GIS SOLUTIONS IN EMERGENCY MANAGEMENT

Serhat ÖZEREN & Erdal GÜMÜŞ

ESRI, Turkey[1]

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Abstract
GIS is a powerful tool to assess potential emergencies; where they are likely to occur; and their potential impacts, damage, and losses. It is a core component of situational awareness for the common operating picture (COP) that is used for daily operations. The COP integrates incident locations, tracking, sensors, video, traffic, hospital status, weather, and other dynamic data with GIS data (imagery, elevations, streets, critical infrastructure, etc.). When emergencies occur, GIS produces relevant content and capability for incident action plans, damage assessment, and information sharing. GIS supports all phases of emergency management including mitigation, preparedness, response, and recovery.

Introduction
Emergency management organizations both government agencies and municipalities at local level are charged with reducing community vulnerability and establishing capabilities to manage and quickly recover from emergencies.

Over the last several years, emergency management has become more complicated. Large-scale emergencies seem to be more prevalent, and new threats exist. The need to plan for, prevent, and reduce the consequences of emergencies is greater than ever. Emergency management has the responsibility to collaborate with and coordinate and facilitate multiple departments in planning, response, and recovery. This paper aims to put forward how geographic information system (GIS) technology effectively improves the workflow in all phases of emergency management and supports the requirements of the recently released emergency management principles.

Basics of ESRI Software Capabilities in Context of Real World Modeling for Emergency Management
Geographic information system is a framework for understanding our world and applying geographic knowledge to solve problems and guide human behavior. GIS can produce information that answers specific questions and allows you to share that information with others. By visualizing relationships, connections, and patterns in data, you can make informed decisions and increase efficiency throughout your organization.

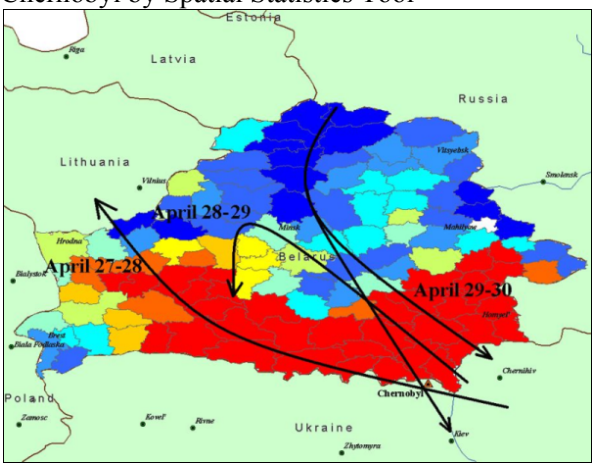
ESRI Information Systems Engineering & Edu. Co. Ltd. Istanbul Regional Directorate. Istanbul Dunya Ticaret Merkezi, A2 Block, 14/419, Yesilkoy/ Istanbul/TURKEY, Phone: +90 2124653980, E-mails: sozeren@islem.com.tr - egumus@islem.com.tr

ArcGIS Desktop

ArcGIS Desktop allows performing advanced analysis, model operational process and visualizing results on professional-quality maps, depicting the emergency event. ArcGIS Desktop gives you the power to manage and integrate your data, allow simultaneous multi-user applications as far as creating and editing databases. Each desktop GIS software (ArcView, ArcEditor, Arcinfo) provides a specific level of ability according to the need of use.

ArcGIS Desktop applications for Emergency management can be expanded with specialized tools. A wide range of optional extensions dramatically expands the functional capabilities of ArcGIS Desktop for the specialized requirements of the emergency management.

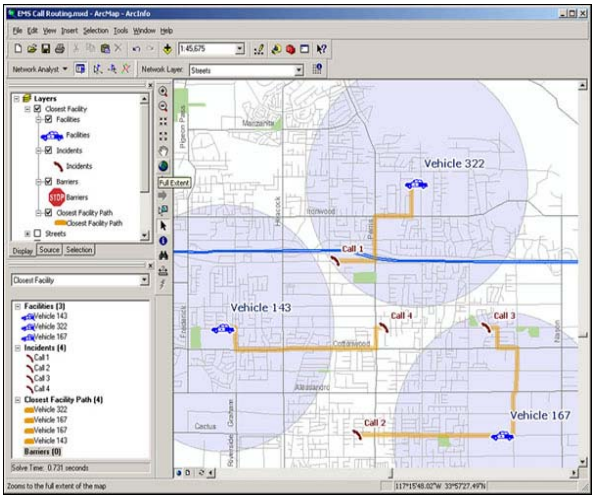
Figure 1: Analyzing the consequences of Chernobyl by Spatial Statistics Tool



Geostatistical Analyst Tool

ArcGIS Geostatistical Analyst is complete package for spatial data preprocessing, geostatistical analysis, contouring, and post-processing. With ArcGIS Geostatistical Analyst tool it is possible to explore data variability, investigate spatial autocorrelation between datasets as far as creating prediction with geostatistical models before an incident occur.

Figure 2: Showing the closest response crew and rout according to the emergency call locations.

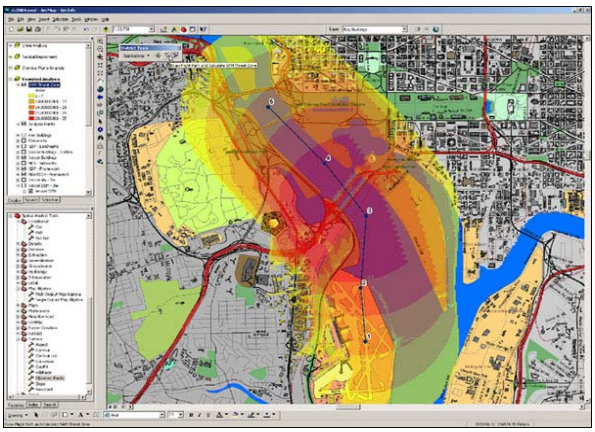


Network Analyst Tool

ArcGIS Network Analyst is a powerful extension that provides network-based spatial analysis like Drive-time analysis, Point-to-point routing, Route directions, Service area definition, Shortest path, Optimum route, Closest facility, Origin-destination analysis.

ArcGIS Network Analyst enables users to dynamically model realistic network conditions in an emergency instance to determine effective routes, calculate drive time or generating logistic base matrixes to deploy the emergency response crews to incidents.

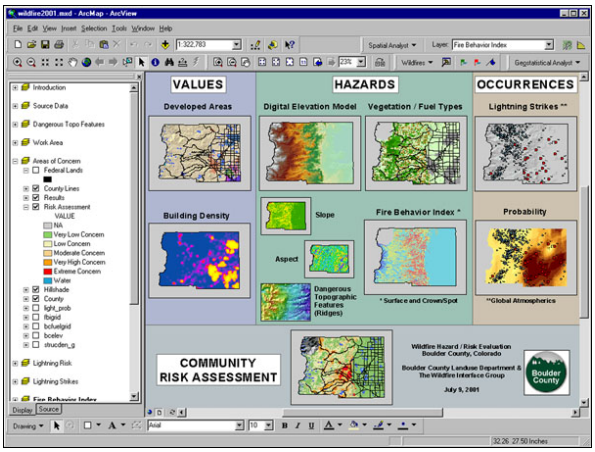
Figure 3: ArcGIS Schematics used to depict the threat source and effected zone route



Schematics Tool

ArcGIS Schematics has useful applications for organizing or representing spatial and nonspatial interdependencies (logical, physical or both) as diagrams to meet the requirements of Emergency Management in context of strategic planning and situation awareness.

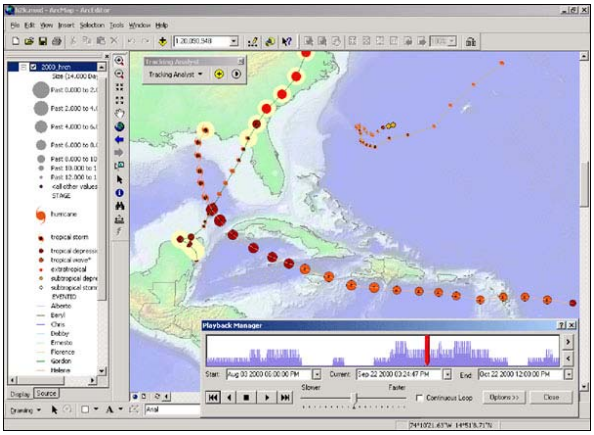
Figure 4: ArcGIS Spatial Analyst accurately identifies areas of high risk to wildfires.



Spatial Analyst Tool

ArcGIS Spatial Analyst provides powerful tools for comprehensive, raster-based spatial modeling and analysis. Using ArcGIS Spatial Analyst, you can create, query, map, and analyze cell-based raster data; create surfaces using interpolation tools such as IDW, Spline, and Kriging; find suitable locations based on multiple attributes with complex terrain attributes and perform statistical analysis based on local environment, small neighborhoods, or predetermined zones.

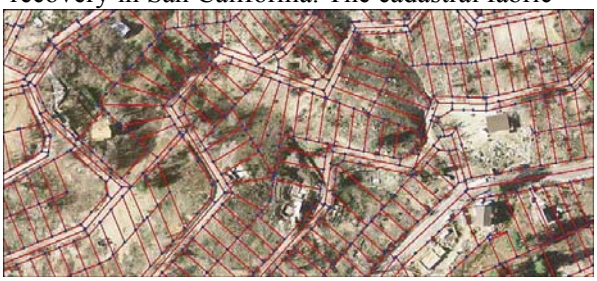
Figure 5: ArcGIS Tracking Analyst shows a hurricane data in context of time and location



Tracking Analyst Tool

ArcGIS Tracking Analyst you can explore, visualize, and analyze information relative to time, location, and change. ArcGIS Tracking Analyst can display data types, including points, lines, polygons, and tracks, for historical or real-time data analysis.

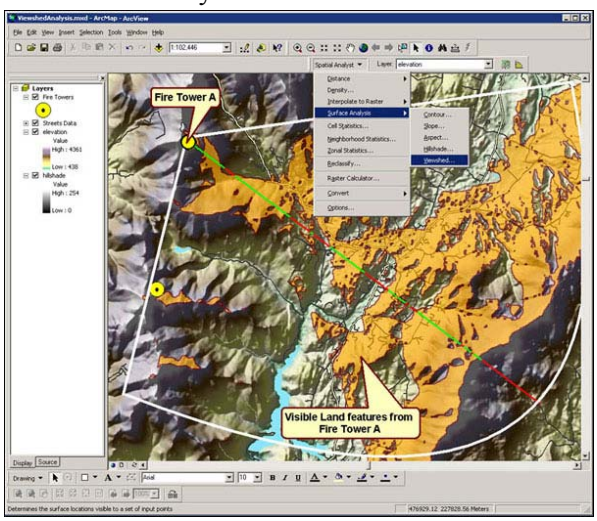
Figure 6: ArcGIS Survey Analyst aids fire recovery in San California. The cadastral fabric



Survey Analyst Tool

ArcGIS Survey Analyst provides to create and maintain surveys and cadastral data in ArcGIS. With this application, surveyors can centrally locate, process, and manage their data, enabling them to work more efficiently.

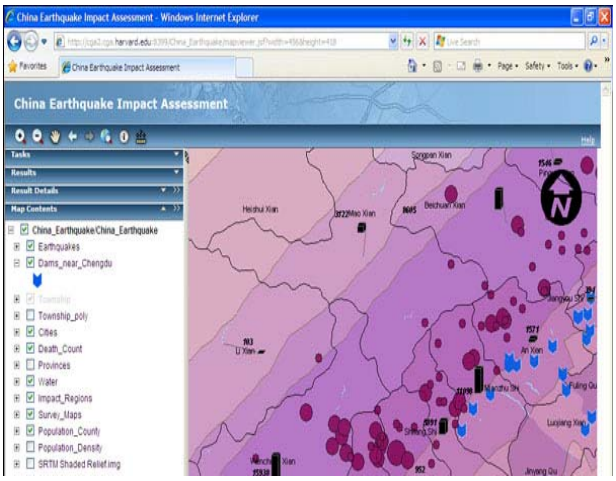
Figure 7: Visibility analyze of a fire tower in ArcGIS 3D Analyst tool



3D Analyst Tool

3D Analyst Tool allows to create more realistic 3D visualization and of the terrain and visibility analysis from a view point. The A rcGlobe application in ArcGIS 3D Analyst is a powerful tool to manage and visualize from a local or global perspective with extremely large sets of three-dimensional geographic data.

Figure 8: An ArcGIS Server publication seen running via internet explorer



ArcGIS Server

ArcGIS Server connects people with geographic information via Web applications and services. Organizations use ArcGIS Server to distribute maps and GIS capabilities over the Web to improve internal workflows and communicate vital issues. With ArcGIS Server it s possible to rapidly build fast, high-quality mapping applications; quickly improving productivity for Web, desktop and mobile workforces; deliver high-performance access to large volumes of imagery; integrating GIS analytics and mapping with other enterprise systems; command spatial data and GIS application resources via internet.

Mobile GIS

ArcGIS Mobile – ArcPAD

Both ArcGIS Mobile and ArcPAD are solutions for mobile GIS. ArcGIS Mobile is designed for non-GIS professionals while ArcPad is intended to the GIS trained professionals.

Mobile GIS platform enables organizations to deliver GIS data and services from centralized servers, providing real-time access to information over wireless networks to a range of Windows Mobile devices. ArcGIS Mobile is powered by ArcGIS Server and allows deploying intuitive and productive mobile GIS mobile applications to increase the accuracy and improve the currency of GIS data across your organization.

ArcGIS Mobile takes your GIS to the field where new data can easily be collected and updated to reflect real-world conditions. ArcPad integrates with GPS, rangefinders, and digital cameras into GIS data collections.

Figure 9: ArcPad allows the emergency field crew to collect and manage response data via ready-to-use forms.

How to Use GIS Solutions in Emergency Management

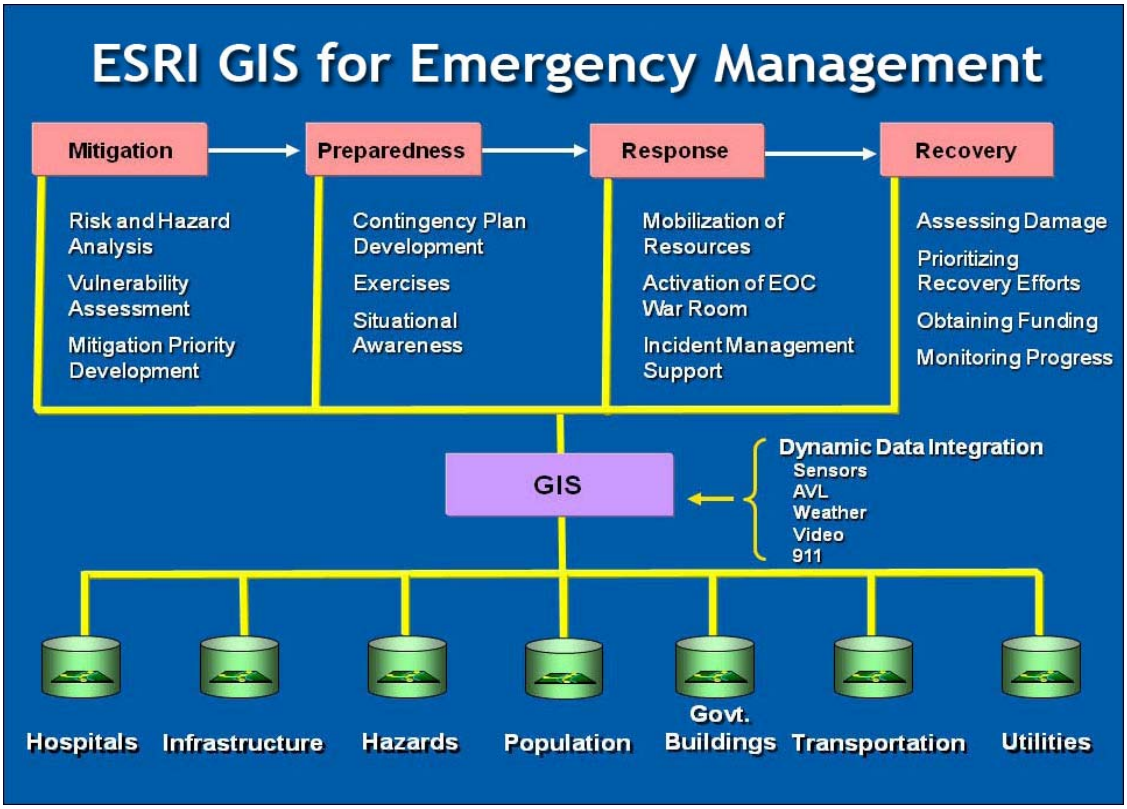
Mitigation

Mitigation efforts attempt to prevent hazards from developing into disasters altogether or reduce the effects of disasters when they occur. The mitigation phase differs from the other phases because it focuses on long-term measures for reducing or eliminating risk. Successful mitigation is a direct result of comprehensive planning and analysis. Emergency management planning is the process of analyzing a community's hazards, risks, and values to determine its vulnerabilities to natural, technological, and terrorist based disasters.

GIS technologies provide the capability to map and analyze hazards of all types and visualize their potential impacts. When hazards are fused with critical infrastructure, population densities, and other community values, vulnerabilities can be observed, modeled, and better understood.

Preparedness
GIS software helps to emergency managers to develop plans of action for when disaster strikes. Priorities for action plan development are identified in the planning and analysis process. Common preparedness measures include some of the following: Selecting and modeling evacuation routes, Identification and mapping of key tactical and strategic facilities and Site selection for adequate evacuation shelters with consideration of where and how extensively an emergency might occur.

Figure 10: The ESRI's emergency management mission and workflow are organized into four phases; Mitigation, Preparedness, Response and Recovery.



When disasters strike, the right information must be available at the right place to support emergency decision requirements. GIS, in addition to supporting the preparedness workflow, is a powerful data management system. GIS provides a platform for the management of geographic data and disparate documents (plans, photographs, etc.) necessary to meet the emergency management mission.

In addition to managing existing data assets, GIS can access and display relevant dynamic data (camera feeds, weather, traffic, hospital status, automated vehicle location [AVL], incidents, sensors, etc.) to provide situational awareness for decision support. Situational awareness is being aware of what is happening around you to understand how information, events, and actions will impact your goals and objectives both now and in the near future. In the context of an Emergency, achieving timely situational awareness is essential to maintain an understanding of events, incidents, and respond to, and manage actual or potential emergencies.

Decision makers and emergency managers can create operation, logistics, tactical, air deployment transportation and incident prediction maps with GIS software.

Response
Emergency management assists in the mobilization of emergency services and resources to support first responders for complex emergencies. Acquiring, managing, and maintaining status of resources from various locations is an important function. GIS supports the response mission as follows: Provide warnings and notifications to the public about "areas in harm's way" can be identified on the map, Determine appropriate shelter activations based on the incident location and optimum routing for affected populations to access appropriate shelters, Establish the capability to collect and share information among department heads for emergency decision making to support emergency operations and sustain government operations and Prepare maps, briefs, and status reports of the emergency incident.

Recovery
The aim of the recovery phase is to restore the affected area to its original state. Short-term recovery is focused on restoring essential services and support. Long-term recovery efforts are concerned with actions that involve rebuilding destroyed property, reemployment, and the repair of essential infrastructure. GIS is integral for recovery by providing a central information repository for assessment of damage and losses that provides: Damage identification via mobile devices and software, Damage cost calculation and determining priorities for reconstruction efforts, Monitoring progress by specific location of reconstruction efforts for both long-term and short-term needs and Publishing maps to share information with the public and other government organizations of progress toward recovery objectives.

GIS Sample Applications in Emergency Management

GIS Emergency Management Application Samples from Turkey
ESRI GIS software is widely used in Turkey in emergency management issues in national and regional level by government institutions and individual researches.

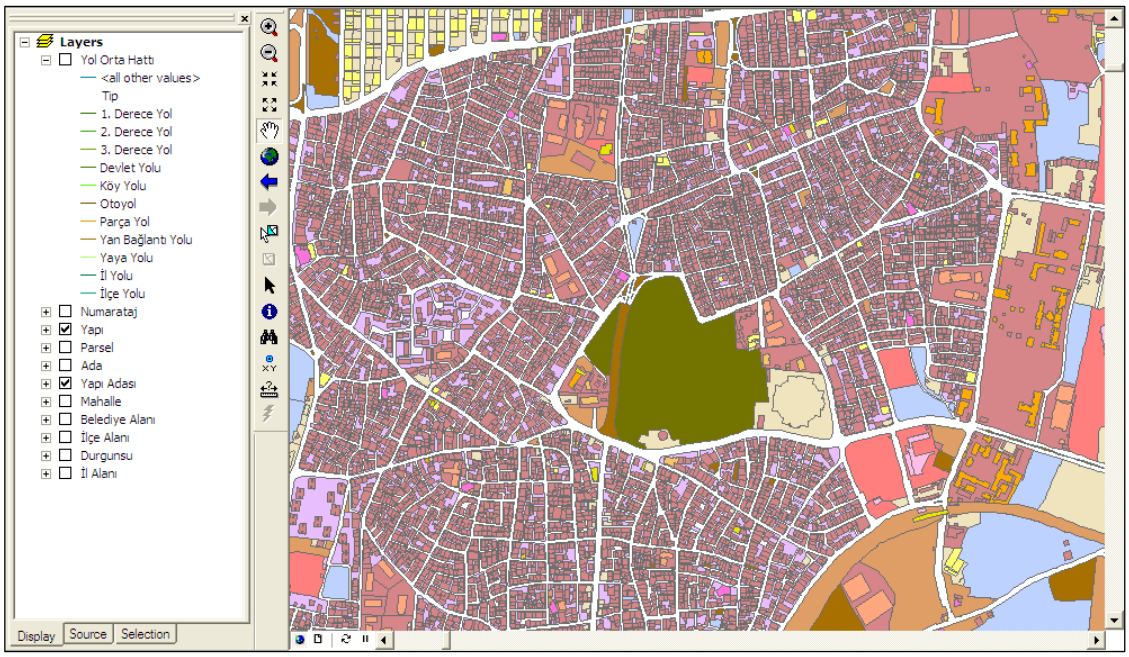
TABIS (Disaster Information System of Turkey)
Due to the catastrophic 1999 Marmara earthquake more than 20000 people and 30000 housing property was lost or severely damaged. First of all, Turkey is still threatened by natural hazards like earthquakes. TABIS project began under this circumstance in 2001 within a protocol between Istanbul Technical University and Ministry of Interior.

TABIS project aims to create a GIS based information and management support system with modern facilities like satellite technologies and databases to serve to ministries and local agencies in case of an emergency instance.

TABIS database was flexibly designed to meet the expanding requirements of the additive datasets from various projects and future innovations. These datasets include: administrative, property areas, settlements, urban services, infrastructure, transportation, address coding, land-use, geology, geomorphology, vegetation, parks, and protected sites.

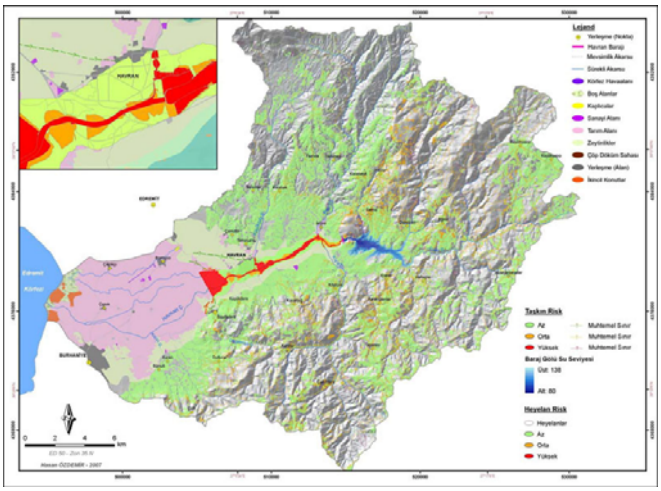
TABIS project also comprises background data creation for the querying and analysis pertaining to the decision support systems. These background data are temporary settlement sites, emergency health service, food deposit and distribution sites, rescue team deploy centers, debris release areas, emergency transportation nets, infrastructure net, land-use and demographic feature.

Figure 11: An ArcMap view from TABIS database of transportation and settlement



ESRI GIS software is also used in regional or local researches mostly performed by individual researchers concerning with emergency management. These researches are not comprehensive but deeply focused on one of the natural or man made hazard like wild fires, avalanche, flash floods, landslides and earthquakes. These stand-alone studies supplies invaluable basement for regional, national and international projects related with prevention, risk assessment, management and recovery.

Figure 12: Landslide and flood risk map (multi-risk) Havran Creek basin (Balıkesir) prepared with ESRI ArcGIS (modified from Özdemir 2007)



One of those researches is flood and landslide risk analysis of Havran river (Balıkesir) basin that has been studied using GIS and Remote Sensing (RS) techniques. The study aims to establish risk management system according to different scenarios of floods and landslides in the basin. GIS based analyses comprehensively consider both the natural and anthropogenic elements at risk and their vulnerabilities and potential damaging events like floods.

Worldwide Applications

USA has started a multi-hazard risk assessment program (HAZUS-MH) in 1992 in collaboration with Federal Emergency Management Agency (FEMA) and National Institute of Building

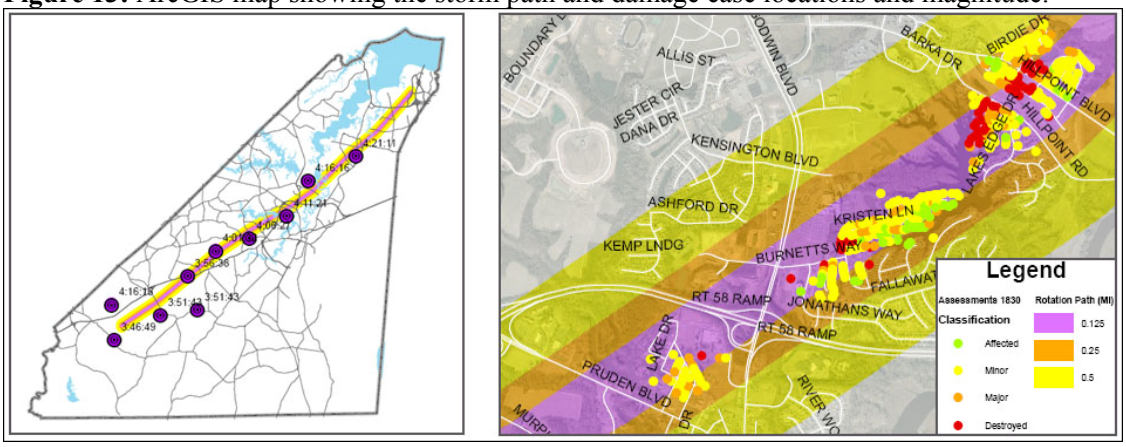
Science which use ArcGIS Desktop to run its calculations and analyses. HAZUS-MH has been used for disaster mitigation purposes in many government agencies like Emergency Operation Centers (EOC) for monitoring critical infrastructure and high-risk targets, economic and physical damage analysis and disaster mitigation.

The HAZUS-MH software run under ArcGIS has specific models for various disasters like hurricane, earthquake, and flood. The map and report outputs of HAZUS-MH differ for each hazard model.

ESRI GIS software is widely used also in EOC servers helps to lessen the impact of disasters and potential catastrophic incidents by meeting the needs of the community through planning, response, and coordination of information and resources.

To assure that accurate and up-to-date information is readily available ESRI GIS solutions allows emergency managers and first responders to access critical information pre-incident, on-route, and on-scene using wireless laptop, tablets, or PDA's. All the geo-spatial data are saved and are accessible from the EOC servers in case the Internet connection is not available. A typical EOC server runs ArcGIS Desktop, ArcGIS Server and Arc SDE for data management and web servicing. The database contains basic layers like Critical Location Data (fire-police stations, hazardous material sites, hospitals), Property (address, owners name, contact person, phone number, offices, stores, commercial facilities, building footage) and raster data like aerial photos and satellite images. Several "ready to use" models created by ArcGIS Model Builder is also included to perform in case of incident and can quickly produce various maps requested by emergency managers. These maps enhance situational awareness for emergency managers for response planning. All data is updated automatically and regularly.

Figure 13: ArcGIS map showing the storm path and damage case locations and magnitude.



Conclusion

Disaster events are increasing, populations are moving into more disaster-prone landscapes, and new threats exist. To meet the demands, professional tools and technology are required. GIS technology can serve a variety of purposes in supporting the workflows and mission of the emergency management profession.

GIS provide a platform for the common operating picture, where dynamic data can be integrated to create a picture of events; their relationship to critical infrastructure can be shared with remote locations, which reduces the need to have everyone in one location. GIS provides a platform for the storage and management of all types of data that can be easily accessed for emergency decision support.

The appearance of mobile GIS (ArcPad-ArcGIS Mobile) enables geographic updates from the field that are immediately posted to the common operating picture, creating actionable information.

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Author Biography

Serhat Özeren
Serhat Özeren was born on 20. 10. 1975 in Ankara. He has studied Geophysics Engineering. Serhat Özeren is professionally interested in GIS and working as a manager in an internationally known GIS Software provider company. He has participated and managed many GIS project like TABIS and IVAYBIS, primarily dealing with emergency management.

Erdal Gümüş
Erdal Gümüş was born in 1982 in Artvin. He has graduated from Artvin Anatolian High School in 2000. In 2001 he attended to Geography Department of the Ondokuz Mayıs University in Samsun. In 2005 he began to master's degree in the Geography Department of the Aegean University of the Greece by ERASMUS exchange program. Between 2006 and 2008 he has worked as a Research Assistant at Ondokuz Mayıs University, Department of Geography. Now he works for an internationally well-known GIS company. Erdal Gümüş has 3 international and 2 national scientific paper publications and many oral and poster presentations in national/international symposiums about geosciences. Erdal Gümüş is interested in nature photography, bird watching and mountaineering.