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USE OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS) IN EARTHQUAKE EMERGENCY PLANNING AT RHODES CITY-GREECE

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Abstract
GIS are useful not only as designing tools for map presentation but also for data processing and coordination of a multidisciplinary study. A map for emergency organization and planning was compiled within ARC/INFO GIS and is presented here, aiming to seismic risk reduction with respect to earthquake primary and earthquake induced effects. Special conditions and parameters at Rhodes island such as active faults, unstable slopes, liquefaction potential and building environment are evaluated bearing in mind both social and economic restrictions. The final goal of the project is the development of a computer model which evaluates the seismic risk (zonation) and can then be used for decision-making on land use and emergency plans.

Introduction

An intergated approach to seismic risk management (prepareness, mitigation, remediation) requires that huge amount of data coming from various scientific disciplines is correlated quickly, accurately and cost effectively. In the early 90's there was an enormous increase in use of powerful personal computers at all research levels and a simultaneous turn to "Geographical Information Systems". GIS are useful not only as designing tools for map presentation but also for data processing and coordination of a multidisciplinary study. They can therefore provide the means for effective decision making.

In order to make the most of these advantages, a map for emergency organization and planning was compiled and is presented here, aiming to seismic risk reduction with respect to earthquake primary and secondary effects. The software package used for the project was the Arc/Info GIS.

In the research project "Earthquake Emergency Planning at Rhodes City" (Lekkas et al, 1995) a first attempt was made towards an integrated resolution of seismic hazard. This project took under account international practice as well as the conclusions of special projects already carried out in the area under concern.

Design parameters

At Rhodes City a number of special conditions and parameters may be critical for the success of the earthquake emergency planning program. These parameters are mainly due to high seismic risk and must be evaluated in close relation to the contemporary social and economic status, that is to say:

- Rhodes city is located at the Southeastern edge of the Hellenic Arc, that exhibits relatively high seismic activity due to convergence of the European and African plate.
- Geologically active and seismic faults run through the area under concern (4 active faults cross Rhodes city itself).
- Earthquake induced hazards such as landslides, subsidence, liquefaction and tsunamis are highly likely given the geology and the topography of coastal areas.
- The building environment and infrastructure are unique (the city is built over the old one established in the middle ages, the roads are narrow, the building density is high and with some tall buildings).
- Seasonal changes in people's lifestyle is expected to determine to a great extent the number and distribution of deaths and the social impact, in general.
- Most cultural, tourist and economic activities, as well as most of government buildings are concentrated at the north part of the city where is difficult to reach.
- Cosmopolitan structure of local society rises significant difficulties on implementation of emergency policy.

Design parameters together with others coming into effective management of natural hazards (cost and budjet, central government policy, cooperation of organisations involved, legislative requirements, etc.) lead to the conclusion that composition of such emergency plan based on overall assessments requires a very complex procedure as shown in table 1. Composition of the final map can be divided into the following stages:

- Data entry using alternatively digitizer or scanner for each thematic map coverage.
- Correction of errors created during digitizing.
- Conversion of coordinates that were set initially into new ones that follow the map projection system.
- Attribute table creation for each geographic unit to integrate thematic data with map features and identification of spatial relationships between map features.
- Map plot following symbol and color selection from existing data libraries.

The final goal of the project is the development of a computer model which evaluates the seismic risk (zonation) and can then be used for decision-making on land use and emergency plans. Simulations of emergency action scenarios will promote public awareness and the operational degree of relevant organizations, minimizing the consequences of a catastrophe.

The role of GIS

The project of earthquake emergency planning at Rhodes involves, among others, composition of a digitized map, that will be the heart of the planning and hazard management systems developed. Further refinements that will be adopted through data bases worknig in parallel with GIS can generate a very powerful decision making system. The earthquake emergency planning map at this stage is composed of the following map units:

- Topography and buildings
- Active faults
- Landslides
- Toppling failures
- Subsidence
- Liquefaction
- City sections
- Muster stations
- Camp Sites
- Local government headquaters and first aid units

The stages followed to produce the map are presented below.

Data entry - Creation of coverages

For data proccessing the PC Arc/Info 3.4 Software package (ArcEdit) in DOS environment was used partly and a SUN Sparcstation LX (Solaris 2.3 operating system) using W/S Arc Info 7.0 also contributed to data proccessing.

For data entry (input) Summagraphics microgrid II digitizer and contex fss 8000 scanner were used alternatevely. The multiple coverage (overlay) method was used to create the final image by designating the same ID to elements (attributes) of different coverages. The coverages created are shown in the table below

Table 1

1.	ticrd	This coverage consists of the points (4 tics) that are identical at all coverages
2.	rodos1.tif	Topography and buildings in raster form used as base for map presentation
3.	dgrda	Arcs corresponding to the coastline and the outer border (box)
4.	dgrdr	Arcs corresponding to borders of buffers around active faults
5.	dgrde	Arcs corresponding to borders of areas where engineering geological hazards are anticipated (landslides, toppling, subsidence, liquefaction)
6.	dgrdo	Arcs corresponding to borders of each city section
7.	dgrds	Areas designated special use (eg. muster stations, camping stations, first aid units, etc.) digitized as points within this coverage

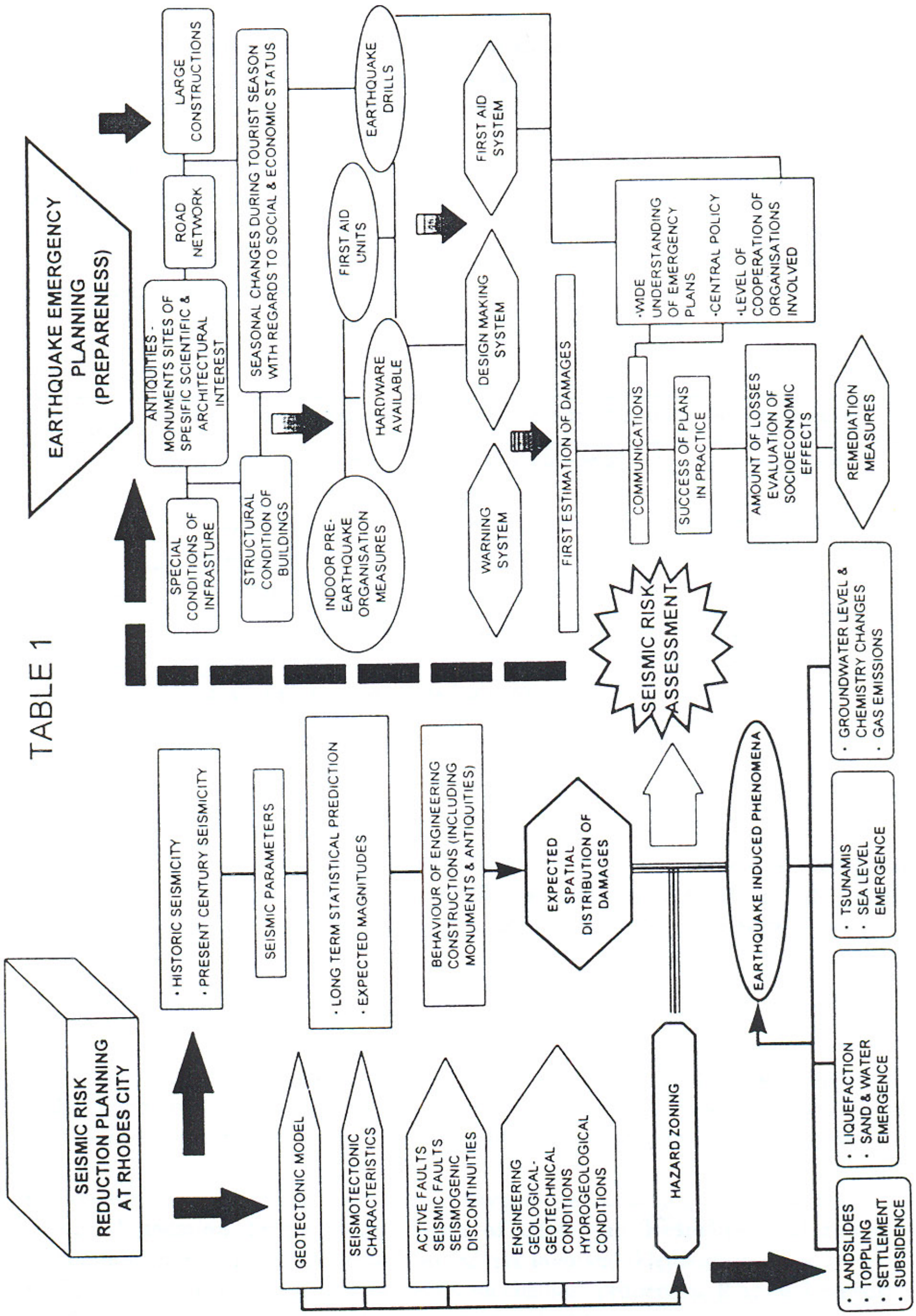
Corrections

The errors created during digitizing were corrected in Arcedit.

Convertions of coordinates

Convertion of coordinates involves creation of a temporary coverage with as many tics as the converted one. Numbering of tics must be exactly identical in both coverages.

TABLE 1


SEISMIC RISK REDUCTION PLANNING AT RHODES CITY
GEOTECTONIC MODEL
SEISMOTECTONIC CHARACTERISTICS
ACTIVE FAULTS SEISMIC FAULTS SEISMOGENIC DISCONTINUITIES
ENGINEERING GEOLOGICAL-GEOTECHNICAL CONDITIONS HYDROGEOLOGICAL CONDITIONS
HAZARD ZONING
· LANDSLIDES · TOPPLING · SETTLEMENT · SUBSIDENCE
· LIQUEFACTION · SAND & WATER EMERGENCE
· TSUNAMIS · SEA LEVEL EMERGENCE
· GROUNDWATER LEVEL & CHEMISTRY CHANGES · GAS EMISSIONS
EARTHQUAKE INDUCED PHENOMENA
· HISTORIC SEISMICITY · PRESENT CENTURY SEISMICITY
SEISMIC PARAMETERS
· LONG TERM STATISTICAL PREDICTION · EXPECTED MAGNITUDES
BEHAVIOUR OF ENGINEERING CONSTRUCTIONS (INCLUDING MONUMENTS & ANTIQUITIES)
EXPECTED SPATIAL DISTRIBUTION OF DAMAGES
SEISMIC RISK ASSESSMENT
EARTHQUAKE EMERGENCY PLANNING (PREPARENESS)
SPECIAL CONDITIONS OF INFRASTURE
ANTIQUITIES - MONUMENTS SITES OF SPESIFIC SCIENTIFIC & ARCHITECTURAL INTEREST
ROAD NETWORK
LARGE CONSTRUCTIONS
STRUCTURAL CONDITION OF BUILDINGS
SEASONAL CHANGES DURING TOURIST SEASON WITH REGARDS TO SOCIAL & ECONOMIC STATUS
INDOOR PRE-EARTHQUAKE ORGANISATION MEASURES
HARDWARE AVAILABLE
FIRST AID UNITS
EARTHQUAKE DRILLS
WARNING SYSTEM
DESIGN MAKING SYSTEM
FIRST AID SYSTEM
FIRST ESTIMATION OF DAMAGES
COMMUNICATIONS
SUCCESS OF PLANS IN PRACTICE
AMOUNT OF LOSSES EVALUATION OF SOCIOECONOMIC EFFECTS
REMEDIATION MEASURES
·WIDE UNDERSTANDING OF EMERGENCY PLANS
·CENTRAL POLICY
·LEVEL OF COOPERATION OF ORGANISATIONS INVOLVED

Real (x,y) coordinates are entered in a special attribute table and the primary coverage coordinates that correspond to distance from a point within the map are then converted to new ones according to the coordinate system used.

Attribute Table Creation

At this stage the topology is established at each coverage as well as the spatial relationships between map features. PAT (Polygon Attribute Table), AAT (Arcs Attribute Table) and PAT (Points Attribute Table) files are created and the following fully updated coverages are generated.

Table 2

1.	dgrda	Arcs corresponding to the coastline and the outer border (box)
2.	dgrdr	Arcs corresponding to areas that can be affected by active faults (bordered by appropriate buffers)
3.	dgrde	Arcs corresponding to borders of areas where engineering geological hazards are anticipated (landslides, liquefaction, subsidence)
4.	crdr	Polygons corresponding to areas that can be affected by active faults
5.	crde	Polygons corresponding to areas where engineering geological hazards are anticipated (landslides, liquefaction, subsidence)
6.	dgrdo	Arcs corresponding to borders of each city section
7.	dgrds	Areas designated special use (eg. muster stations, camping, first aid units, etc.), digitized as points

Map plot

Arc plot is the graphic display and query module of Arc Info and was used for the final cartographic output. Color and symbol selection utilised existing W/S Arc Info 7.0 data libraries. All comands that produced the map (Rd.map) were saved in an AML file (Rd.AML).

The complete plan

To be successful the complete emergency plan requires further refinements dealing with ground conditions and the building environment. The following steps are highly recommended to the local authorities responsible for development of such plans:

- Creation of engineering construction inventories according to construction age, type, foundation, height, design factor of safety, etc. Evaluation and zoning of building environment with regards to the risk involved (elements at risk).
- Detailed geotechnical survey to assess mechanical properties. It should consist of laboratory testing of samples taken at various depths.
- Geophysical investigation, adopting modern methodologies, to locate buried fault zones that cross Rhodes city and identify the hydrogeological regime.
- Simulation of expected strong motion using one and two dimension computer models.
- PGA evaluation per building block (hazard) and the effect of PGA level on various building types (building vulnerability).

- Production of seismic risk map based on correlation of data. Map overlays (coverages) will produce the appropriate zoning. The maps to be used here involve building vulnerability geotechnical properties, active faults and earthquake induced secondary effects.
- Detailed traffic survey with time and the role of seasonal critical parameters at Rhodes city.
- Design of appropriate measures at all levels (new roads necessary, one way streets, wider lanes, etc.).
- Synthesis of all parameters with existing data within the GIS to produce the final emergency action plan (muster stations, escape network, first aid stations, location of headquarters, personnel structure and organisation of committees and consultant boards, hardware available, etc.).
- Development of special software for hazard management and decision making within GIS, based on knowledge from simulations of a disaster and emergency scenarios.

The main innovation from development of such planning system is that it facilitates continuous adjustments according to new pieces of information. Earthquake planning is dependent upon too many parameters that make it very fragile and require such adjustments based on new scientific theories or experience gained during implementation.

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