GROUP REPORT
&
ABSTRACTS

Group 8

Preparedness and Recovery: Business and Industry

GROUP 8 REPORT
PREPAREDNESS AND RECOVERY - BUSINESS AND INDUSTRY

Co-Chairpersons: Fil A. Bernal and Hideki Kaji

Our objective is to examine the potential for resumption of business following a major earthquake, to as near normal operations as possible. We began by comparing existing methodologies used in the United States and Japan following minor to moderate earthquakes. The goal was to determine if a set of universal guidelines could be developed which were applicable to both large and small organizations. Hopefully these guidelines would be further refined and developed at future conferences.

Japanese participants related some of their experiences and observations from various earthquakes and flood disasters in their homeland. Much of the same lethargy for earthquake preparedness that exists in the U.S. is also experienced in Japan. Over the years earthquake mitigation has been the purview of large corporations and most of the work has been applied toward structural integrity.

In a study of 205 Japanese industries such as supermarkets, construction companies, manufacturing plants, transportation, and wholesale companies[1] it was estimated that approximately 46% of them have natural disaster plans; 30% have earthquake plans, but only 21% have "backup headquarters" facilities. It was explained that much of this lack of interest can be attributed to a lack of "real emergencies." The study also showed that on average 16% of these industries organized 1.6 earthquake drills per year, and 2/3 of the employees participated. The U.S. delegates echoed that the same type of apathy must be overcome in America as well. The subject then turned to the topic of preparing small and medium sized organizations for resumption of business following an earthquake.

In this area there was general consensus that small business vulnerability is greater than that of large to medium sized business. Usually, large industry has enough resources to return to business rapidly or has the capacity to "wait out the down time." On the other hand, small businesses may never recover without substantial help from governmental agencies. Current aid programs do not meet the short-term needs of small business. This was the case in a 1983 Nihonkai-Chuba earthquake where 900 people were laid off from the local lumber mills and other small businesses. To compound matters, the post-earthquake fires further decimated homes and "service" type businesses. It is estimated that approximately 600,000 workers may lose their jobs in Tokyo after a second Kanto earthquake, should it occur.[2]

It is at this end of the economic scale where the impact of loss appears to be overwhelming. The specialty shops, restaurants, small retail outlets are the businesses that most need guidelines for recovery and help following a major disaster, but they are very often the ones that are neglected. It is almost a truism that large industry does not necessarily need service-type organizations, but the reverse is not a valid statement. Interdependencies do exist for large and small businesses, but not to the extent where a large industry would close up shop if it lost a small, independent supplier. The large industry would simply go elsewhere to fill the need.

The majority of the most current information stems from our observations following the 1989 Loma Prieta earthquake. Scores of smaller businesses failed where large enterprises such as Hewlett-Packard could "be down" for fives months and still recover.

The economic losses, both direct and indirect, totaled approximately $10,000,000,000[3].

1 Source: Studies by Mr. Ohnishi
2 Estimated by Dr. Hideki Haji
3 Total includes down time, loss of savings, unemployment, taxes, rents/leases, decreased land value, etc.

One point is clear: additional study is required to examine the most effective methods and techniques to recover from an earthquake. Further, a history of engineering, design and technical changes (and a cost-benefit study of making these changes) must be accomplished in order to reduce future earthquake damage.

The group agreed that the potential for training small organizations is enormous, and several underlying problems affect the recovery process. These are:

- lack of education regarding disaster recovery,
- apathy (or denial) for the entire process,
- lack of resources to do proper business resumption planning,
- minimal governmental assistance in this area, and
- failure of the system to transfer existing knowledge to potential end users.

It was recommended that a structured approach to training emergency planners be a goal for colleges in both the U.S. and Japan. It was also recommended that a "hands-on" training approach be used, along the lines of the Federal Emergency Management Agency and/or the California Specialized Training Institute. Existing collegiate programs offer certificates which may not address the areas of need for a small, medium or large business emergency planner.

An international structured approach to emergency training would eventually produce a professional rank of emergency planner. Conceivably a demand for professional emergency managers would arise who are credentialed, knowledgeable and who could help bridge the gap between the research and development areas to practical use in the business and industry worlds.

Development of a collegiate level, structured emergency planning curriculum will require the involvement of both private enterprise and government agencies. Private corporations could assist in funding but, more importantly, would bring post-disaster experiences to be utilized as case studies or models. The governmental aspect lends the base foundation needed to gain universal acceptance but would also provide funding to continue required research and development. It was explained that in Japan this approach may be difficult due to the government's reluctance to provide funds directly to commerce since this is viewed as too narrow an application. However, if the research has wide a level of utilization, then perhaps the idea could be "sold" in Japan as well.

However, in Japan there may be a wider level of acceptance due to the citizens' general acceptance of earthquakes as a national risk. While in the U.S. most citizens regard earthquakes as a local risk relegated primarily to California with some concern by people in the New Madrid Fault region. Our group believes the message which must be delivered is that earthquakes pose a substantial economic risk *across* the U.S.

In summary, our committee feels that future collaborative efforts by U.S./Japan delegations should focus on the four areas listed below.

1. A comparison of indirect economic losses,
2. A systematic earthquake training program,
3. A methodology to develop earthquake planning to include four key areas: mitigation, preparation, response and recovery - An optimal earthquake preventive investment on the basis of risk assessment.

4. A bilateral transfer of U.S./Japanese knowledge.

In considering the above topics and areas of discussion our group also unanimously agreed that the transferability of solutions to earthquake problems depends greatly on the cultural setting.

WORKING GROUP ABSTRACTS

POST-EARTHQUAKE BUSINESS AND INDUSTRY RECOVERY

Fil A. Bernal

Brief History of Business Resumption Planning (BRP)

A. What is BRP?
B. How it began
C. How the earthquake threat has changed plans

How to Begin

A. Gaining support from the "top"
B. Equating dollar outlay with potential rewards
C. Support staff
D. To contract or not to contract
E. Establishing reasonable time frames

Maintaining the Momentum

A. Convincing the next levels down
B. Keeping the hierarchy in the loop
C. Developing a usable product
D. Customizing the product for various operations

BRP Acceptance

A. Making the BRP maintenance "routine"
B. Fitting BRP into the general emergency planning function
C. Identifying interdepartmental relationships
D. Identifying, securing and testing backup sties
E. Testing the BRP
F. Refining and feedback

Interfacing with Governmental Agencies

A. Which agencies affect your business?
B. Sharing your BRP with selected governmental agencies
C. What does your business need from government?

Spreading the Word

A. Mutual assistance agreements
B. Sharing your BRP with similar industries
C. Establishing business and industry self-help organizations

Summary

A. BRP today and tomorrow
B. What remains to be done

Southern California Gas Company,
Emergency Preparedness, Box 3249, Los Angeles, CA 90051

ESTIMATION OF WORKERS DISMISSED OR LAID OFF FOLLOWING THE SECOND KANTO EARTHQUAKE

Hideki Kaji[1] and Ken'ishi Murakami[2]

Abstract

The Expert Committee for Disaster Prevention of the Tokyo Metropolitan Government is currently trying to estimate the extent of the damage which could be caused by the second Kanto earthquake, should it occur. The committee has already shown the results of collapse of buildings, lifeline disruption, areas burned by post-earthquake fires, and the number of dead and injured. This paper attempts to illustrate socioeconomic consequences following an earthquake on the basis of this physical damage estimated by the Committee.

It is expected that an earthquake of similar magnitude to the Kanto earthquake will have a strong influence on industrial activities, resulting in cutbacks or temporary closure of operations and, in an extreme case, a number of industrial companies may go into bankruptcy. Thus, a huge number of workers will possibly lose their jobs through layoffs or dismissals. This consequential unemployment has been observed in past earthquakes such as the Nihonkai-Chubu earthquake in 1983 and the Mexico earthquake in 1985.

Most of the unemployed will be able to find new jobs sooner or later and will be absorbed into a new social structure as the recovery and reconstruction works proceed. In this process, however, society will inevitably become unstable and some drastic structural changes in the industrial sector could take place unless an appropriate policy is prepared beforehand based on a better understanding of the potential situation.

This paper aims to provide a clear picture of the social catastrophe after a big earthquake by estimating the number of workers who will be laid off or dismissed after an earthquake in metropolitan Tokyo.

In general, there are two reasons why unemployment is generated after an earthquake. One is due to companies' having to close or cut back on their operations because: the buildings collapsed: facilities and equipment destroyed; lifelines such as telephone, water supply etc., destroyed; or economic demand for their activities dropped. Another is due to workers' personal reasons: the workers themselves were killed or severely injured; workers lost their homes and were forced to move to other locations.

In this study, a questionnaire survey was conducted to estimate parameters which determined post-earthquake behavior of enterprises. About one thousand companies were sampled on the basis of their business type and scale of operation. In the questionnaire, it was assumed that the earthquake caused damage to those companies at several different levels of severity. Thus, depending upon the degree and type of damage resulting from the earthquake, employers were asked whether they would: continue operations as before, cut back on operations; temporarily close operations, resuming shortly; or terminate operations. On the basis of these responses, it was also asked whether they intended to dismiss, lay off, or give leave to their employees. The effective samples of 516 companies were collected. The other parameters on workers' personal damage were determined by using the figures of the number of dead and injured and the number of houses destroyed, which were estimated by the survey of the Expert Committee mentioned above.

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1 University of Tsukuba, 1-1-1, Tennoudai, Tsukuba-shi, Ibaraki-ken, 305, Japan
2 Tokyo Fire Department, Tokyo, Japan

The result indicated that in the worst case scenario about six hundred thirty thousand workers (9.4 per cent of the total work force) may lose their jobs after an earthquake. More importantly, there are few workers laid off by big companies, while the majority of the unemployed (43 per cent of the total) would be generated from small-scale companies. It can be therefore concluded that damage from disasters tends to concentrate on the weak.

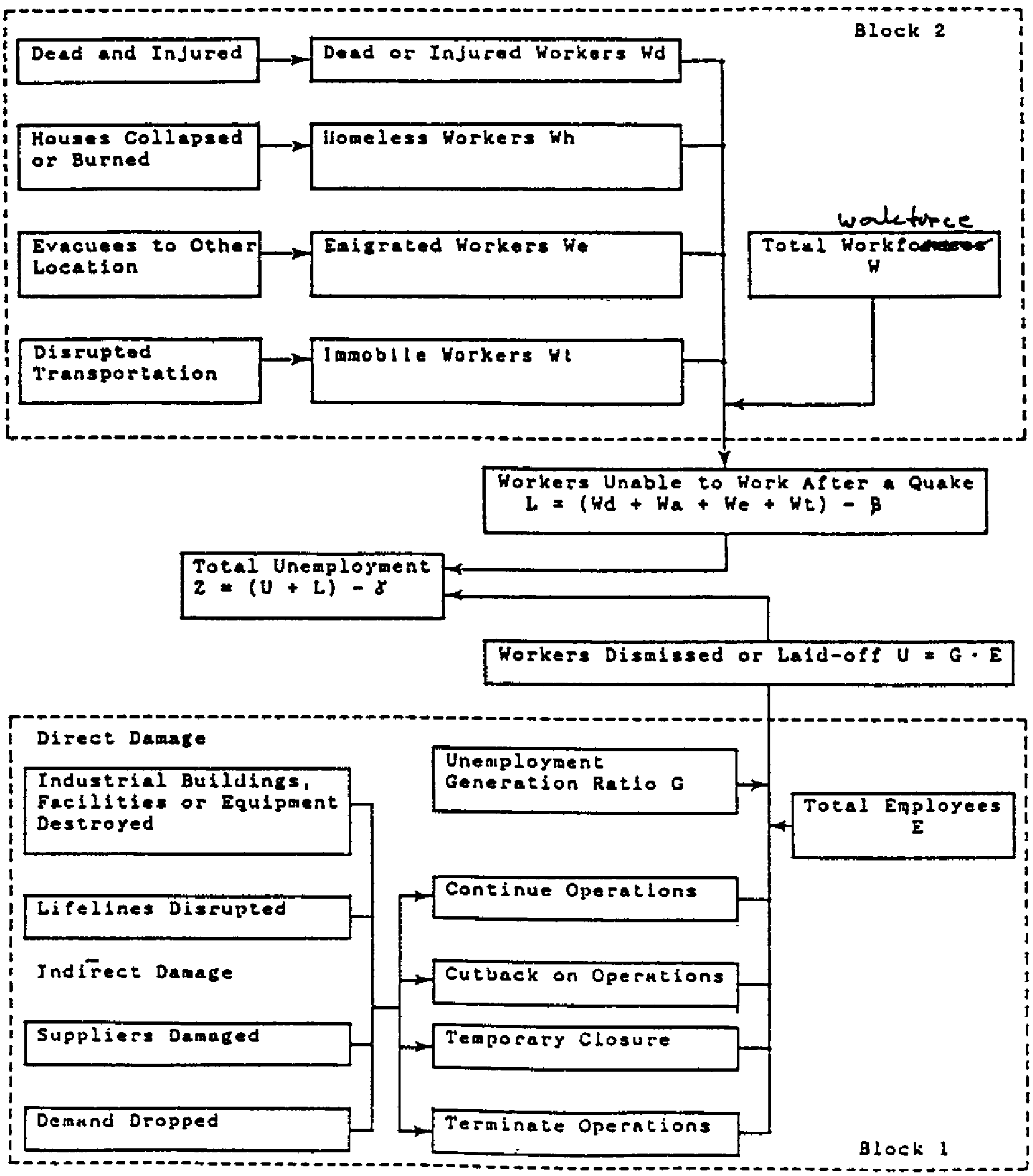

Figure 1. Model Diagram

PREPAREDNESS AND RECOVERY - BUSINESS AND INDUSTRY

Robert H. Lanning

New Critical Issues

Although communications was known to be an important issue before the earthquake, its absolute critical nature was not understood until afterwards. The radio system to cover this need was being installed and therefore not operational. Cell-Sites were overloaded on both cellular systems, frustrating cellular phone attempts. Now that the HP private radio system backbone is installed, the new critical issue is getting the last of the division/sites to convert from their old radios to the new ones. It cost them money. Additionally, learning to manage the message traffic is vital.

Coordinating a multi-divisional, multi-site response is difficult even when a response plan is in place. Ours was being formulated and only partially implemented at the time. The critical issue is knowing or anticipating what each site and organization is doing and how it will be reporting status or requesting assistance.

Technical details of building systems are very important. If key staff members are not present it is impossible to stem the onslaught of water and to recover from internal power outages. There must be more than one or two people who can locate critical control valves and circuit breakers. Additionally, documentation of these systems' control points is needed.

Cooperation between departments and between divisions/sites is critical. The company is made up of many divisions that operate in concert with other divisions during normal business conditions. During an emergency they must function as one company and appear that way to the public. They are not used to this.

Identify lessons that have been learned

Building inspections must be conducted using multiple teams. It took 10 days to inspect 80 buildings using one team. Far too long! Building occupants had to make their own decisions until the reconnaissance team arrived, sometimes days after requesting them.

The team worked very effectively using some of ATC-20 techniques spending from 20 minutes to an hour in most buildings. The team consisted of two consultants on retainer just for such an event, and one company representative. In the future the team needs to consist of only two members, a qualified inspector and a company representative to make the decision as to the disposition of the structure.

Although difficult, it is critical that information gathering be quick and accurate. Because the communications system was not in place the divisions/sites were not notifying headquarters of their status and headquarters was not able to talk to the sites. Local divisions were making statements to the news media that were not consistent with the company's position.

Employees need accurate information about their homes and the condition of their commute routes It is better to provide this information and let the employees decide whether to attempt to get home or to stay at the work place.

Hewlett-Packard Company, Corporate Real Estate
3000 Hanover Street MS-20DX, Palo Alto, CA 94304

Changes that have been made as a result of experience

Importance of drills and exercises has been heightened among skeptics. More time is allowed for such exercise or drills. Managers with emergency response responsibilities are spending more time on this aspect of their jobs.

Earthquake program issues are now included in more of the business decision making processes. New construction or a potential lease or purchase or of property is getting a seismic review. Structural and nonstructural components are being reviewed.

Issues not receiving adequate attention

Developing company internal building inspection teams is not happening. The selection of the Preliminary Evaluation team members and their training is vital to the success of the response effort. These teams would make a preliminary evaluation on the spot so response and recovery plans can be executed. Later, when the Seismic Reconnaissance team arrives, it will review the decision of the preliminary evaluation team.

Food and bedding for stranded employees still needs to be coordinated and funded. Some sites have stock; other sites have nothing.

Safety and Emergency Response Team members are not being measured on their performance in these roles. They are measured on other portions of their jobs but not the Safety or ERT readiness aspect of their responsibility. Without this performance evaluation, there is little incentive to spend time improving the process.

Areas of research to address these issues

Management techniques need to be studied to provide insight into how to sell a preparedness plan in a company not structured with top down management. Preparedness is costly in direct dollars and in the consumption of people's time. These costs are borne by the divisions and therefore subtracted from the bottom line of their profit and loss statement. The divisions think corporate should bear the cost, but Corporate has no "super fund." It can only spend the money the divisions make in their profit margin through a tax or bill-back scheme. This still does not address the divisions "buy-in" to the scheme and therefore their acceptance of the plan.

How to pay for preparedness expenses. Capital items can be amortized as depreciation over the life of the item being upgraded (building or equipment). Expense items are a one-time lump sum "hit" at the time the money is spent. This can significantly tarnish a division's performance of meeting expenditure targets. What makes sense: Corporate paying or the Division paying?

Development of a "cookbook" approach to the Incident Command System and the operation of an Emergency Operations Center is needed. This includes typical EOC physical layout and how it functions with the other areas of the business recovery team.

THE STATE OF DEFENSIVE PREPARATION AGAINST DISASTERS IN PRIVATE ENTERPRISE

Kazuyoshi Ohnishi and Yositeru Murosaki

Introduction

The aim of this research is to clarify the state of capability of private enterprises to prevent disasters and the problems facing them. For this purpose a survey has been conducted. Disasters compel the existing private enterprises, as well as other local organizations and residents, to defend themselves and their regions. Above all, in the case of large-scale disasters, the aspect of damage in a locality is mainly affected by the defense system and regional collaborative system. Therefore, the role and contribution of private enterprises to the disaster prevention in a community cannot be ignored. Based on responses to the questionnaire, we clarify the state of the defensive preparations of private enterprises against disasters and discuss the problems facing them in disaster prevention in a community.

Method

In order to select the subject areas of investigation, we categorized the areas into four. An earthquake-prone area and an area prone to storm or flood; each of them subdivided into two categories: the area which had experienced a disaster recently, and the area which had not. Sendai City (Miyagi Pref.), Ota Ward (Metropolis of Tokyo) and Shizuoka City (Sizuoka Pref.) were selected as the earthquake-prone areas: and Kobe City (Hyogo Pref.) and Nagasaki City (Nagasaki Pref.) as the areas prone to storm or flood. Sendai City was hit by an earthquake registered magnitude 6 which occurred off the coast of Miyagi Prefecture in 1978, and Nagasaki City suffered damage seriously from a heavy rainfall registered 128 mm of maximum precipitation an hour in July 1982.

Then five categories of businesses were selected as the subject of the questionnaire research in the above areas: those dealing in finance and insurance; large-scale distribution, construction and traffic services; chemical manufacturing with dangerous objects; and production and wholesale of emergency commodities. About 20 enterprises were sampled at random from NTT telephone directory for each type of business in the four areas (except for Kobe City), totaling 358 in number. (As for Nagasaki City, the enterprises dealing in chemical manufacturing were excluded, and another city's National Factories List Book (1988) was used for sampling of chemical manufacturing instead of NTT Townpage.) As for Kobe City, 286 enterprises were selected from a printed list of members provided by Kobe Chamber of Commerce and Industry.

The questionnaire investigation was made by mail to 644 enterprises in October and November of 1990. Data were collected from 205 enterprises, with the rate of collection at 31.8%.

Department of Environmental Planning, Faculty of Engineering,
Kobe Univ., Rokko-dai cho, Kobe city, Hyogo, 657, Japan

Main Findings

This research study consists of the following topics:

The system and plan for disaster prevention.

The preparations against disasters in enterprises are divided into four steps. First, system preparation; second, an extensive training of employees; third, saving the emergency commodities; and fourth, taking defensive measures.

Preparation of an emergency system

Coping with disasters at an early time plays an important role in decreasing the damage when disasters occur. Therefore, it is necessary for the enterprises to arrange a system to take advance measures and also to prepare an operational manual for times of disaster. Accordingly, we will examine the procedure for notifying employees and evacuating customers.

Training and educating for disaster prevention

It is necessary to evaluate the prevention capability against disasters considering two aspects: hardware and software. In order to strengthen the prevention capability against disasters from the standpoint of software, education must be carried out together with the preparation of a defense system. Therefore, we will consider training for disaster prevention which is to raise response capabilities in the face of an emergency, and education for disaster prevention, which is to raise employee awareness.

Saving emergency commodities

The following should be regarded as emergency commodities: food, drinking water, medicine, fuel, clothes, as well as facilities, instruments, and materials for emergency operations. These emergency commodities may be expected to be supplied from an official organization or from other areas at the time of disaster. However, it is desirable to save the minimum commodities necessary in case there is a delay or shortage in the supply.

Advance measures for the prevention of damages

There are several points to be considered in order to avoid expected damages when a disaster occurs. These include the improvement of buildings and facilities in structure and equipment, and the improvement in the location of buildings. Here we will examine the measures to be taken against the interruption of communication, power failure, collapse of buildings and breakage of facilities, outbreak of fire, and submersion.

Joining and contribution to the local rescue works

Private enterprises are expected not only to safeguard themselves but also to join voluntarily in the local rescue or relief efforts to mobilize people and utilize their material resources. Such cases are found in the past; e.g., a construction company participated in the rescue operation during an earthquake in the central part of the Japan Sea, and a milk company joined the rescue effort when Nagasaki was hit by a flood. In order to actualize the participation in the local rescue work, it is important to always join the activities of disaster prevention in the locality, to maintain a rescue plan, and also to assemble rescue commodities and supplies.

REMODELING EARTHQUAKE CASUALTIES FOR PLANNING AND RESPONSE: MODEL DEFINITION AND USER OUTPUT REQUIREMENTS

Robert A. Olson

Historical Overview

Better casualty estimates are needed to strengthen arguments for and the practices of earthquake hazard mitigation, disaster preparedness, and actual emergency response operations. The writers of the first loss estimation study for the San Francisco Bay Area in 1972 used the crudest of techniques to estimate the expected number of deaths, serious injuries, and minor injuries that might be expected from a recurrence of the 1906 earthquake. The method basically consisted of extrapolating on a per capital basis fatality and injury information from relatively recent earthquakes that occurred in "comparable" locations. Examples included Arvin-Tehachapi (1952), Alaska (1964), Santa Rosa (1969), San Fernando (1971), and Nicaragua (1972). The "formula" used today in the absence of anything better consists simply of estimating deaths on the basis of the ratio of one or two per thousand of the population of the affected area. Serious injuries were a multiple of four times deaths, and minor injuries were estimated to be thirty times deaths.

In the early 1970s the Earthquake Engineering Research Institute, in its field guide for earthquake investigators, included a form to collect data on earthquake casualties. The intent was to provide data to the engineering community so that it could design less life-threatening buildings. Only recently, especially since the Chilean and Mexican earthquakes of 1985, have researchers undertaken the kind of work needed to eventually improve casualty estimates. While earlier post-earthquake studies reported general casualty statistics as indicative of the seriousness of the event, recent efforts have focused on the casualty-producing environments and the epidemiology of earthquake injuries. Both seek to improve our understanding of the exact causes of casualties and the nature of them so as to be better able to anticipate future "casualty loads." Such data would improve response planning and operations by providing more reliable information on which to base the mobilization and allocation of human and material medical resources. The data could also help the building design and construction industry reduce physical hazards from those structural and nonstructural building elements that produce casualties.

An Improved Approach

Casualty estimation is a problem; so what can be done 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.

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 validate immediate response assignments. The second model deals with a sophisticated capability that considers a more comprehensive set of variables. This would produce casualty estimates for smaller areas. Perhaps one is derived

VSP Associates, Inc.
455 University Avenue, Suite 340, Sacramento, CA 95825

from another, and certainly they are related.

Generally, there would appear to be four major classes of input data necessary for purposes of casualty estimation. These would include: seismic data; structural data; occupancy data; and population data. All of these data are currently available, although they are not necessarily always in the precise file structures needed.

Use of Geographic Information Systems (GIS) in Casualty Modelling

Virtually all cities and most highly urbanized countries 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 existed for several years.

One of the principal features of the rapidly advancing GIS technology is the ability to model various alternatives for meeting a client's 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 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 are 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 local systems. Unless these systems are developed at the county level, we probably will be faced with massive incompatibility.

The Attributes of a Good Model

1. The model should be simple to use. 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. The inputs were reduced to six primary variables, and the rest could reside in reference tables. At that point the model took on an operational role and became part of the dispatchers' normal regimen.

2. The model should have the capability of varying the level of aggregation to meet the needs of users with different interests. Depending upon users' responsibilities, interests in modeling casualties could include: geographically defined areas containing many similar type structures, polygons which define similar shaking intensities or ground acceleration levels, land use zones, census tracts, postal codes, or city and county boundaries.

3. The results of the model should be easily understood and 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 and others.

Conclusion

Through the use of 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 seems possible that we can define the most essential inputs and provide the proper ratios to provide some level of useful approximation of fatalities and injuries, which is an improvement on what is currently being used. 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 more will be required?

There is almost a certainty that question two will have to be initially answered in the absence of information from the scene. We cannot rely or wait for information from within the disaster area. Too much time is lost. Once those data start to arrive, adjustments to the response can be made if necessary. Meanwhile, emergency medical support will have already been directed to the area, hopefully on the basis of an effective casualty estimation system.

ANALYSIS OF HAZARDOUS MATERIALS RELEASES DURING THE LOMA PRIETA EARTHQUAKE

Guna Selvaduray[1], Ed Wyatt[2], and Jeanne Perkins[2]

The occurrence of hazardous materials problems during the Loma Prieta Earthquake was investigated in detail and the findings compiled in a computerized data base. All 10 counties surrounding the earthquake epicenter were surveyed. This outline presents the method(s) of investigation utilized, and the results of the findings. The data base program used was Foxbase™, a software package that is compatible with dBase.

Data collection was done by contacting a large number of institutions directly. These are summarized in Table 1. The standardized information gathering checklist shown in Table 2 was used to ensure uniformity of data gathering. This information was then entered into the database.

A total of 490 hazardous materials incidents of all sorts were found to have occurred during the Loma Prieta earthquake. This total number specifically excludes the natural gas leaks in the gas distribution system. Of this total number, 46.1% (226 cases) involved spills in laboratories. The next highest rate of occurrence was release of asbestos, which accounted for 16.5% or 81 incidents. Other major occurrences involved releases from tanks, releases due to sloshing, releases from other containers, and releases from pipes. This data are summarized in Table 3.

Of the 490 events, 43 were identified as being particularly "large" occurrences. As can be seen from Table 4, of these large events, the major problem was with sloshing. A total of 19 of the sloshing events were classified as being large. The data contained in Table 4 report the percentage of total occurrences, for each category, that were large. For example, there were 8 releases from equipment (Table 3), and of these 4 were large releases, for a percentage of 50.

The incidents were also classified in terms of the specific chemicals released, and these data are shown in Table 5. Laboratory chemicals were again on top of the list, followed by asbestos. The next largest releases involved miscellaneous liquids, propane, plating solutions, fuel and petroleum products, and acids.

Information on containment of the releases was obtained for only 67.7%, or 331 of the documented releases, and is shown in Table 6. Of this total number, 188 or 57% were contained. Fifty-two releases, or 15.7% were partially contained. Ninety incidents, or 27.3%, were not contained. The fate of the releases not contained, based on available information, is summarized in Table 7.

The majority of the clean-up effort was undertaken in-house, as shown in Table 8. This accounted for 70.4% of the incidents. In 24.6% of the cases the local Health Departments were involved in the clean-up, in 11.2% of the cases the local Fire Departments were involved in the clean-up, and in 19.67% of the cases the clean-up was done by a private contractor. It should be noted here that there were more than two responding agencies for a large proportion of the releases; as a result, the sum of the frequencies reported in Table 8 exceeds 100.

By comparison with hazardous materials problems reported during past earthquakes, the Loma Prieta earthquake appears to have had an unusually large number of releases. This is probably due to the fact that such a thorough investigation of this topic was not undertaken

1 Department of Materials Engineering, San Jose State University, San Jose, CA 95192-0086
2 Association of Bay Area Governments, P.O. Box 2050, Oakland, CA 94604-2050

for previous earthquakes, and not due to any unusual feature of the San Francisco Bay Area. Though it is possible that the large number of industries and educational and research institutions in the San Francisco Bay Area could have contributed to an increase in the total number of releases, this fact alone cannot account for the large discrepancy.

This investigation shows that some of the major areas for future hazard reduction efforts should be concentrated on laboratories, asbestos releases, and sloshing problems. Institutions or organizations handling or possessing hazardous materials should also be capable of cleaning up releases that occur during an earthquake.

Acknowledgments

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Table 1: Organizations contacted for information on Hazardous Materials Releases that occurred during the Loma Prieta Earthquake

Clean-up Companies - 10	U.S. Coast Guard
U.S. Environmental Protection Agency	California Office of Emergency Services
California Highway Patrol	Regional Water Quality Control Boards (San Francisco and Monterey)
Air Quality Management Districts (San Francisco Bay Area and Monterey Area)	Office of Emergency Services - 10 counties
Environmental Health Departments 10 counties	Fire Departments - all those with hazardous materials teams
Business Groups	All hospitals in 10 counties
All Universities and Colleges in 10 counties	All Public High Schools in 10 counties

Table 2: Information gathering checklist

Name of company/organization	Address, City, County
Type of Problem	Material released
Quantity released	Units defining the quantity of materials
Comments on the details of the release	Was the release contained?
Organization doing Clean-up	Source of information

Table 3: Verified Hazardous Materials Releases during the Loma Prieta Earthquake of October 17, 1989

Type of Problem	Number of Occurrences	Percentage of Known Events
Laboratory	226	46.1
Asbestos	81	16.5
Tank	49	10.0
Sloshing	40	8.2
Container	39	8.0
Pipe	36	7.4
Equipment	8	1.6
Cylinder	4	0.8
Valve	3	0.6
Indirect	3	0.6
Transportation	1	0.2
Total	490	100.0

Note: The total reported here does not include naturalgas leaks from the gas distribution system.

Table 4: Types of Problems for Largest Releases

Type of Problem	# of Large Occurrences	Percentage*
Equipment	4	50
Sloshing	19	48
Tanks	11	22
Pipes	5	13
Container	4	10

*Note: Percentage of releases that were "large" for each type of problem in Table 3.

Table 5: Types of Hazardous Materials released during the Loma Prieta Earthquake

Material	Percentage of Total Number of Releases
Miscellaneous Lab Chemicals	41.6
Asbestos	16.1
Miscellaneous Liquids	11.1
Propane	6.9
Plating Solutions	5.6
Fuels & Petroleum Products	5,6
Acids	3.0
Ammonia	2.4
Pesticides	2.2
Formaldehyde	1.2
Paint	1.2
Bio-hazards	0.8
Solvents	0.6
Other/Unknown	0.8

Table 6: Containment of Hazardous Materials Releases during the Loma Prieta Earthquake

Extent of Containment	Occurrence (%)
Fully contained	57.0
Partially contained	15.7
Not contained	27.3

Table 7: Fate of Hazardous Materials Releases that were not contained during the Loma Prieta Earthquake

	Liquids	Gases
Atmosphere	10	11
Drain	16	-
Soil	7	-
Fire	3	3
Treatment	2	-

Table 8: Organizations involved in Clean-up of Hazardous Materials Releases after the Loma Prieta Earthquake

Clean-up Organization	Frequency (%)
In-house	70.4
Local Health Department	24.6
Local Fire Department	11.2
Private Contractor	19.6
Unknown	30.1

Note: The total of the frequencies adds up to more than 100% because more than one organization was involved in several of the clean-up efforts.