CHAPTER 5
LOCAL GOVERNMENT PROGRAMS

INTRODUCTION

Local governments are recognized as the first line of responsibility for disaster mitigation and emergency management (FEMA, 1984). Embedded in this concept is the fact that earthquake safety can become part of master planning, zoning regulations, and subdivision ordinances. For instance, local authorities can use hazard and multihazard mapping, create special districts, and enforce setbacks and density ordinances in order to regulate construction in hazardous areas. Development can be restricted through the planning of capital facilities and use of financial incentives. Local authorities can require geological studies as preconditions to authorize development in areas suspected of being affected by earthquake hazards. During the design and implementation of redevelopment programs there are many opportunities to adopt sound land-use planning provisions leading to the reconfiguration of urban sites that can meet adequate earthquake safety.

As local governments are faced with the responsibility for implementing urban programs they are also confronted with the need for financing these programs. The decline in federal aid since 1978 has ushered a major reliance on local government revenues to finance needed development projects. Since the federal government began turning more responsibility back to local governments, municipalities and counties have assumed greater autonomy in directing and greater responsibility for financing public services. The potential to utilize financial incentives for earthquake safety has been extensively researched by Building Technology Inc. (1990), BAYREPP (1992), and Berke and Beatley (1992).

This chapter has two objectives. First, it identifies how jurisdictions can promote earthquake safety within their planning process. Second, the chapter describes a number of mechanisms that can be used by local governments to generate or increase their funding for development and redevelopment programs incorporating earthquake safety.

PROMOTING NON-HAZARDOUS DEVELOPMENT

When earthquake related hazards can be recognized, one way to enforce positive action is to issue ordinances which override conventional zoning by restricting development in hazardous areas. Such regulations are particularly important when selecting sites for critical public and private facilities and lifelines, and high density human development.

However, the avoidance of hazardous areas can be controversial. When land is privately owned but expectations exist for intense use or land is optimally suited for development and has become a scarce commodity, there can be strong pressures from interest groups to disregard risks from natural hazards. Local authorities may be compelled to follow an approach in which market forces, instead of community welfare, dictate the policies for urban development. In the San Francisco Bay region, hillsides and uplands occupy more than half the land area, even though, landslide is the most costly and pervasive geological phenomenon and it is likely to increase in the future as more hillside land is developed. (Brown and Kockelman, 1983).

In areas affected by high earthquake vulnerability but where earthquake recurrence is over long periods of time, the lack of earthquake awareness can mitigate against earthquake safety. Earthquake safety provisions can be completely ignored within the planning process and only under certain circumstances, addressed by the building codes, such is the case of Charleston and Memphis (see case studies). In these cases imposing land restrictions to avoid earthquake hazards is extremely difficult. In reality, the avoidance of high risk areas is almost exclusively possible if both policy-makers and implementors have a thorough understanding of the existing vulnerability of a particular site and the risk to people and property in the event of an earthquake.

When avoiding risk areas and searching for compatible forms of land-use, **setbacks** play a prominent role. The concept of setbacks has long been part of traditional zoning and land-use controls. Setbacks are typically used in urban settings to ensure that sufficient land is available for future roads and other improvements, and that adequate light, access, and separation of structures are provided.

The concept of setbacks in terms of earthquake safety emerged with the enactment of California's Alquist-Priolo Special Studies Zones Act. This Act stipulates that a structure shall not be located across the trace of an active fault and that a uniform 50 foot setback from the fault line must be required unless geological studies prove the absence of branches at a particular location.

In many counties and cities of California, setback ordinances, commonly exceed the Alquist Priolo Act. This type of ordinance usually establishes setbacks through which the more critical the structure or the higher the earthquake hazard the greater the setback limits. For example, Portola Valley has imposed two different setbacks, depending upon whether the fault trace location is known or simply inferred.

In general, various type of setbacks can be used to enforce seismic safety. For instance, building setbacks can be recommended in geologically hazardous areas; seismic setbacks can be recommended where areas of proposed development are crossed by known or inferred active faults; slope stability setbacks can be established where unrepaired active landslides and dormant or old landslide deposits have been identified (recommendations can include very steep slope areas subject to active soil creep processes and possible shallow landsliding and debris flows); and erosion prone area setbacks can be required to restrict development in areas of erosion prone terrain.

In addition, setbacks can be used to impose appropriate separation of buildings located a short distance from each other in order to reduce **pounding effects** during an earthquake. Adjoining buildings can become destructive forces to each other since individual structures do not have identical modes of earthquake response and, therefore, have the tendency to pound against one another. This phenomenon is most common in urban areas where high-rise, medium-rise, and low-rise structures, all of which have different types of construction systems, are combined in close proximity. Past earthquakes are replete with these types of examples. The Preliminary Report on the Loma Prieta Earthquake indicated that pounding of buildings was found to be a significant source of damage in both San Francisco and Oakland. During the 1985 Mexico City earthquake, pounding between buildings contributed largely to damaged structures. When dealing with high-density, congested metropolitan centers located in areas of high seismic risk, serious consideration must be given to the potential of pounding between adjacent structures, separations between buildings, interstory drift limitation, and the planning of entire urban blocks as a unit. What is most surprising is the fact that even though this damage scenario has been recorded in earthquake after earthquake there is almost no setbacks limitations or seismic provisions that presently deal with this problem.

Another important type of setback that can be imposed are those directed at regulating the distance from buildings to sidewalks or areas of intense pedestrian circulation. The main purpose of these setbacks is to avoid the loss of lives and injury of people resulting from collapsing debris and parapets during an earthquake. Drift is the lateral displacement of one floor relative to the adjacent floor. Because of the drift or movement of each individual floor, the exterior envelope or **cladding systems** of buildings can be distorted until they fail. Their failure is especially dangerous within an urban environment because of the risks they impose on pedestrian and vehicular traffic below the building. During the 1985 Mexico City earthquake, some 70 percent of the normal street capacity was largely lost due to collapsed structures and debris.[9]

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[9] Lessons Learned from the 1985 Mexico Earthquake

Together with setbacks, **densities** constitute one of the most important functions of zoning. Density is a device that determines the number of families, persons, or houses per unit of land. Most of these types of ordinances establish this limitation by setting a minimum required size for each lot or by limiting the number of families per acre or by setting a minimum required lot area for each dwelling unit on a lot. Larger cities usually regulate their densities by establishing controls that limit building height and the proportion of the lot area that may be covered by buildings.

Berke and Beatly (1992) have collected extensive data and information on how several Californian cities are using density factors to mitigate the effects of earthquakes. The central concept is that certain types of land-use are more suitable for seismic hazard zones than others and that local governments can limit through these ordinances the amount of construction in vulnerable sites and risk areas.

Formulas to establish densisties and land-use restrictions throughout California are not uniform. They typically vary to fit local and particular natural hazard requirements. For instance, San Mateo County's zoning ordinance specifies a series of district areas within which the amount of development that can take place is restricted when the presence of landslides or active faults are identified.

The City of Santa Cruz, in order to conserve and protect areas characterized by combustible vegetation and unstable slopes, has enacted an ordinance restricting building permits in areas such as canyons, arroyos, slopes over thirty percent, and areas susceptible to landslides. Erosion control measures are required for all projects located within, or adjacent to, erosion hazard areas. For liquefaction areas, site investigation reports must be incorporated into the design of the project.

Santa Clara County adopted a plan directed at reducing the potential damage from liquefaction. A study was prepared dividing the planning area and defining their land-use. Risk zones were identified based on the potential for settlement and ground failure under both seismic and non-seismic conditions. A matrix was developed providing criteria for permissible land-use. Geologic reports and site investigations are currently required for all subdivisions on or adjacent to potentially hazardous areas as depicted on the county hazard maps.

San Jose has adopted seven ground-response zones based primarily on depth to bedrock. Expected ranges of maximum ground surface acceleration and fundamental periods were estimated for each zone. Land restrictions were imposed in terms of site performance, that is, where ground-shaking characteristics could cause serious damage to particular types of structures. (USGS, 1979)

Riverside County has developed a set of matrices which correlate, within the county, each seismic zones with land-use. This matrix imposes restrictions in zones susceptible to fault rupture, liquefaction, and ground shaking. Uses are divided into four broad categories and correlated to the vulnerability of the area: Critical uses (e.g., nuclear facilities, dams, hospitals); essential uses (e.g., police and fire stations, power plants, sewage treatment plans, major highways, schools, and public assembly structures); normal- to high-risk uses (e.g. multifamily residential of 100 or more units); and normal- to low-risk uses (e.g., single-family residential).

Portola Valley found that the combination of slope-density regulations, along with a provision for cluster development, was a reasonable and suitable approach for land development. The adopted provisions were not only beneficial for earthquake safety they were adequate for rain-induced landslides and compatible with environmental regulations.

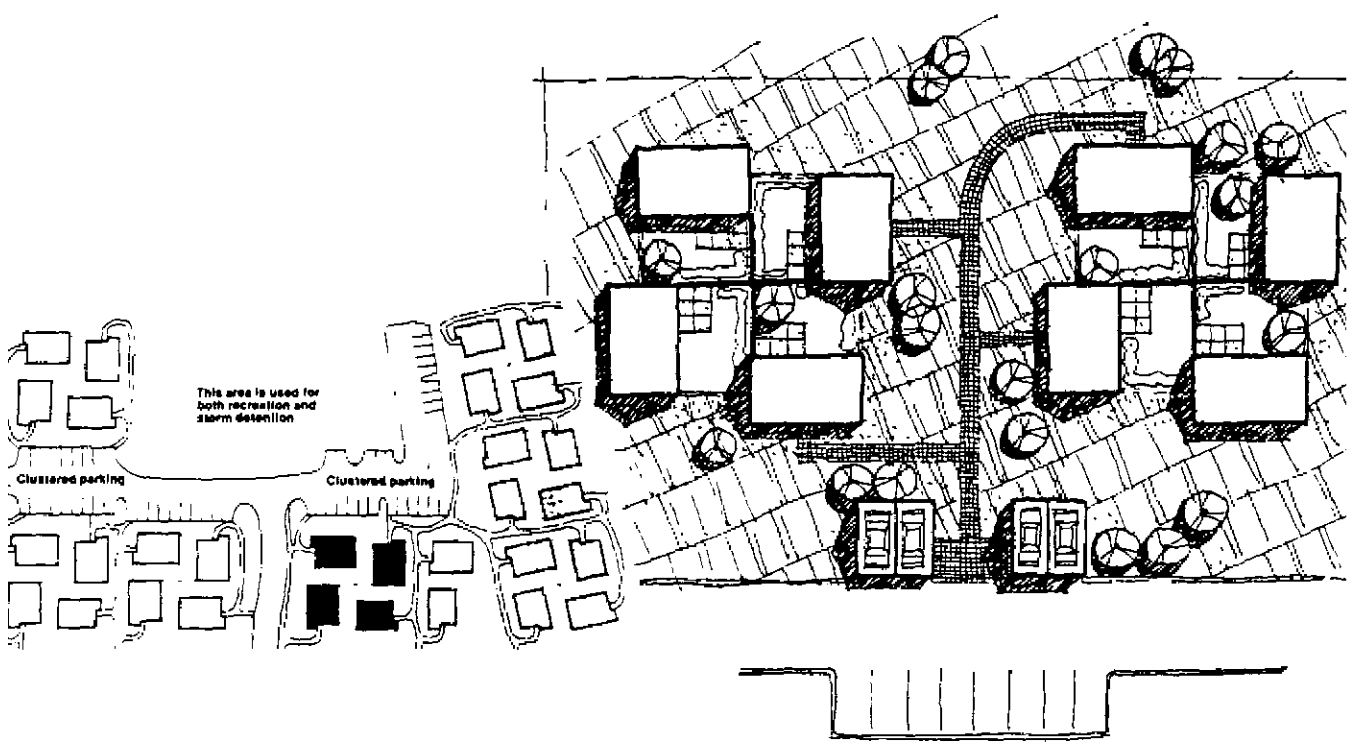
Another way to avoid hazardous sites is by using **planned unit developments**. This approach is a form of development that allows for unconventional zoning ordinances. The final project approval might involve a type of development that otherwise might not be allowed under standard regulations. This concept which has increasingly becoming an integral part of subdivision regulations, is an excellent strategy to promote seismic mitigation measures.

Planned unit developments encompass a number of design approaches such as the clustering of units, the mixing of housing types, and the development of large common open spaces. Clustering is a land-development technique that groups structures and/or lots.[10] Density is usually based upon overall dwelling units per acre with allowable units clustered on the most buildable area of the site, leaving the rest undeveloped. (NIBS, 1990) This measure allows buildings and services to be concentrated in the less vulnerable areas of a particular development. For example, Portola Valley encourages clustering under its zoning and subdivision regulations as a way to avoid seismic and landslide hazard areas.

Within planned unit developments, design criteria can be set for several acres of land or for the entire development. Density or intensity bonuses are typically offered and negotiated as part of the review and approval process. In terms of local governments, the advantage of using planned unit developments is that construction costs for roads and utilities are reduced since housing units are clustered requiring less site and service development.

CLUSTERING USE TO AVOID HAZARDOUS AREA

Exhibit 5



Source: American Planning Association in *Land-Use Regulation Handbook* (NIBS, 1990)

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[10] Clustering of lots can be distinguished from the clustering of units Some zoning regulations permit lot sizes to be reduced from the usual standard to a predetermined minimum. Other regulations allow that attached and detached units be combined. Some ordinances permit the clustering of both lots and units simultaneously.

Typically **clustering** has been used to protect important land resources. Land developed in clusters typically allows the creation of open spaces as an integral part of the development. In terms of earthquake safety, open spaces are extremely important. Within a particular development, open spaces can be reserved for areas susceptible to earthquake hazards in which permanent occupancy is disallowed. In addition during an earthquake disaster, open spaces can provide people with an immediate refuge after an earthquake. Evidence has shown that even in cases where buildings have suffered little damage, the risk of injury is still prevalent after an earthquake due to structures being weakened by the initial earthquake and being susceptible to damage from after-shocks. Also open spaces can be used for helicopter access, emergency vehicle access, buffers between damaged buildings and circulation, public service units, and temporary emergency housing.

In addition to the regulatory process described in this section, Ziony and Kockelman (1985) have found that **awareness campaigns and funding incentives or disincentives** are important techniques for discouraging hazardous development. A range of methods for reducing earthquake losses in potentially hazardous areas including public-information programs, posted warnings, public recording of the hazards, special assessments, tax credits, lenders' policies, public facility service-area policies, and disclosure to real-estate buyers.

Within this framework, **posted warnings** are required by many cities in California and Utah. Salt Lake City has an ordinance which requires that owners must disclose that their buildings can become hazardous in the event of an earthquake. This measure has been taken as a mechanism to pressure owners to retrofit the large stock of privately owned unreinforced masonry buildings located in the highest risk area of the city. In addition, Salt Lake County has issued an ordinance that forces the owner of a parcel susceptible to natural hazards to record a restrictive covenant in terms of the land in a form satisfactory to the county, prior to the approval of any development or subdivision of the parcel. The State of California is in the process of taking steps to require disclosure by sellers of the residential and commercial properties' seismic condition. The city of Palo Alto is already using disclosure of a building's seismically hazardous condition as an incentive for owners to retrofit. The City of West Hollywood has adopted an ordinance that requires that the city records the URM status of a building so that it can be fully disclosed to potential owners before a sale.

Finally, land restrictions can be influenced by public facility service-area policies. Local governments can influence land-use patterns through the allocation of capital facilities. The construction of water, sewer, and road systems, as well as airports, ports, and other amenities can influence the development and use of new sites. The restriction on construction of capital facilities in vulnerable sites can be applied to both, private and public infrastructure.

REGULATING BUILDING CONFIGURATION

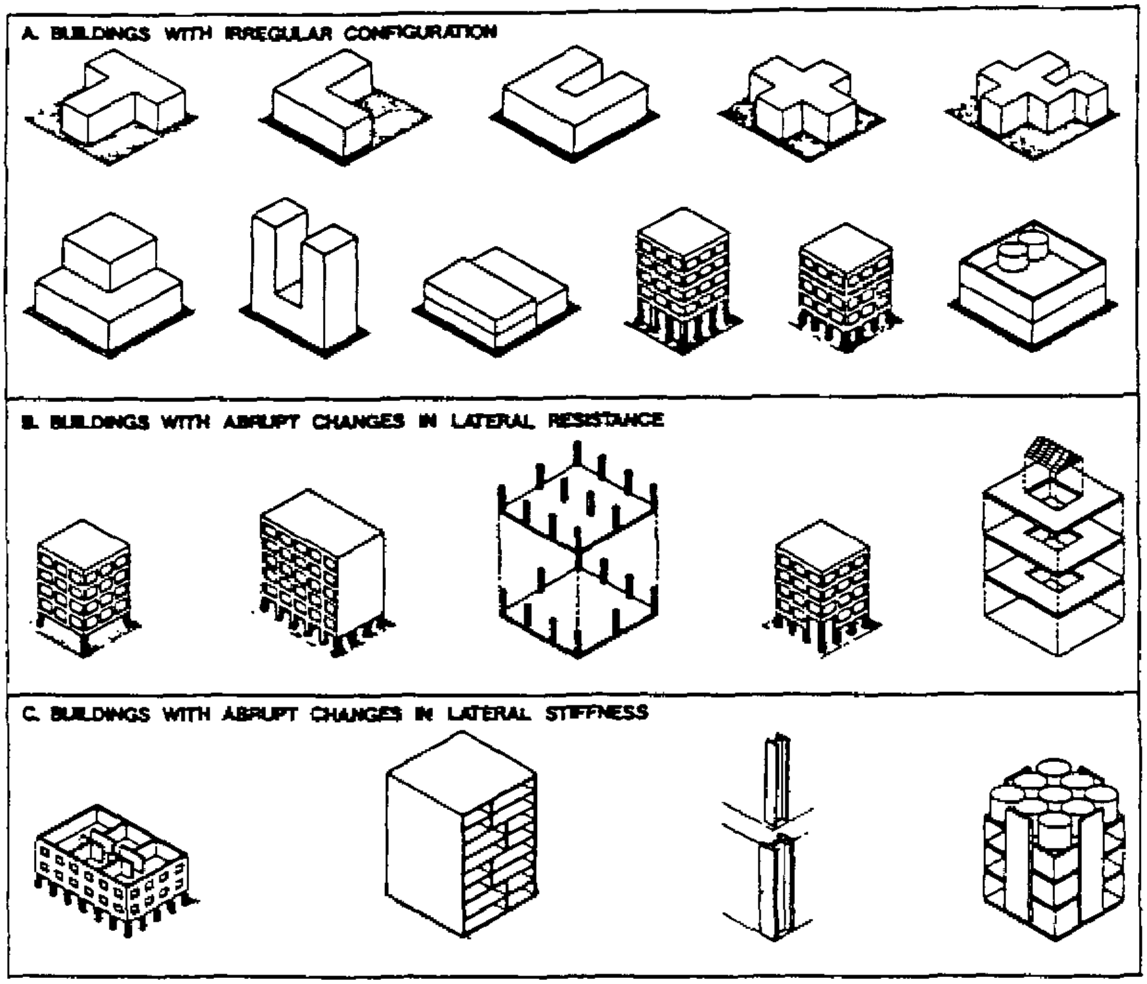
Configuration is defined as building size and shape. Within the urban environment building configuration is almost always determined by the existing site shape and zoning ordinances regarding building height, densities, and setbacks. Because economics dictate recovering the largest amount of square footage within the typically constrained urban site, urban buildings may have a range of configuration influences which determine the performance of the building and adjacent buildings.

Some of the more serious configurations in terms of earthquake performance are reentrant corners, soft stories, variations in strength and stiffness, and variations in support stiffness.

Reentrant corners refer to buildings that are L-,T-, H- and U-shaped. These shapes permit large plan areas to be accommodated in a relatively compact form while still providing a high percentage of perimeter rooms with access to outside light and view. Because of these characteristics, they are commonly used on urban sites especially with hotels and office buildings. These configurations are so common and familiar that the fact that they represent one of the most difficult problem areas in seismic design may seem surprising, but examples of earthquake damage to reentrant corner type buildings is well documented. First noted before the turn of the century, this problem was generally acknowledged by seismic experts of the day in the 1920s.

BUILDING CONFIGURATION TYPES

Exhibit 6



Source: Steve Arnold in *Designing for Earthquakes* (AIA, 1979)

The basic problems concerning these building shapes is that structures following these type of configurations tend to produce variations of rigidity and, hence, differential motions between different portions of the building that result in a local stress concentration at the *notch* or reentrant corner. In addition, the wings of a reentrant corner building often are of different heights so that the vertical discontinuity of a setback in elevation is combined with the horizontal discontinuity of the reentrant corner in plan, resulting in an even more serious problem. The setback form --a highrise tower on a base or a building with steps in elevation-- also has intrinsic seismic problems that are analogous to those of the reentrant corner form. The different parts of the building vibrate during an earthquake at different rates, and where the setbacks occur, a *notch* is created that results in stress concentrations. During the 1985 Mexico City earthquake the high rate of damage to corner structures (42 percent of severely damaged buildings were located on corners) may have resulted from the inadequate performance of buildings with non-symmetrical configuration originating from site constraints[11].

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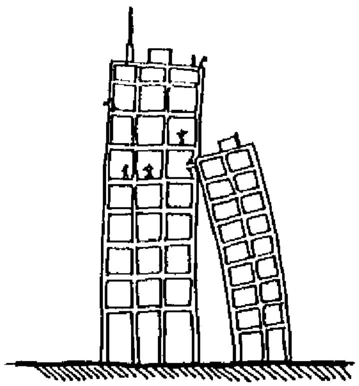
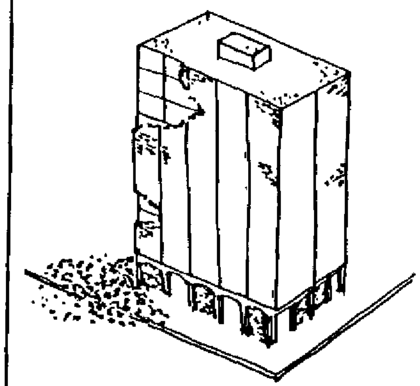
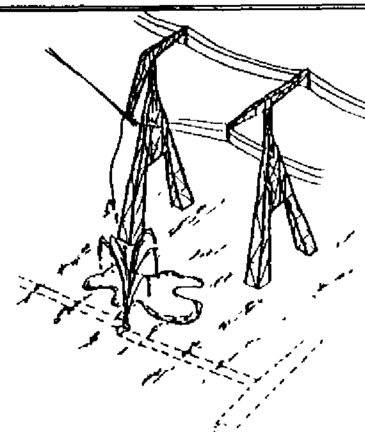
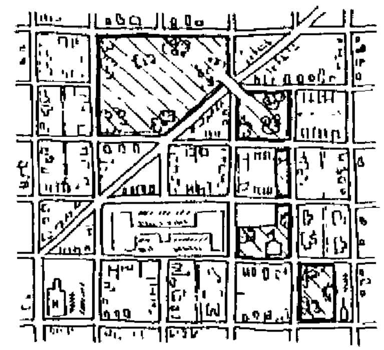
[11] Architectural and Urban Design Lessons from the 1985 Mexico City Earthquake

Exhibit 7

MAJOR URBAN CONCERNS

	POUNDING	CLADDING SEPARATION	LIFELINE DAMAGE	OPEN SPACE USE
GRAPHIC				
DESCRIPTION	Pounding or hammering refers to the phenomenon of adjacent buildings (or parts of the same building) striking each other due to seismic drift (lateral sway). The problem is made worse when buildings (or parts) have different natural frequencies, such as a tall building adjacent to a shorter one. When the floor deck (a stiff horizontal diaphragm) of one building hits an exterior column of an adjacent building, collapse of the second building is likely.	The separation of cladding (exterior non-loadbearing skin) from the building structural frame poses a serious hazard to ground level activities below. Sidewalks and streets become littered hampering rescue efforts and evacuation. The problem is most severe when the natural frequency of the cladding system or material is significantly different from that of the structural frame.	Lifeline systems refer to utility generation and distribution systems (water, electricity, natural gas), communication networks (telephone, radio, television), and transportation facilities. In the case of the latter, some interruption is virtually inevitable in a major earthquake. For example, both pounding and cladding separation result in street-blocking debris. Damage to utility systems is directly related to proximate fault displacements.	Open space refers to public areas such as municipal parks, school grounds, and outdoor recreational facilities. These can play crucial roles during and after an earthquake by providing a place of relative safety. Reports indicate that (weather permitting) displaced people in times of disaster prefer outdoor spaces to government provided shelters. Linked together physically, routes for emergency vehicles can be generated.
MAJOR DOCUMENTED OCCURRENCES	San Francisco 1906 Anchorage 1964 Managua 1972 Mexico City 1985 Whittier Narrows 1987 Philippines 1990	Charleston 1886 San Francisco 1906 Charleston 1959 Anchorage 1964 Managua 1972 Mexico City 1985 Whittier Narrows 1987 Loma Prieta 1989	San Francisco 1906 Japan 1923 San Fernando 1971 Managua 1972 Mexico City 1985 Loma Prieta 1989 Philippines 1990	Charleston 1886 San Francisco 1906 Japan 1923 Mexico City 1985
SUGGESTED MITIGATING IDEAS	Control the spacing of buildings through zoning or environmental regulation Control drift magnitudes by providing increased structural stiffness Align floor decks for new construction	Encourage retrofit of existing curtain wall systems Increase resistance of tie systems (design, size, frequency of fasteners) for new construction Establish minimum setback distances to avoid blocking thoroughfares	Require the use of ductile materials for all pipelines and conduits Increase resistance of water and electric towers, require compression as well as tension bracing Increase resistance of utility poles Increase resistance of "ceramic" towers at electric transmission stations Control the placement of natural gas lines Increase resistance of crucial bridges Increase resistance of transportation terminals Harden potential landslide slopes at crucial roadways Establish plans to maximize the efficient use of helicopters in times of disaster	Increase the number of open spaces, especially in economically disadvantaged neighborhoods Link open spaces together where feasible Provide sanitation facilities Provide adequate drainage Plan for the timely and efficient use of military assistance, food kitchens, etc Provide on-site storage for emergency supplies Maximize use of existing pavilions and shelters

Another problem involving building configuration is the use of soft stories. Soft stories refer to buildings in which one story, generally the first, is significantly lower in strength or stiffness than adjoining floors. This condition can occur in several ways in the urban setting. The use of taller columns in the first floor (a common design style for urban office buildings) results in a more flexible structure and less stiffness at the *soft story* level. The use of a heavy exterior cladding system above an open first floor (a common urban style which allows retail stores with large expanses of glass on the first floor of an office building) results in a similar discrepancy of stiffness. The use of a smaller number of vertical supports at the first floor (another common urban style) which will experience the greatest earthquake forces, results in a relatively weak floor. A particular case of the soft story, which has resulted in serious damage in past earthquakes, is that of the discontinuous shear wall, in which shear walls are omitted at the first floor, generally to achieve planning flexibility at this location. The effect of such soft story designs is to concentrate stress at the second floor column-floor connections, due to the exaggerated deflection of the weaker or more flexible first floor.

In addition, variations in strength and stiffness throughout a building must be taken into consideration. These variations generally occur as a result of different functional requirements around the perimeter of a building. A typical urban solution for mixed use buildings results in facades that vary in an unbalanced fashion from solid to open. A characteristic condition is that of a corner storefront building which may have two adjacent open sides, and two adjacent heavy party walls. This condition creates unbalanced resistance, caused by a lack of symmetry in the location of resistance elements (even though the plan may be rectangular and symmetrical), and consequent severe torsion.

Furthermore, variations in support stiffness or short columns occur when the vertical resistance of the building consists of elements that vary greatly in stiffness. Earthquake forces will be attracted to the stiffer elements, which will be called on to carry a disproportionate share of the loads. This condition is frequently caused by sloping urban sites and the use of heavy infill, nonstructural walls in which columns occur or are created that are significantly shorter than those on adjoining floors or the same floor and, because of their additional stiffness, become overestressed.

The NEHRP Recommended Provisions and the Uniform Building Code have started taking building configuration into account in various ways. Poor configurations from a seismic point are penalized by requiring them to be designed to high earthquake forces, thereby requiring higher degrees of analysis and more expensive design solutions.

The need for ordinances that regulate configuration to a reasonable degree can not be overemphasized. As mentioned before, most research endeavors have concentrated on the development of engineering provision for codes and standards. At present, more inquiry is needed to generate guidelines for both the building configuration and non-structural elements (e.g., cladding, ceilings, partitions, doors/windows, stairs, furnishing and equipment contents, parapets, canopies).

CREATING SPECIAL DISTRICTS

Special districts have been formed in the United Stated since the 18th century. However, not until recently have they been perceived as a tool to improve urban earthquake safety. Particularly in California a substantial number of special districts are being created to respond to long-term earthquake recovery programs. The cities of Santa Rosa and Santa Cruz formed special districts to finance redevelopment programs after major earthquakes (see case studies). Other cities have established special districts to respond to a state law demanding the rehabilitation of unreinforced masonry buildings.

The creation of special districts can take different forms depending on particular local needs. In California, the use of tax increment districts, Mello-Roos community facilities districts, and special assessment districts are widely used for long-term recovery and rehabilitation and retrofitting programs.

Special districts are limited-purpose governmental units that exist as separate corporate entities. States can adopt special legislation to establish special districts or enact general laws authorizing state agencies or local governments to approve the creation of these districts. Special districts are governed by elected or appointed boards that are responsible for fiscal and administrative functions of the district. They are typically, by law, subordinate to a parental governmental unit that represents two or more state or local governments and performs functions that are essentially different and independent from general-purpose governments (i.e., redevelopment agencies). They may be created or dissolved through a number of procedures including petition, public hearing, state action referenda, and court action. Typically they are enacted through a municipal ordinance. (Porter, et. al., 1992)

The central purpose of these districts is to meet diverse collective demands for public service. They are formed to finance infrastructure improvements that support new development. Their popularity is based on the fact that new taxes generated by these districts are based on *benefits-received principles*. These types of taxes tend to have a better acceptance among community members.

Since the 1940s, the number of special districts in the United States have increased from 8,299 to 28,719 while other local units of government remained virtually unchanged. The reason behind this increase is that special districts are presently offering an opportunity to local governments to finance important capital service projects in areas where the administrative capacity of these governmental units is constrained. Special districts are found in every state. Each state has adopted its own approach to the use, type and function of special districts. (ICMA, 1987)

The adoption of financing mechanisms depends primarily on community objectives, revenue potentials, and the levels of risk accepted by the community or private sector. Prior to the adoption of a special district, the city must estimate the amount of money needed to finance public improvements under different funding mechanisms and prepare a general plan. Special taxes, user and indirect fees, assessments and bonds are extensively used for urban improvements in special districts.

In spite of the advantages that special districts give to local governments in the delivery of public services, some planners and policy-makers have opposed the creation of these subordinate units. They argue that special districts can whittle away the powers of local governments and lead to a fragmented, unmanageable and ineffective clutter of governmental units. However, in California a project studied the performance of selective districts created for the provision of sewage plants. The study shows that the governing unit of special districts can provide services, manage, and finance capital expansion projects in a more efficient way than general-purpose units of governments.

The significance of special districts in terms of earthquake safety is important. The major focus of earthquake research has been on individual buildings. For example, after the Long Beach earthquake, the state of California adopted *the Field Act* in 1933 which set guidelines for the design and the construction of public school buildings. In 1971, after the San Fernando earthquake, the state adopted a set of seismic safety elements for hospital buildings. However, buildings do not operate in isolation within the urban system. Buildings, infrastructure, and open spaces are part of a strongly interrelated system which works as a *"knit fabric composed of many interdependent activities, services, and facilities."*[12]

The creation of special districts within urban redevelopment programs can offer the opportunity to consider and adopt comprehensive earthquake safety regulations in already built areas. For instance, the creation of special districts can influence land-use planning and offer innumerable opportunities to adopt codes, regulations, and standards for entire districts. District-wide land-use controls dealing with urban systems,

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[12] Earthquake, An Architect's Guide to Nonstructural Seismic Hazards

configurations of buildings, open spaces, parking, streetscaping, and construction and placement of utilities are analyzed when formalizing the creation of special districts. Most of the land-use recommendations included in this chapter (i.e., building configurations, setbacks for building adjacency and the collapsing of falling building elements during an earthquake) can be studied and adopted during this stage.

In addition, the flexibility that governs most redevelopment units, allows them to expand their development agendas to incorporate earthquake safety provisions as part of their normal redevelopment program. Although limited-purposed government units do not enjoy the power to zone, they can act as subordinate or parental units of local governments, coordinating zoning with governmental planning departments. In California redevelopment agencies (e.g., City of Fullerton in Orange County, California) are establishing general rehabilitation programs within their program agenda as a form to comply with the URM law. Loan bonds, and special taxes are used for the financing of this seismic retrofit program.

Special districts operate beyond general-purpose government boundaries. Through the formation of special districts, local governments are able to combine human and capital resources thus maximizing municipal assets. For example, in inner-cities, a cluster of URMs can transcend the geographical boundaries of local governments. A rehabilitation program intersecting several local government boundaries, can be more efficient in terms of aggregated taxes and issuance of development bonds than, for instance, a single rehabilitation program directed toward individual owners.

USING CONCESSIONARY ORDINANCES

Certain type of ordinances and programs allow local governments to impose earthquake safety regulations by providing certain concessions, benefits, and sanctions to property owners and developers.

The **transfer of development rights** is a concept in which the development rights of a property --in which a community (or state) wishes to limit development-- are separated from the land itself; the development rights can then be sold for use in an area desirable for high-density development. Typically this approach has been promoted as a way to retain farmland, preserve endangered natural environments, protect historic areas, and promote low- and moderate-income housing. (NIBS, 1990)

For undeveloped land, less vulnerable sites can be made available for developers in which less stringent land preparation and construction standards may be required. Also as part of transfer of development rights **density transfers** can be used. Density transfer is the permitting of unused allowable densities in one area to be used in another area. Where it is allowed, the average density over an area would remain constant but would vary internally. Within a single development the result would normally become open space.

In terms of historic buildings, transfer of development rights can be established when repairs are not cost effective. For example, the particular usage of a unreinforced masonry building may not justify an extensive retrofitting program but might be desirable from an historical perspective. The measure is also applicable in historic districts where no demolition or intensification is permitted. In this case, development transfer rights can be allowed at a lot within the same zoning district or adjacent districts where intensification of development is supported.

Although the transfer of development rights is gaining acceptance -- especially throughout the State of California -- in terms of earthquake safety especially for high risk underdeveloped sites and vulnerable historic buildings, its implementation can be controversial.

Another way of promoting benefits from the adoption of earthquake safety measures is through the use of **bonuses or incentive zoning**. Bonuses can increase the willingness of interest groups to adopt certain mitigation measures. Typically, this type of incentive allows developers to exceed limitations --usually height or density restrictions imposed by conventional zoning-- in exchange for certain project amenities or modifications.

For instance, higher structures may be allowed in exchange for the construction of low-income units in projects directed toward middle- and upper-income stratas. A similar concept can be used for earthquake safety. Height limitations can be exceeded in exchange for better adjacency between buildings, adequate building configurations, appropriate setbacks, and the adoption of mitigation measures surpassing those enforced by current codes and standards. Also, density bonuses or other incentives might be provided for proposed developments that effectively avoid hazard areas.

In historical districts where unreinforced masonry buildings contribute to the architectural character of an area, intensity bonuses can allow specific increases in the maximum permissible building density and help to offset the added costs of seismic retrofit. In Palo Alto, California bonus incentives provide that an owner who strengthens a building may add 2,500 square feet or 25 percent of the existing usable floor area -- whichever is greater -- up to a maximum zoning floor area ratio of 3:1, and remain exempt from on-site parking requirements.

A particular type of incentive was granted by the city of Sonoma, California. Through an ordinance the city established a grant as part of a seismic upgrading program. The city grants each owner a reimbursement per building of up to $2.00 per square foot of eligible building area.

The Bay Area Regional Earthquake Preparedness Project (BAYREPP) (1992) suggests that to provide a strong legal foundation for this type of incentive, a community's general plan policies should specifically identify the purposes to be achieved by a density/intensity bonus programs. In other words, plans should directly address the need for seismic improvements.

Another approach that can be used by local governments as an incentive to adopt seismic safety is the use of non-conforming provisions. These provisions are primarily directed at offsetting the added cost associated with retrofitting older structures in inner-cities. For instance, Santa Rosa and Santa Cruz (see case studies) require that unreinforced masonry buildings be brought in compliance with earlier codes than those presently enforced. This approach is widely used by many jurisdiction in the State of California. The intent of such an ordinance is not to assure that unreinforced masonry buildings will withstand a major earthquake but that buildings can resist progressive forces before a sudden total collapse. Typically this type of regulation requires a schedule for upgrading the structure to meet pre-determined seismic standards within a stated period of time.

The adoption of non-conforming ordinances varies from jurisdiction to jurisdiction. For instance, the city of West Hollywood, California, does not require buildings that undergo major rehabilitation to comply with new zoning or land-use requirements. This allows buildings owners to avoid demolishing a building or evicting current tenants because the retrofitted building would not be in compliance with zoning requirements. The City of Fullerton, California adopted a mandatory seismic retrofit ordinance in 1990. The ordinance applies to all buildings constructed prior to 1934. This ordinance does not require alteration of existing electrical, plumbing, mechanical or fire safety systems unless they constitute a hazard to life of property as determined by the building official. (BAYREPP, 1992)

Other approaches are demanding more stringent mitigation measures for the building units but remain more flexible in terms of other zoning requirements. For example, buildings might be required to be brought into compliance with present codes and standards, while the number of parking lots, setbacks, and access routes (all of which cost the owners) do not have to meet existing requirements. The City of West Hollywood, California enacted an ordinance that exempts buildings undergoing major rehabilitation to comply with new zoning and land-use requirements.

The need to promote the seismic rehabilitation and retrofit of older structures in inner-cities can not be overstated. Enforcement of regulations in already developed areas can be more cumbersome than regulations adopted toward new development. For developed areas the major problem lies in the fact that buildings and infrastructure already exist and that any type of alteration dictated by the regulatory process can be costly and difficult to implement. This situation reaches the extreme when large numbers of old unreinforced masonry buildings are concentrated in a particular inner-city. Measures to abate the damage from a particular hazard include the adoption of retrofitting programs; securing and or removing non-structural components, such as parapets and other building appendages; changing occupancy and/or uses to less intensive ones, or demolishing very hazardous structures for which retrofitting programs cannot be cost effective.

REQUIRING GEOLOGICAL INFORMATION

Special studies and geological investigations can be a precondition of project approval for hazardous sites. Many cities require these types of studies and investigations as part of the formal permit and approval process. Their main objective is the identification of a site's geological conditions and recommendations for appropriate development of the proposed site. Many cities (e.g. San Juan Hill Area in Belmont, California and Salt Lake County, Utah) have developed precise standards for geological studies and investigations. An extensive engineering and geological investigation is usually required when preliminary studies indicate an existing and/or potentially hazardous condition. These studies must be conducted by a certified geotechnical engineer. Recommendations might include building setbacks, seismic setbacks, slope stability setbacks, erosion prone area setbacks, and drainage improvements. Local zoning, subdivision and grading ordinances can be required to mitigate the effects of earthquake related hazards. Many times municipal governments retain a geologist to review building permit applications and establish local policies consistent with good engineering and geological practices.

At present, geological and scientific information generated by research endeavors and geological studies are used in the development of natural hazard maps throughout the states of California and Utah. Maps depicting earthquake hazards are a typical way of incorporating earthquake information in local government planning. Zoning ordinances, subdivision regulations, and master plans typically include maps depicting the location and boundaries of different areas and districts. These maps can accommodate information on natural hazards. For instance, land-use regulations can be based on detailed maps showing the distance of existing and proposed buildings from hazardous geological conditions such as earthquake faults. Avoidance or fault hazard easements can be then recommended and enforced. Salt Lake County has developed maps showing detailed geological information within different jurisdictions. When conflicts arise and boundaries and field conditions differ or when detailed investigations show that the mapped hazards are not present, the Salt Lake County Natural Hazard Ordinance requires that technical and geological evidence must be provided to support the claim. Deviations from the mapped boundary lines are only allowed if the evidence conclusively establishes that the natural hazard boundary is incorrect, or that the mapped hazard is not present within a particular area.

In California the preparation of maps including geological data is mandatory. The Alquist-Priolo Special Studies Zones Act was enacted in 1972 by the State of California after the San Fernando earthquake. This act prescribes that major fault zones are to be mapped and that no new structures are to be built astride these faults (San Andreas, Calaveras, Hayward, and San Jacinto).

The process of combining land-use with natural hazard information can vary. Spangle and others (1976) developed a set of guidelines for utilizing earth-science data within general planning maps. Maps adopted by the various levels of governments should be prepared in accordance with the necessary detail to fulfil the specific needs of the different agencies. Typically local level planning requires more detailed data than that needed at the state or national levels.

One of the best sources for obtaining maps depicting earthquake hazards and geological information is the USGS. This federal agency is responsible for carrying out earth sciences research and hazard mapping. As such, it publishes maps depicting faults and evaluates their degree of activity, and compiles and maintains records of historical and recent seismic events. Other sources include the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, U.S. Forest Service and