MODELING EARTHQUAKE CASUALTIES FOR PLANNING AND RESPONSE
MODEL DEFINITION AND USER OUTPUT REQUIREMENTS

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This Paper was prepared for use at the Workshop on Modeling Earthquake Casualties for Planning and Response at the Asilomar Conference Center in Pacific Grove, California, on December 4-6, 1990.

Included is a summary of current casualty estimation data, a description of a generic model, used in a Geographic Information System; a ten step approach to model development, and a brief discussion of the first three steps in that process.

Introduction

The pre-event estimation of earthquake casualties for planning purposes is a difficult problem. Also difficult, is trying to estimate probable casualties at the time of the emergency when there is no or very little casualty information coming in from the affected area.

My perspective on these problems comes from involvement in developing emergency plans with local jurisdictions and several large industries over the last eight years I am also a strong advocate for the application of geo-processing system technology in emergency preparedness planning.

Current Approach to the Problem

For every client whether it is a municipality or a company, an essential first part of the response planning process is the hazards analysis and risk assessment. This is a required element in the planning process.

The estimation of possible casualties is an integral part of the hazards analysis It provides a baseline from which all planning proceeds.

How is pre-event casualty estimating being done now? To a large extent it is not being done, or at least not being done very well. Sometimes the estimating approach at the local jurisdictional level is based on resource availability This is the tail wagging the dog approach where the available response resources define the casualty load that can be handled.

Some jurisdictions, especially those who contract for public safety services, do not face the issue of having to manage the dead and injured, and turnover this kind of planning to the county They essentially ignore the high probability that county services may not be available to all jurisdictions simultaneously at the time of a major disaster.

Existing scenarios for the major earthquake faults do not provide much useful information in the area of casualty estimation. Partly this is due to lack of methods for estimating casualties, and partly to the emphasis placed on "lifeline" type analyses. This is unfortunate, and does not provide the planner with all of the information he or she needs to develop a comprehensive emergency response plan.

The approach which I currently use to estimate casualties is based on the information contained in the USGS Open File Report 81-113 - The Metropolitan San Francisco and Los Angeles Earthquake Loss Studies: 1980 Assessment.(1) This documentation provides tables on fatalities and injuries for various earthquake scenarios at three times of the day.

The estimation of the injured in this report is expressed as a ratio to the number of fatalities. That is, hospitalized injuries are four times the number of fatalities and non-hospitalized injuries are thirty times the fatalities. Estimates of fatalities are based on the intensity of shaking, (established by an intensity model), land use (which helps to define the class of structures), time of day, and factors related to population characteristics.

Using the USGS 81-113 data for a Newport Inglewood earthquake for Los Angeles and Orange counties, the earthquake related deaths range between I person per thousand to 5 persons per thousand.

What Do These Estimates Provide?

The table below describes the fatalities, seriously injured and injured for a range of population classes using the ratios described above.

Casualty Estimation Table

Population	Fatalities 1 to 2 per Thousand	Ser. Inj. 4 per Death	Inj. 30 per Death
5000	5 - 10	20 - 40	150 - 300
10000	10 - 20	40 - 80	300 - 600
20000	20 - 40	80 - 160	600 - 1200
40000	40 - 80	160 - 320	1200 - 2400
60000	60 - 120	240 - 480	1800 - 3600
80000	80 - 160	320 - 640	2400 - 4800
100,000	100 - 200	400 - 800	3000 - 6000
200,000	200 - 400	800 - 1600	6000 - 12000
400,000	400 - 800	1600 - 3200	12000 - 24000

For whatever its accuracy, this formula is simple in application In using these data over the years, I probably have had an equal number of clients who think the estimates are very low, to those who think they are very high.

Where Do We Go From Here?

We all know casualty estimation is a problem, so what is it we can do about it? With advancing geographic information systems capability, and better knowledge in the causal factors related to earthquake injuries, we should be able to employ this knowledge in the application of casualty models which will measure the level of risk relative to a wide range of demographic and structural considerations.

My concern is not so much can it be done, as it is when and how. Also, because of the varied users and user needs, we may need to consider the development of two models or perhaps different versions of a base model. The first of these would produce a quick assessment for initial planning or to validate response assignments. Hopefully, this would be a major improvement on the table shown above. The second model deals with a more sophisticated capability that considers a more comprehensive set of variables. This would produce casualty estimates for a smaller area Perhaps one is derived from another, and certainly they are related.

What Should Be The Framework of A Model?

Generally, there would appear to be four major classes of input data necessary for purposes of casualty estimation. These would include: seismic data (of one or more forms): structural data (many possible classifications); occupancy data (reflecting various use types) and population data (several possible classes). All of these data are currently available, although they are not necessarily always in the precise file structures we may desire.

The Use of Geographic Information Systems in Casualty Modeling

Many cities and virtually all cities and most highly urbanized counties within the next few years will operate with some form of an automated land and environmental information system. These systems are developed from various combinations of Geographic Information Systems (GIS) and relational database capabilities that have been around for several years.

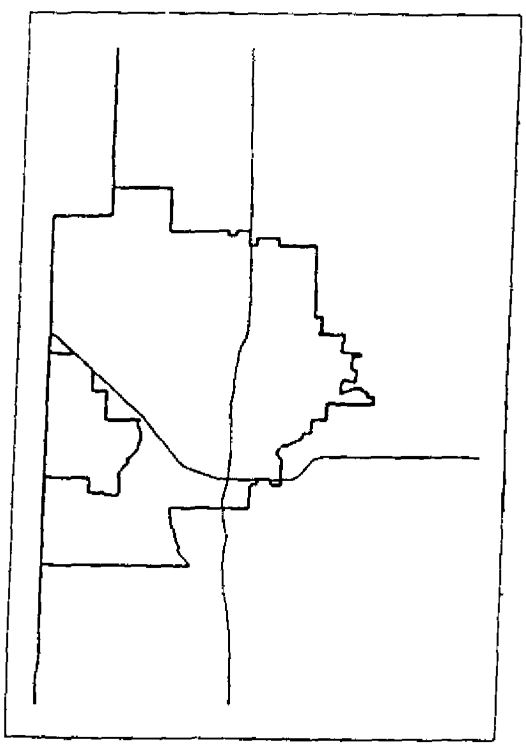
These systems are built upon, and operate using a standard base map that is in digital form The content of the base map will be those elements which are standard for all or most of the jurisdictional operations. These might include political boundaries, large topographic features, major highways, etc. Other digital data layers (files) are then added based upon the client's needs. Each data layer contains the essential elements of information for overlay onto the base map, and includes a range of attributes associated with those elements.(2)

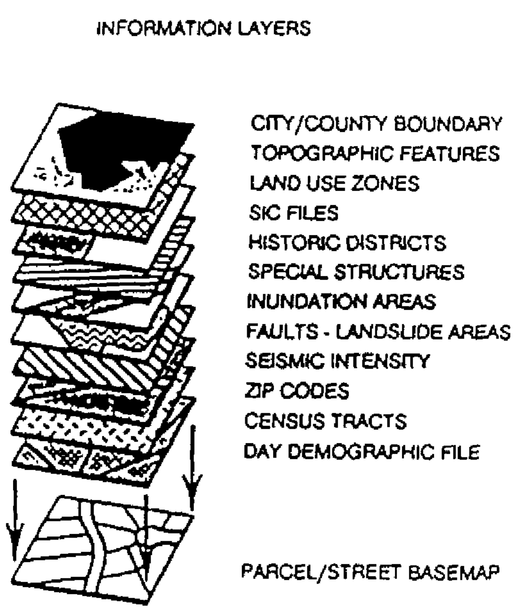
In these kinds of systems, there are virtually unlimited file or information layering capabilities Using the relational database capability in a GIS, the system has the ability to mix data files, swap data between files and provide a full range of tabular reports, statistical analyses and a variety of map and other graphic outputs Various client needs for maps at various scales can easily be accommodated. The system is only limited by the attributes associated with the files in the database.

One of the principal features of the rapidly advancing GIS technology, is the ability to model various alternatives for meeting a clients needs In the case of an emergency planner, several scenarios related to natural hazards can be introduced and examined for their possible effects upon other elements of the database

The bad news in the GIS world relates to incompatibility in software and hardware systems which makes it more difficult to obtain interaction and information transfer between systems. There is no assurance that the systems being used in jurisdictions will be interactive or that there will be a means for aggregating the data which is produced on them for use on state level systems. There is no practical way at the state level to obtain the outputs required without some form of interaction or communication with the localized systems. At the local level, we can probably safely say that unless these systems are developed at the county level, that we will be faced with massive incompatibility.

In the accompanying figure, I have outlined a few of the data layers or files which the casualty estimation model would function with at the jurisdictional level.





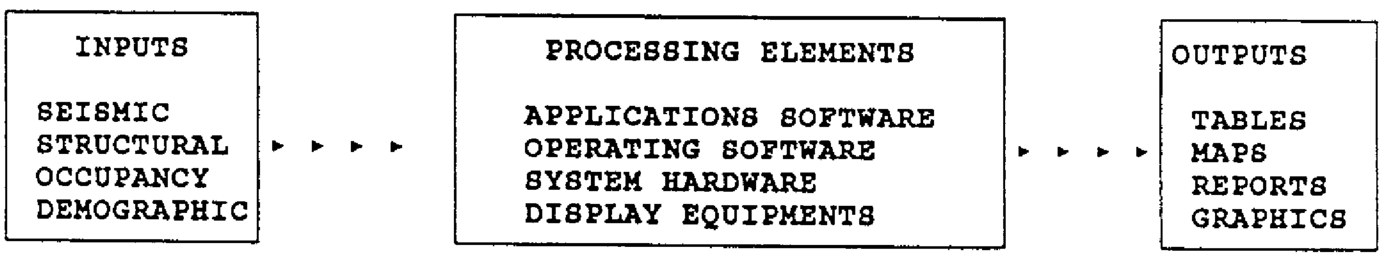
In municipal GIS applications, every department in the city can use the basic structure and other application software can be developed to meet individual departments objectives.

The processing part of the system will contain the applications software (the injury algorithms), the hardware system, including output peripherals, and the operating software.

The final component are the outputs, which could be a range and a mix of tabular data maps, and imagery which provides a real potential for enhanced photo mapping and display.

This framework in a simplified diagram looks like the following.

MAJOR COMPONENTS OF A CASUALTY ESTIMATION SYSTEM USING A GEOGRAPHIC INFORMATION SYSTEM



The knowledge of potential casualties is essential information to local planners. The use of a casualty estimation model in a response mode, where in the absence of other information, a quick casualty estimate projection could be run would also have potential value to the local responder. The greatest value however, maybe to county and state response planning which will be focused on mobilization of the external response.

Steps In Model Development

Listed below are ten steps toward model development, testing and implementation

1. Define the general attributes of a good model
2. Describe the model users
3. Describe user needs and information output requirements
4. Determine data input requirements. Describe the files and files structure for the database
5. Evaluate existing models/systems for applicability.
6. Define and produce the algorithms necessary for data processing. This will become the Applications Software.
7. Determine hardware and operating software requirements necessary to run the model
8. Develop a prototype(s) - Maybe modify something that exists?
9. Test the model and modify as necessary
10. Update and improve the model as better structural and injury cause relationships become known

The following is a brief discussion on the first three steps.

Step 1 - Define The Attributes of a Good Model

Three characteristics of a casualty estimation model are

- The model should be as simple to use as possible.

  A good analogy to use is the development of the wildland fire spread model done as a part of the FIRESCOPE Program. The object was to develop a model which would provide estimates of forward and lateral spread, flame heights, and acreage burned. Between 20-30 inputs (or perhaps more) were required before the model could be run

  The resulting model was fairly accurate, but because of all the input variables it was difficult to use, even in a pre-fire planning environment. Trying to use it for verification of the adequacy of initial response dispatching was impossible because of the number of variables required, and the length of time necessary to input all of the variables.

With some more effort the inputs were reduced to six primary variables, and the rest could reside in look up tables. At that point the model took on an operational role and became part of the dispatchers normal regimen. All wildland fires were then "modeled" to see if the planned response was the right one. Obviously there was some degradation of results by reducing the inputs. However it was good enough to do the job...and most importantly ...it was used. There is a good lesson to be applied from this. That is, keep it simple.

- The model should have the capability of varying the level of aggregation in order to meet the needs of users with different interests.

  Depending upon user responsibilities, interests in modeling casualties could range across the following needs:

  - A geographically defined area containing many similar type structures.
  - Polygons which define similar shaking intensities or acceleration factors
  - Land use zones
  - Census tracts
  - Zip codes
  - A city or a county

- The Results of the Model Should be Easily Understood and Easy to Apply.

  The model needs to be user oriented. Easy to use tables which provide the needed outputs are adequate for many needs. If using or combining the model with a geo-processing capability such as a Geographic Information System and a relational database, then output maps depicting the casualty data within the designated zones of interest would be helpful. Also helpful would be to show the spatial relationship of potential casualties to casualty collection points, hospitals, transportation networks, regional evacuation points etc.

Step 2 - Clearly Describe Who Will be the Users

The list below is only a partial one, but probably includes the key players in both the pre-planning activity as well as the initial response effort.

- City/county Emergency Service Coordinators
- Operational Area Medical Coordinators
- County Coroners - Medical Examiners
- Regional Medical Coordinators
- State OES Regional Planning Staffs
- State Operations/Coordination Center Staffs
- State Medical Coordinators
- Large Industry Emergency Planners
- Academic and Research Organizations

Step 3 - Describe User Needs and Requirements.

Two things are of obvious importance. The first is to know the number of serious injuries requiring immediate medical attention.

It would seem useful to use the model as an advance triage tool Triage provides the method for sorting casualties and is designed to maximize the number of survivors. Triage attempts to define the following in a simple and rapid manner For example:

Level 1 - First Aid level injuries - No hospitalization

Level 2 - Hospital care required but non-emergency

Level 3 - Emergency care required - top priority

Level 4 - Dead or non-salvageable

Initially, the development of a casualty estimation model should try to emulate some form of triage. If the model did nothing more than output the anticipated number of serious injured then it would be possible through internal look-up tables to estimate the percentages of those injured which would require intensive trauma care and those of a non-emergency nature.

The second important consideration deals with fatalities. How many persons might be expected to die as a result of the direct effects of the event, and where are they. We often hear in our planning that we do not have to worry about the dead. This is an overlooked area that has not received adequate attention.

The management of fatalities at the local level is going to be a major problem particularly in heavily populated counties. It is a problem not clearly understood, and not sufficiently considered There are legal, health and psychological implications to handling and moving of the dead, and most non-county jurisdictions have little capability and no desire to be involved. County Coroner or Medical Examiner capabilities are geared for the routine day-to-day problems and would be easily overloaded in a major disaster. A casualty model which could reflect potential fatalities from a variety of earthquake scenarios could be a very useful tool in the hands of planners, and help to place needed emphasis on managing this function.

Summary

Through the use of a casualty estimation model, planners, responders, and those responsible for coordinating a major response effort could get some insight into the magnitude of the problem. Obviously, no model is ever going to be a totally accurate indicator of the injury situation.

It would seem possible, given that we can define the most essential inputs and provide the proper ratios, to provide some level of useful approximation which is an improvement on what we are currently using. This would be sufficient to evaluate the potential demand for medical resources.

The model should provide enough information to answer the following questions.

1. Prior to the event:

   Has there been adequate planning and preparation for the level of medical response needed?

2. At the time of the event:

Will the planned and activated response be adequate to meet the needs?

If not, what will be the required needs?

There is almost a certainty that question two will have to be initially answered in the absence of information from the scene. We cannot not rely or wait upon information from within the disaster area. Once that data starts to arrive we can make adjustments to our response if necessary Meanwhile, emergency medical support will have already been directed to the area, hopefully on the basis of an effective casualty estimation.

References

1. Steinbrugge K V et. al. Metropolitan San Francisco and Los Angeles Earthquake Loss Studies: 1980 Assessment. USGS Open File Report 81-113.

2. Dangermond, J. Software Components Commonly Used In Geographic Information Systems Environmental Systems Research Institute, Redlands California