, since they exceeded 100.000. Temporarily the homeless were settled in some hotels, as well as in camps set-up for the occasion (more than 22.000 tents were distributed). With the responsibility of the Red Cross, the army and the Municipalities, food was supplied to the people who suffered damages by the earthquake, while at the same time social workers provided psychological help.

The overall cost of the disaster is estimated to reach over 100 billion drh, including the financial help to the people who suffered by the earthquake, since 200.000 drh. were given to the people whose house was marked red or yellow, 2.000.000 drh. were given to the families who lost a member during the earthquake and a grant of 120.000 drh. was given to the pensioners.

Generally, all the inhabitants of Attica Prefecture whose buildings suffered damages from the earthquake were given the opportunity to participate in a restoration program for injured buildings of the Greek Ministry for the Environment and Public Works, receiving free state loan for the reconstruction and repairing of their buildings, grants and financial aid from the state.

4. DAMAGES ON BUILDINGS FROM EARTHQUAKES

4.1. Post quake damages differentiation

The damages that appear on a building's structure after an earthquake can be differentiated according to their type and extent as below:

✓ *Local type damages:* they appear only on particular elements of the building. Their type and extent don't affect the general stability of the building. They're differentiated to:

a) *Damages on the load bearing system:*
   - Severe or not severe damages on beams and slabs
   - Capillary cracks of any direction on vertical load bearing elements (concrete columns, walls)

b) *Damages on the infill elements of the building:*
   - Not severe: when cracks appear on coatings or worse on the wall - load bearing system contact surface. Local repairing is required.
   - Severe: when heavy side to side (diagonally or crosswise) cracks and mass dislocation appear on the walls. Removal and replacement are necessary.

✓ *Wide type damages:* they are overall damages on the load bearing system of the structure, affecting the stability of the building according to their type and extent. These damages possibly reveal problems in:
   - the system's structure and planning
   - the foundation ground
   - calculating the system in the original plan
   - not keeping the original plan
   - the strength of the concrete etc.

The damages on the load bearing system might be followed by small, serious or even severe damages on the infill brickwalls. The damages on the infill elements are considered as severe when there is fracture, heavy side to side cracks, mass dislocation to the walls, brick breaks, vertical declination of almost all the infill brickwalls of the building.

4.2. <u>Characterization of the buildings after the earthquake</u>

Buildings were marked according to their adequacy for residence as following:

✓ *Green:* are the buildings, which are safe to use. This category includes buildings that suffered no serious damages and their endurance against the earthquake wasn't reduced. Damages that might appear are:
   - Slight cracks on infill brickwalls and on the roof coating
   - Capillary non-diagonal cracks on horizontal elements of the reinforced concrete load bearing system.

✓ *Yellow:* are the buildings that are temporarily improper to use. This category contains buildings that their endurance to the earthquake is reduced, as well as buildings that should not be used (for safety reasons) until face or other non-load bearing elements are fixed. Additional safety measures like supporting or pulling down hanging parts could possibly be required. Usually the damages arise as following:
   - Detachment of large wall and roof coating pieces.
   - Slight damages, partial or total sliding, or even collapsing of the roof cover.
   - Damages on chimneys, attics, parapets.
   - Diagonal or other fissures on the load bearing walls.
   - Diagonal fissures or fragmentation of walls between windows, doors or similar elements of the construction.
   - Fissures on the reinforced concrete load bearing elements (columns / beams / walls).
   - Damages, collapsing or serious roof distortion.
   - Slight deformation of load bearing elements.

✓ *Red:* are the buildings, which are dangerous and permanently improper to use. This category contains buildings that have suffered serious damages and are likely to entirely collapse or even just a part of it. They should be evacuated and immediate safety measures should be taken, as the protection of the surrounding area and the prohibition of access. Usually the damages arise as following:

- The load bearing elements suffer serious damages and deformations.
- There are serious damages on the load bearing elements joints.
- The whole building or just a floor, is seriously deformed
- The load bearing walls show vertical declination, mass decay or serious fissures
- The whole building or just a floor, collapsed totally or partially.

The classification above cannot be used as a panacea. For example, there are "green" constructions, which have no damages or have trivial damages on the infill elements, presenting however damage on the load bearing system.

4.3. Reasons for the appearance of damages on buildings

- ✓ Large mass and inflexibility buildings, which draw great seismic forces.
- ✓ Poor quality of plasters or stonewalls.
- ✓ Poor building of walls and joints.
- ✓ Stress concentration in the corners and openings.
- ✓ Asymmetry or irregularity.
- ✓ Bad roof supporting.
- ✓ Insulation, which divides the wall into unarticulated parts
- ✓ Liquidation of sandy or mad-sandy soil

4.4. <u>Photographic documentation of the damages</u>

1^a. Disconnection of an infill brickwall from the load bearing system.
1^b. Shear cracking of an infill brickwall.

2. Collapse of a reinforced concrete slab due to yielding of a reinforced concrete column

3. Fracture of a beam at the perimeter of the load bearing system, close to its corner

5^a. Overloading of a corner column due to seismic action. The lack of adequate stirrups is evident.

4. Disorganization of a beam to column joint

5^{b}. Cracking of shear wall at the corner of the building

5^{c}. Inclination of a shear wall due to lack of stiffness in the perpendicular direction to its surface

6. Collapse due to failure of columns at the soft ground floor

7[a]. Collapse due to total failure of columns

7[b]. Partial collapse of the load bearing system

8. Absorption of seismic energy at the region where there is concentration of large mass of reinforced concrete

5. DEVELOPMENT OF THE SYSTEM

5.1. Objectives of the system

The need for the best, easiest and fastest administration of the post-quake situation, urged the development of a set of Land Information Systems in the Laboratory of Photogrammetry, in the Faculty of Rural & Surveying Engineers of the National Technical University of Athens. The systems were developed as parts of a general program and refer to the areas struck by the earthquake such as the Community of Thrakomacedones, Panorama of Parnitha, as well as the Municipalities of Acharnes, Kamatero and Ano Liossia. The system is aiming to offer integrated and reliable information for the overall confrontation of the problem by the authorities in charge.

5.2. Data collection

The data gathered for the development of the system needed to be the appropriate in terms of subject, quantity and quality:

- ✓ For the Ano Liossia Municipality, analogue maps and digital background were provided in AutoCad R14 format, including the legislated Town Plan of the area, the Urban units of the municipality, Survey maps and the road network, produced by the Local Authorities.
- ✓ For the Panorama of Parnitha location, Acharnes Municipality provided the study of accession of this region in the Town Plan in AutoCad R12 format. This study includes information relevant to the street-plan of the location and the limits of the properties before and after the Implementation Act.
- ✓ For Thrakomacedones Community, the general land-use map on a scale of 1:3000, was given by the Local Association. This map includes the city blocks and the limits of properties.
- ✓ The digital backgrounds have the Greek Geodesy Reference System (EGSA '87) as a reference system. For this reason, the coordinates of the neighboring trigonometrical points were requested from the Army Mapping & Geographical Service.
- ✓ The information for the system's database creation comes from the Autopsy Sheets of the second-degree Inspection as well as from the demolition protocols of the dangerous-ready to collapse buildings (red buildings). The information above was provided by the National Greek Statistics Service, Thracomacedones municipality and the Acharnes Department of Post-Quake Rehabilitation, while much of it came from inquiries on the spot.
- ✓ Aerial Photographs on a scale of 1:4000, shot on 13/09/1999 and 14/09/1999, few days after the earthquake, were given by the Hellenic Mapping and Cadastre Organization and the Ministry of Environment and Public Works. Also, for the Ano Liossia Municipality, Aerial Photos of 1998 were used on a scale of 1:10.000.
- ✓ Historical data from the Municipality of Ano Liossia.
- ✓ Pictures of the buildings which were marked as yellow or red during the second-degree inspection were taken, showing typical damages of parts of the buildings.
- ✓ Finally, typical buildings were videotaped.

5.3. Software used

The software used for the realization of the system was PC ArcView 3.1, an especially widespread desktop G.I.S. due of its ability to support data from ArcInfo (coverages, E00), AutoCAD (dwg, dxf), shape files etc, to support multimedia material (images, video, audio), as well as to support dBASE / INFO databases and others through SQL connection. The graphic User Interface is quite simple, user friendly and easy to custom format, giving a lot of potential, for the development and management of the database and the output to thematic maps, tables or charts.

Also, to a lesser extent and especially for changing data formats, other software was also used. In AutoCAD 2000 environment, the initial digital background was provided, the digitization of the rest took place and they were all exported to dxf format, compatible with ArcInfo. There, the final levels of information of the system were created and their topology was built in order to be inserted in ArcView. The building of the DataBase took place in Ms Excel, from which dbf files were exported, compatible with ArcView tables. Finally, the pictures and the video-clip were edited using Adobe software (Photoshop and Premiere, respectively).

5.4. Structure of the system

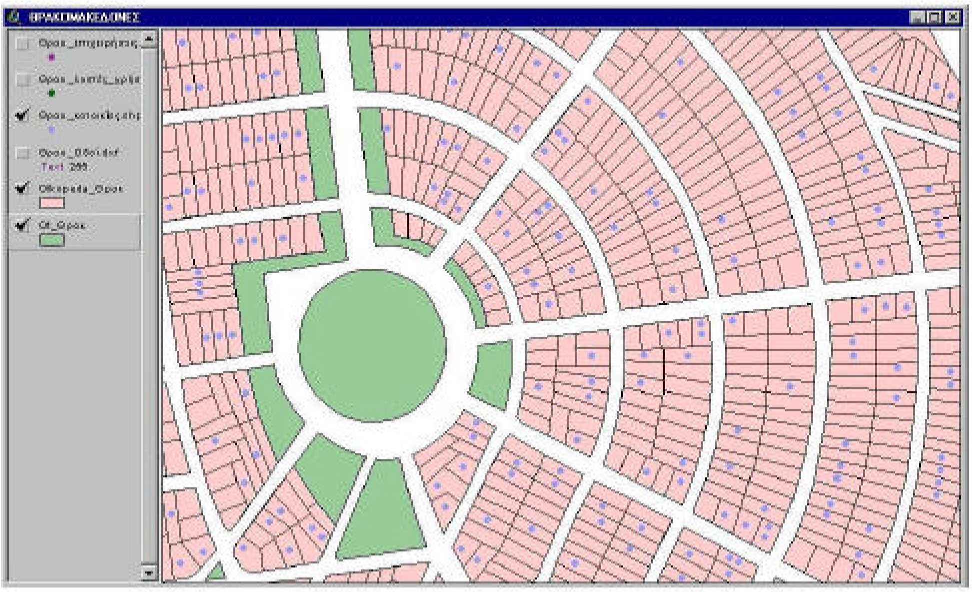
The system was structured according to the following stages:

1. *Background Creation:* The digital data provided by the public services was edited and the analogue backgrounds were digitized, in order to unify the format of the system information levels (ArcInfo coverages): the building blocks of the study area (ot), the limits of the properties (oikopeda) and the buildings (ktiria).
2. *Building Classification:* The buildings included in the system, are indicated as points on the thematic maps and are the buildings marked as “red” or “yellow” during the second degree Inspection. They were put in the system, according to their use, under three categories: “residence”, “business” and “other” (schools, churches, recreation centers).
3. *Design / Realization of the DataBase:* The Data Base was structured in the DBMS software Ms Excel, because of the operation tools it provides, very useful when applied to mass data. The xls files, which were created, were converted to dBase Files (dbf) in order to be compatible to the ArcView Tables. Also, some new descriptive fields were added for the following information: name and address of the owner, type of business, number of floors of each building, date of building, characterization of building according to the damage, type of the main damage and further description of the other damages.
4. *Input of Entities to the System:* the position of the buildings on the map were digitized in ArcView, corresponding to the id of the database records, in order to join the shape file’s table to the original descriptive database.
5. *Automations:* the Graphic User Interface of the system (G.U.I.) was modified in order to be more user-friendly. Automations were created in Avenue environment, applied to menus, buttons and tools of the project’s interface. The programming scripts developed, provide the ability of locating an entity by entering the owner’s name or address and also of projecting in a window data from the DataBase, as well as a picture (if available) of the entity chosen. Additionally, the projection of a relevant video and aerial-photos, taken few days after the earthquake is also possible.

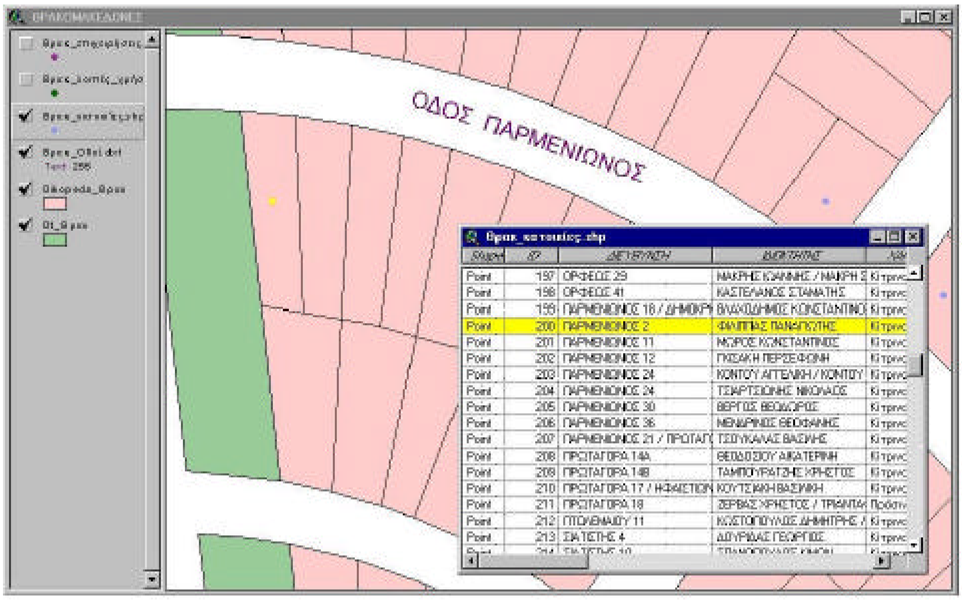
5.5. Description of the system

Although the system was developed for the entire area of the west suburbs of Athens, hit by the 7/9/1999 earthquake, this particular application applies only to Thrakomacedones community and to Panorama of Parnitha.

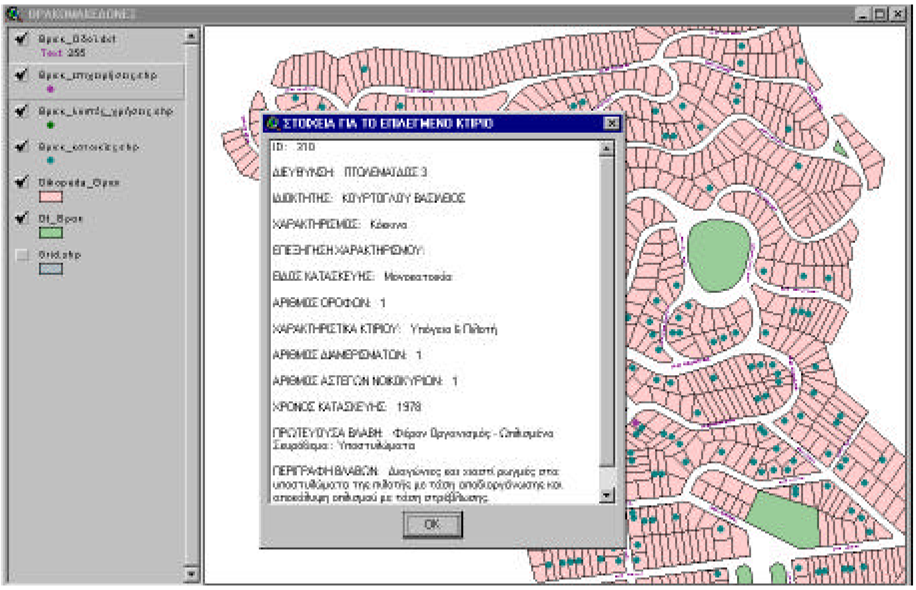
Entering the system, the user can select the area that interests him, e.g. the Thrakomacedones community. The damaged buildings of the area (including houses, companies and other buildings) are presented as points, differentiated according to their category, which is presented in the thematic map legend. Below, a typical section of the view of Thrakomacedones is presented. The “residence” theme is active:



The descriptive information of the entities, which is in an external DataBase, is joined to the relevant theme attribute table by the common field “id”. In the following picture there’s an example of an entity selection from the view of Thrakomacedones and its location in the attribute table.

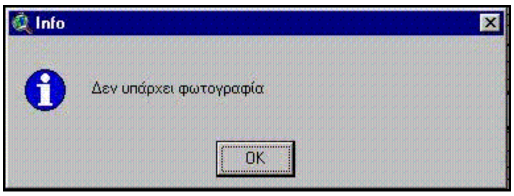


This process can take place in the opposite way as well, by selecting a record from the Data Base. The information inquiry from the system becomes easier by using the proper automations, created for this purpose. In this way choosing by the tool the entity from the view, all the existing information in the DataBase is projected in a frame followed by a picture of it (when available). In the following pictures an application of this particular automation is presented.

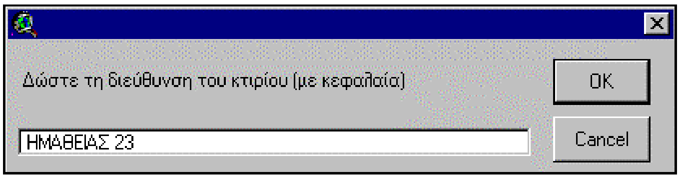


Apart from the descriptive information included in the system's DataBase, additional multimedia material like video-clips and photographs are also included, which appear in the below illustrated way:

On the contrary, when there is no photograph of the entity, the following message appears:

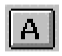


For the case that the information provided for the search of an entity is the owner's name or the address of the building, a menu was created titled: "BUILDING INQUIRY", including the sub-menus: "Through owner's name / Through building's address". The user after choosing one of the two, he has to fill in the space provided the owner's name or the address of the building he's searching for, with capital letters, as follows:



Instantly, after the location, the system focuses on the selected entity, zooming in the surrounding area on a scale of 1:4000.

As we mentioned before, this system supports the projection of video-clips. The reason for including a video-clip in the multimedia material is the necessity for better informing the system's user about the conditions existing after the earthquake in an instant and direct way. The video-clip includes a "tour" in the damaged areas, as well as video recording of specific buildings, which have suffered serious damages. The presentation of damages using a video-clip gives the complete picture of the damage a building has suffered, while the photographs show one part of the building at a time. For the area of Thrakomacedones three videos were created, which are projected through Windows Media Player. The recording (total duration: 45 min) was done by an analogue video camera and then the material was digitized producing three files in avi format compressed by MPEG-4 of total duration 3.5 min each. For their projection the menu VIDEO was created, from which the user of the system can take a "tour" in a small part of the area after the earthquake, or see the serious damages which two houses in the area have suffered and the demolition process of these buildings.

Finally, the system contains aerial photos of the community of Thrakomacedones, taken few days after the earthquake. For their projection a grid was created in the area view, in every section of which an aerial photo corresponds. So, by choosing the tool 

and clicking on any of these sections, the relevant photo appears.