Special Population Planner – A GIS-Based Emergency Planning System

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Abstract

Argonne National Laboratory has developed and implemented an emergency planning geographic information system (GIS) to support the State of Alabama Emergency Management Agency's Chemical Stockpile Emergency Preparedness Program. One of the challenges is preparing for the possibility of an accidental release of toxic chemical weapons agents at Anniston Army Depot. The Special Population Planner (SPP) was designed as a county-level emergency planning system with detailed, geographically referenced information about populations, facilities, potential events, resources, infrastructure, and traffic access/control points. The system has three main components: 1) databases of special-needs persons and facilities requiring special planning; 2) GIS base map and planning specific layers, including point locations for persons and facilities; and 3) the interface containing the planning tools that allow planners to integrate these features with existing databases and systems.

Because a generic approach is used in the database and interface design, SPP has the on-screen tools to plan for and respond to all hazards. This system provides for easy production of maps, reports, and analyses to develop and revise emergency response plans. The data collection methods, database content and design, geocoding methods and improvements, interface design, and the approaches to documentation and training are broadly applicable. The use of a GIS to support emergency management, both in response and planning, has become easier.

IDENTIFYING SPECIAL-NEEDS PERSONS AND FACILITIES

Argonne National Laboratory, supported by the State of Alabama Emergency Management Agency (AEMA) under a Federal Emergency Management Agency (FEMA) grant, has developed the Special Population Planner (SPP). AEMA and six Alabama counties are involved in the Chemical Stockpile Emergency Preparedness Program (CSEPP) that is responsible for increasing the protection of residents in the vicinity of the Anniston Army Depot from the consequences of an accidental release of toxic chemicals from that installation [1]. Some 2,254 tons of chemical weapons agent, including most agent and munitions types, are stored at the Depot [2]. SPP is a geographic information system (GIS) designed to support emergency planners as they address emergency management issues. It includes capabilities that support collecting and importing data, the review of data in a spatial context, and GIS tools for emergency planning.

People need to be able to comply immediately with protective action instructions given over sirens, tone alert radios, radios, televisions, and cable interrupts during an alert. Therefore, a public safety survey was conducted to identify individuals with special needs, special populations, and places of employment where special planning assistance might be needed. Special-needs individuals identified included those who have physical or mental problems, persons without transportation, or persons too young to drive. Special populations identified included those at public congregation areas (churches, shopping malls, hotels, etc.) and facilities hosting controlled populations (hospitals, schools, and nursing homes, etc.). In addition, places of employment were identified, especially manufacturing facilities with loud noise environments and facilities with large employment numbers.

Two planning zones are used for emergency planning around the Depot. The Immediate Response Zone (IRZ) encompasses an area 8-10 miles from the Depot where the response to an accident would be most urgent. The Protective Action Zone (PAZ) is an area up to 30 miles from the Depot, beyond the IRZ, that would still be affected by a chemical release, but where the response may not require the same level of urgency.

The first requirement when planning for special-needs populations is finding them. Argonne initiated an aggressive search for special-needs individuals as part of its research for AEMA that utilized multiple techniques. SPP supports techniques to identify those with special needs, including saturation mailing of a self-registration form to all households; a 10% random sample survey of IRZ households to identify special-needs persons; a search for neighborhood opinion leaders; and a request to organizations and agencies

to provide lists of persons with special needs or to distribute self-registration forms. Referrals to special-needs persons were sought from identified special-needs individuals and from neighborhood opinion leaders. Approximately 3,000 persons with special needs were identified from among 35,000 IRZ households. Argonne was able to identify almost five times as many special-needs individuals as the two IRZ county emergency management agencies (EMAs) had compiled during the previous four years by relying on self-registration postcards in their annual calendars. An additional 3,000 persons were identified from among 125,000 PAZ households by using only a saturation mailing. All mailings were synchronized with a set of newspaper and radio announcements and letters to elected officials.

SPP supports a streamlined approach to permit individuals to verify or change their data on an annual basis. Verification forms are printed with each person's data, and each form is addressed for use in a windowed envelope for easy mailing. Updated information can easily be entered into the system by relying on the person's ID.

Data on group locations, special facilities, and places of employment were acquired via commercial electronic data sets and local and state agency and organization electronic and non-electronic data sets. Procedures were developed within SPP to update individual records and to maximize the automation of an update process.

SPECIAL POPULATION PLANNER

SPP is used to help create plans for responding to emergencies. It is designed to simplify preparing and maintaining maps related to emergency plans and descriptive text regarding emergency response personnel actions. SPP presents relevant information to the planner in a graphical interface to reduce the effort needed to prepare plans that include evacuation routes and traffic flow control points. It visually presents the magnitude of a needed response and the resources needed to support special-needs individuals and facilities. Although SPP was explicitly designed for preparing response plans for conceivable events at the Depot, it is a general-purpose tool suitable for planning for other emergency events.

The system has three main components: 1) databases of persons and facilities needing special emergency planning efforts; 2) GIS base map and planning specific layers, including point locations for persons and facilities; and 3) the interface containing tools that allow planners to integrate these features with existing databases and systems. The general structure of the data tables and the queries they needed to support were determined after discussions with the six affected Alabama counties.

One of the challenges faced in developing SPP was locating persons and facilities based on the addresses developed from public data, the surveys, and other project-specific data collection efforts. The process of locating persons and facilities on a map using their address (geocoding) requires an accurate map and accurate addresses. This information is rarely available at the quality required, so it was necessary to develop a process and tools to support address cleaning and validation, and to support developing an addressed street layer of sufficient quality.

The customized user interface supports two primary activities: 1) using the data to prepare plans and to respond and 2) updating the data. Preparing and editing plans involves using the tools to present the data in an easily viewed map format, with the routes and control points for traffic flow selected or drawn in. The data relevant to planning are examined and analyzed. Output includes maps and tabular reports drawn from the database. The tools take advantage of existing databases installed at each of the six county EMAs and at the AEMA. Maintaining the data involves either loading external files or directly editing existing files. The users of these tools are often self-supporting in their daily computer operations.

SYSTEM CAPABILITIES AND USER INTERFACE

System Components

The SPP interface has two main components that operate as ArcView extensions. ArcView is GIS software system produced by the Environmental Systems Research Institute (ESRI). The first extension is the planning toolkit, which allows users to query and examine data, create and retrieve emergency response plans, and generate maps and reports. The second extension is for database maintenance, including tools to edit street addressing, look up supporting information, and maintain the database tables.

The planning toolkit is centered on a set of planning zones identified by emergency response agencies for the Depot, and a table of predetermined emergency events for analysis and planning. Each emergency event has a unique ID number and identifies the set of planning zones relevant to it. Users can also define their own emergency events, specify the planning zones they cover, and formulate plans for them. Data that can be quickly retrieved and displayed show the location (clustered, scattered, or along major routes) of special-needs persons (including their individual special-needs problem), facilities (type, number of residents, enrollment or employment size and capacity, and physical situation), and resources available and time with which they could respond. Map features can be queried by areas, including circles; rectangles; parallel buffers; or

manually sketched areas to reflect potential or actual plumes, spills, paths, floods, and other hazards.

When an emergency event is selected for planning or response, a map of the planning zones and supporting GIS layers associated with the event is generated, and tools for planning are enabled (Figure 1). The planning tools are sufficiently generic to adapt to a wide range of emergency planning and responses, and include customized menus, buttons, tools, and windows, as well as standard ArcView functionality. Database activities essential for planning have been customized and simplified for the user; however, knowledgeable ArcView users still have access to the standard ArcView tools with which they are familiar. The written plan is stored and is easily retrievable. Reports and maps are generated using the current contents of the database. Although it is essential to maintain a hard-copy version of the plans, many elements of the electronic plans are dynamic and will reflect changes in the database when they are reopened on the system.

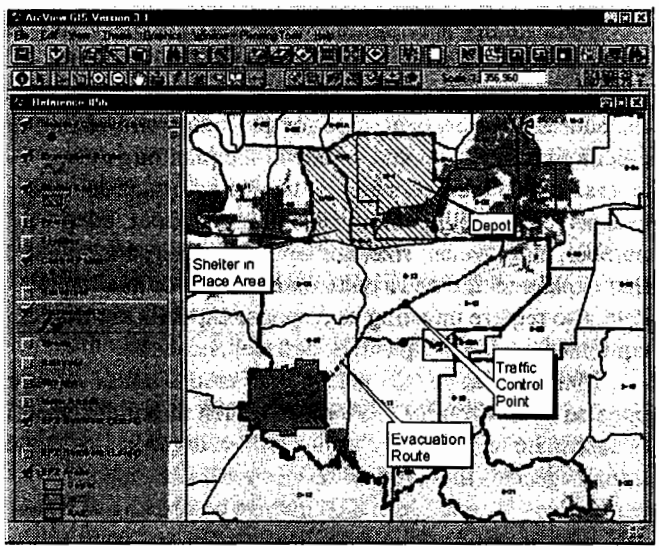

Figure 1. Example of planning map view with hypothetical event and customized interface

The data maintenance extension provides many tools to manage the database. A set of street layer maintenance tools supports the critical task of editing the addressed street layer. A location editor tool (Figure 2) manages edits to the coordinates in the point data themes. This tool is used to input or edit locations using a street address, map coordinate, or by clicking within the map view. Similarly, an attribute table editor tool (Figure 2) manages edits to many of the supporting database tables. As the database is maintained, changes to the underlying database are immediately available to planners.

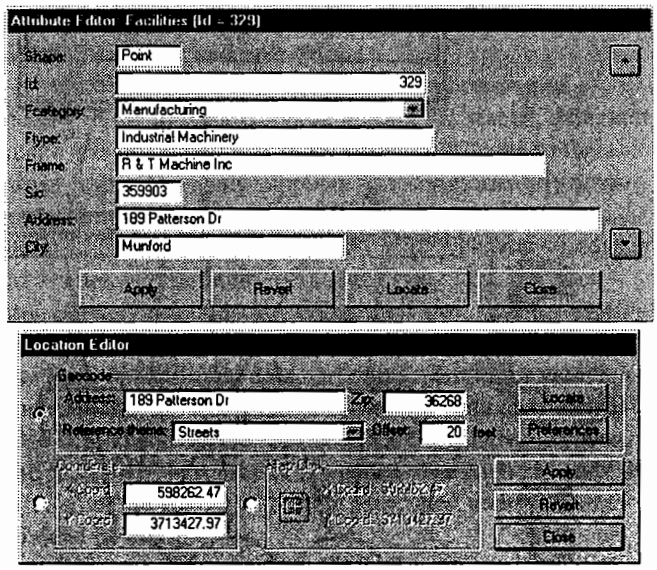

Figure 2. Attribute editor and location editor tools

Architecture

The software is written primarily in Avenue, the ArcView scripting language, and is implemented as extensions that run under a standard ArcView 3.1 or 3.2 installation on Windows 98, ME, NT, or 2000. The ArcView extensions use several other software programs for file access, database access, report generation, and plan editing. If the files are stored on a UNIX or Linux server, SUN Solstice, Hummingbird NFS Maestro, or Samba can be used. If files are stored locally, or on an NT, 2000, or Netware server, the default client (or no client) is used. Oracle, SQL server, or Access with an ODBC connection can be used for data storage and retrieval. Seagate Crystal Reports is used for report generation, and Microsoft Word or WordPerfect are used for plan documents (Figure 3).

Some Programming Issues and Approaches

One of the significant challenges of the project was developing editing tools for the addressed street layer. The address editor tool is used to edit and validate addressing fields for a street. Six other tools allow users to add, delete, split, combine, reverse the direction of, and redigitize street lines directly on the map. Many of the tool elements, such as a list of valid street type abbreviations, are loaded from text configuration files that can be easily modified by the end user. During editing activities, the user often needs to consult several sources of data, either in tables or GIS layers. For these functions, location finder and table lookup tools were developed.

Another challenge was to allow storage of both coordinates and attributes of point layers in the database,

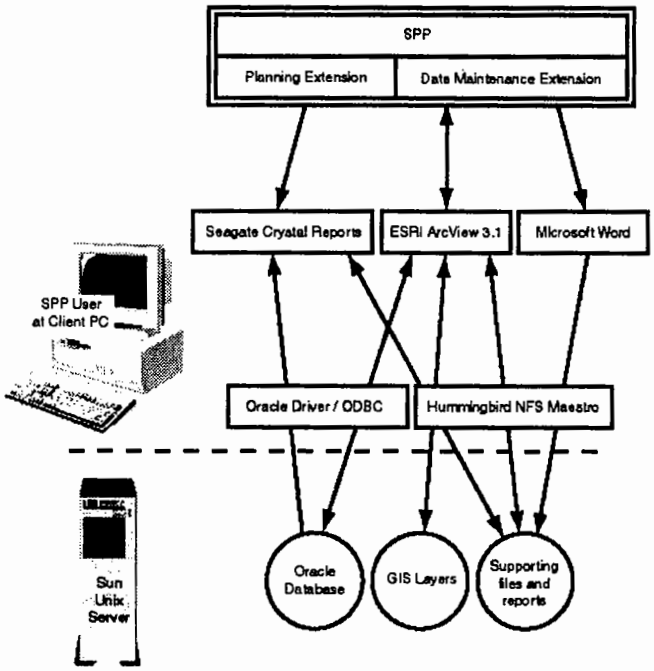

Figure 3. System architecture

while giving the user access to ArcView geocoding tools. The ArcView geocoding tools do their work with Shapefiles on disk. SPP augments standard ArcView geocoding functionality with a procedure to store the results in Oracle or other database and displays point locations dynamically using database coordinates. The system also provides alternative methods for locating points (by coordinate or mouse click) for cases when geocoding fails or to improve accuracy. Crystal Reports, which is bundled with ArcView, was used for report generation, allowing attractive report templates to be designed and populated with specific results. Reports corresponding to planning events were designed for the system, along with the interface, to produce a specific report based on current database contents. In response to fast-paced, special queries, reports and maps can be quickly and conveniently generated to provide answers in a list or visual format.

DATABASE DESIGN, DEVELOPMENT, AND MAINTENANCE

Designing and Compiling the Database

Emergency planning database information was organized into three categories and stored as a series of database tables. The first database category pertains to persons with special needs who may need assistance in the event of an accident. This table was populated by Argonne researchers by using six complementary data-gathering methods. The second database category contains two data sets: places of employment and special facilities. The third category contains data on planning zones, resources, and control points needed by emergency response personnel for effective planning. The confidentiality of these data is being protected in accordance with Alabama law.

Tools in SPP allow emergency planners to define and add sets of geographic planning zones with event descriptions according to their needs. These user-defined events might relate to technological or natural events. The Control Point data are important for planning evacuations and other protective actions. Traffic control points, for example, are road intersections on an evacuation route. The information associated with these points includes the maximum traffic throughput and the estimated time for a responder to reach the point. The data tables are designed to be as self-explanatory as possible by using descriptive field names and descriptive data in fields rather than codes found in many of the source databases.

Maintaining the Database

Maintenance is essential to keep the database viable for future planning activities. Maintenance involves many levels of the system. It involves activities, such as updating the addressed street layer used for geocoding and adding or deleting geolocated points in one of the planning data layers. It also includes revising tabular information, such as a person or facility name, type of impairment, telephone number, employment size, and updating emergency plans that depend on the underlying data. Resource availability data also require updating as response capabilities, training, equipment change, capacities, and status change.

Maintenance of the Facility and Persons tables can use updated data regularly, from sources such as handicapped license plate registrations, senior citizen organizations, and transit agencies that provide service for handicapped populations. Updates can also involve comparing existing data with annual updates from commercial and state agency databases. Some mismatches require manual checking, while others can be done on an automated basis. For the Persons table, the annual update procedure relies on a report that places existing data on a verification form for mailing to all in the database for verification, edit, or deletion.

STREET MAP EDITING AND GEOCODING

Street Layer Sources and Their Limits

The power and flexibility of SPP lies in its integrated spatial and tablular databases. For the spatial databases to work, they must be correct. Geocoding is locating a point in a GIS layer based on a street address. ArcView provides a variety of methods for geocoding. For this project, the

"U.S. Single House with Zone Address Style" method was chosen because it takes advantage of the most detailed information in the TIGER data. The method uses both the street address and the zone (zip code) to locate an address. Using the zip code was essential to be able to distinguish addresses for street names duplicated in different parts of the project area. While geocoding is a relatively simple concept, the process is complex. It depends on successfully matching street names in the address to street names in an addressed street layer, and then using linear interpolation of the address number to determine the location along the street. During the process, the address is broken into components, standardized, and compared to a set of eleven address fields in a street layer. Adjustments can be made to account for spelling variations, and a scoring technique is used to find close, but imperfect matches. Determining the cause of a mismatch can be difficult,and researching and making edits to the addresses and the street layer is time consuming and complex.

The street addresses in the tables were first geocoded against TIGER/Line files (Topographically Integrated Geographic Encoding and Referencing), produced by the U.S. Census Bureau. These files were used to develop the initial base layer of streets with address ranges for all six counties. Later in the project, two of the counties provided street layers for their areas with addressing attributes superior to the publicly available TIGER data; others provided various data files from their 911 centers. These data files, although very helpful, still were not entirely complete or accurate.

Although TIGER street files are frequently used for geocoding addresses, the data files have many inherent problems. Many street segments do not have names or address ranges, have incorrect names or address ranges, have inconsistent names for the same street, use alias names that are not mail-deliverable street names, are not spatially accurate or even representative of the actual street, or have incorrect or missing zip codes.

For the six-county area covered by the project, the TIGER data were categorized by addressing status to better understand the capability of the layer to support geocoding. In the initial street layer, only 27% of the streets had both name and address attributes. Quite a variation existed between counties with regard to the completeness of the TIGER files with a high of 58% for Calhoun County and a low of 0.26% for Clay County. The average for the six-county area was 27%, meaning that 2,981 street miles had name and address ranges, while 4,046 street miles had names, but no address range, and 4,059 street miles had no name or address range. Replacing TIGER data for two counties with layers they provided improved the percentages somewhat. Many other inaccuracies beyond the simple presence or absence of street attributes required extensive editing and updating.

Obtaining local knowledge of the addressing of a county in the form of contacts, editing assistance, data, and maps was essential for making meaningful edits to the street layer. Materials supplied varied significantly among counties, ranging from CAD files, E911 map books and data, and standard road maps. After a workshop on editing tools attended by county personnel, two of the counties immediately responded by doing their own editing. Each of the remaining four counties provided assistance, mainly in the form of additional data and maps. Zip codes were not found in the E911 databases, or were of limited accuracy. The U.S. Postal Service ZIP+4 Code State Directory was the most reliable source of zip codes. For each zip code, it lists all of the streets with their associated address ranges divided by block.

When accurate maps or CAD files were provided, they were used to validate the information in TIGER. Where these materials were not provided or were not available, Argonne relied on commercial maps, road databases, city and county directories, and web-based mapping programs to help identify street names and address ranges and locate people and facilities.

As a result of the efforts to create an accurate street base map, the six counties will be able to utilize a much more accurate street data file for a wide range of county activities beyond the initial scope of this emergency planning program.

DOCUMENTATION AND TRAINING

Documentation of SPP was designed to satisfy two broad objectives: 1) to provide relevant and easily accessible information in a sufficiently concise format to enable users to quickly familiarize themselves with each aspect of the system, and 2) to provide enough information to be used for training purposes once the system had been fully developed and installed on the client systems. To serve both objectives, documentation was produced both in the form of an electronic help file and in hard-copy format. The RoboHELP system produced by BlueSky Software, which produces Windows-style help files with a range of printing options, was used to document the system.

The SPP help file contains various information to enable the user to quickly understand general aspects of the CSEP Program, Census TIGER files, survey methods being used along with examples, data collection techniques, and processes and procedures used to increase data and map accuracy. The help file contains an overview of the development of the interface, together with a description of the objectives of the software, its relevance to issues faced by CSEPP planners, and the adaptability to other areas of

emergency planning, as well as other uses. A section details the steps involved in opening an event for planning and using the system to make a plan. Users are provided information on all the tables, including field names, descriptions, and field lengths. A key section describes tools and procedures for updating the various GIS layers and database tables as new information becomes available.

Hardware and software requirements for successful installation and operation are fully described. A system administrator section outlines procedures for maintaining the software, together with backup procedures.

Each of the seven EMAs (state and six counties) received training and documentation in the use, data maintenance, and system administration of SPP. Emergency planners in rural counties often have very limited resources available and also experience relatively high turnover, meaning that all the advantages of the system would not be fully realized unless the help system is usable and relevant, and sufficiently informative to allow future users to easily and quickly train themselves.

CONCLUSION

Although SPP is designed for CSEPP planning, the more generic approach used in the interface and database design allows its application for a wide range of other activities. This enhanced utility increases its chance of being used and queried with greater frequency. Thus, when CSEPP planning needs arise, users will have maintained a familiarity with the system, data, and its maintenance. The need for a county-level emergency planning system with detailed, geographically referenced information about populations, facilities, special events, resources, and control points is not specific to this hazard or this location. The data collection methods, database content and design, geocoding methods and improvements, interface design, and approaches to documentation and training are all broadly applicable. The use of GIS to support emergency management, both in planning and response, is increasing. As this project demonstrates, developing such a system for a localized area is both uniquely valuable and challenging.

ACKNOWLEDGMENTS

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Biography

Jim Kuiper, is a GIS analyst in the Environmental Assessment Division at Argonne, with an MS in biometrics, a certificate of remote sensing, and a BS in natural resources. He has over twelve years of experience in GIS, programming, and remote sensing projects.

William C. Metz, Ph.D., is manager of the Social Science Applications Section at Argonne and has his doctorate in the field of geography. He has researched and published extensively on a wide range of controversial siting issues, including nuclear reactor and high-level radioactive waste facility siting, chemical and nuclear reactor storage and disposal, and planning the reuse of Department of Energy sites. He has been involved with emergency planning and exercising at nuclear reactor and chemical weapons depots for over a decade.

Dan Miller, is a systems architect in the Integrated Analysis Section, Decision and Information Sciences Division at Argonne with a degree in Economics. He has 14 years experience in systems integration and design.