8th Canadian Conference on Earthquake Engineering / 8ième Conférence canadienne sur le génie paraséismique
Vancouver – 1999

Acceptable Seismic Hazard Risk — Whose Problem?

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INTRODUCTION

The purpose of this paper is to discuss acceptable seismic risk and the stakeholders who have standing in establishing the community preferences in deciding *acceptable seismic risk* in a community. Seismic risk in California is a statewide issue, although the probabilities of major seismic events vary considerably throughout the state. I argue, that total seismic risk is comprised of three components: technological, economic, and societal. So far, the major area of concentration has been to address the technological component. Recent major earthquakes (Loma Prieta, 1989, Northridge, 1994, Kobe, Japan 1995) have demonstrated that the non-structural damage and direct and indirect economic consequences, far exceed the structural damage to physical facilities. The far-reaching societal consequences are yet to be fully assessed, and current loss estimation models are weak in incorporating economic and societal risk components.

I briefly describe the social and cultural base of risk and propose that total seismic risk must have community input. Subsequent to assessing total seismic risk, *acceptable seismic risk* needs to be determined. As a major seismic event causes considerable damage economically and socially to a community as a whole, decision on acceptable risk involves many players at different levels of the society. Acceptable seismic risk varies from community to community and is dependent upon numerous factors specific to a community and its interdependencies. The interactive process in reaching an understanding rather than consensus on acceptable seismic risk is further complicated by the use of language by technical experts, in explaining probabilities. The complex nature of these interactive processes between technical experts and the public, between technical experts and the politicians and between politicians and the public, involving various levels of authority in the government, have led to not debate the issue of acceptable seismic risk. Who has and who should have standing in determining acceptable seismic risk has not been discussed rationally so far.

The acceptable seismic risk is discussed along three dimensions: *ethical and moral, economic value and societal value.* Since my argument rests on the premise that the community must decide acceptable seismic risk, I have identified the stakeholders who might have a say in its decision-making. Reaching an agreement on acceptable risk on a community-wide basis is an exhaustive process in a complex social environment.

This paper attempts to discuss various issues, which impact the decision-making on acceptable seismic risk. The focus of this paper is to identify the stakeholders and discuss the bases for their standing in determining *acceptable seismic risk.* Each stakeholder is discussed in the context of its own organizational structure, its organizational behavior and interdependencies with other organizations. The paper does not discuss the complexities of the intra-organizational decision-making processes. Much of the literature on decision-making focuses on the dynamics of relationships within an organization rather than the inter-organizational decision-making processes (Mujumdar, 1997).

Stakeholders for acceptable seismic risk are identified and divided into six groups: *controllers of financial resources, political decision-makers, physical property owners, lifeline support systems providers, engineering and scientific experts*, and *rescue and relief agencies*

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BACKGROUND

Defining risk is not simple, because its meaning and perceptions are different to different people, organizations and institutions and is dependent upon their utility functions. The meaning of risk is also time dependent and is influenced by culture. For the purposes of this paper, we simply recognize that risk contains uncertainty and has the probability of causing some degree of loss, either to property or life and that the magnitude of risk varies with each situation.

Nature of Seismic Risk

Natural hazards pose a different kind of risk than man made hazards. Natural hazards are thought of as *acts of nature beyond our control* and therefore find more acceptability than manmade hazards. Earthquakes have been long feared as one of the most terrifying phenomena of nature. The magnitude of an earthquake depends on the rate of movement of tectonic plates and degree of interlock between them. Although damaging earthquakes are expected to have long time periods between their occurrence, the frequency of damaging earthquakes in California has increased lately (San Fernando 1971, Whittier 1985, Loma Prieta 1989, Landers 1992, and Northridge 1994). The focus of this study is major earthquakes, those with a magnitude of 7.0 or higher on the Richter scale.

SOCIAL AND CULTURAL THEORIES OF RISK

Since the form of definition of risk is broad and the perception of risk by the public is socially and culturally based, which plays a significant part in its definition, many researchers have argued that risk is a social and cultural construct. Renn (1992) notes, that people determine character and magnitude of risks after having filtered the information received from family, friends and coworkers. Covello and Johnson (1987) argue that risks are exaggerated or minimized according to the social, cultural and moral acceptability of the underlying activities. Douglas and Wildavsky in their original work on selection of risk by the public point out, that societal selection of risk is a function of social and cultural values, rather than scientific evidence. They further argue that these values also determine risk agendas selectively for attention, e.g. certain risks are discussed soon after an event causing a significant loss has occurred, because the pressures from social criticism demand such actions. The Field Act, requiring school facilities to perform to a higher safety standard, was enacted within a month of the 1933 Long Beach earthquake where many school facilities were seriously damaged.

That the social influences shape the behavior of individuals and their response to risk, has been demonstrated by Renn, Thompson and Wildavsky (1992). They have identified four types of cultural behavioral patterns including competitive individualists, egalitarians, bureaucrats, and stratifieds. It is important to understand these patterns as they influence the acceptable risk determination.

TOTAL SEISMIC RISK

Total risk is comprised of technological, economic and societal components. These components are interdependent and together impact the extent of damages and costs associated with the damages. The costs associated with each, component contributes to the total cost of damages. I will not discuss in this paper various factors in the three components of risk, but they include direct and indirect economic effects and societal costs in addition to technological costs.

Based on the delineation of various factors that go into estimating total cost due to a major earthquake event, we need to make the loss estimation model usable by assessing total cost in quantifiable terms.

One could argue that if all the existing buildings, physical facilities, utilities, and infrastructure were retrofitted to the latest seismic codes, then the damage potential would be virtually eliminated by removing the risk. The cost of such endeavor would represent a one time total expense. Theoretically the argument is powerful. However, in reality the cost to retrofit all facilities may be judged unacceptably large, impractical and socially disruptive and therefore does not present a viable option to citizens or decision-makers (Tierney and Nigg, 1993).

Therefore, I present the concept of **'Acceptable Risk'** to a community. Acceptable risk is defined here as the amount of risk that is voluntarily accepted by an individual, a family, a group, community or society based upon considerations of ethical, economic, technological, social and political aspects.

To determine acceptable risk, we need to know and rank-order the preferences of the stakeholders. Once the preferences are rank ordered, appropriate weight needs to be attached to each preference. The weighted combination of the three components of risk: technological, economic, and societal will determine the acceptable risk for a particular community.

STAKEHOLDERS

The six groups of stakeholders cannot be neatly separated as they are interrelated and actions undertaken by one group impact other groups. That is precisely the reason why input is required from all the six groups to formulate acceptable seismic risk. Although the groups are interrelated, they are discussed here individually for clarity.

Six groups of stakeholders are: *controllers of financial resources, political decision-makers, physical property owners, lifeline support systems providers, rescue and relief agencies, and engineering and scientific experts.* Each group is discussed along three dimensions: Organizational structure, behavior, and interdependencies with other organizations.

CONTROLLERS OF FINANCIAL RESOURCES

Financial resources are controlled by three distinct entities: Government, private industry, and financial institutions. Government controls public expenditures and private industry controls resources within their organizations. Financial institutions are lenders to the private industry and have virtually unlimited financial capacity as they can collaborate internationally if required, to mobilize additional financial resources. Homeowners are limited to protection of their assets and concerns about immediate family members and as such they are not considered as controllers of financial resources.

Government

Government expenditures operate at state and local levels. At the state level, the legislators control the allocations of resources in their annual budgetary process. Allocation of revenues for seismic mitigation purposes has to be judged along with priorities for numerous other programs. Unless the statewide constituency or special interest groups demand, there is little incentive to vote for allocation of significant revenues for seismic retrofit purposes. Since the governor has to ultimately approve and sign the budget, the governor can also influence allocation of resources for seismic mitigation.

One of the main responsibilities of the state government is to assist communities in the recovery effort after a major earthquake event. Since resources are limited, and the recovery efforts are expensive, the government needs to concentrate on assessing *acceptable seismic risk* and invest in mitigation effort ex-ante. The interdependencies of the government are minimal. It is the ethical and moral responsibility of the legislature and the executive branch to address issues of societal importance for the good of the public at large and go beyond the election dominated actions.

Private Industry

The private industry is a large and complex conglomeration of various interests. The members range from large businesses to very small businesses, and from heavy manufacturing industries to high technology service industries. It is not possible to discuss private industry as a unit. However, there is an underlying common feature to their organizational behavior that stems from a singular consequence, i.e. "*impact on the business*" due to a major seismic event. The impact varies with the size and location of business, type of business and type and range of products or services.

Some small businesses may suffer damage so extensively, that it becomes impossible for them to continue business afterwards, as their assets are wiped out and their ability to restart is limited. (Eguchi, 1997). Large businesses are interested in limiting the amount of time they would remain inoperable, and limiting the physical damage to their real property assets, business assets and inventories. If the product of a firm depends on businesses outside the impacted area for inputs and outputs, the effects of such externalities need to be taken into account, e.g. the 1995 Kobe, Japan, earthquake impacted business owners in the United States, as many U.S. companies had production operations in the city of Kobe. The effects of the Kobe earthquake went well beyond the impacted area.

The interdependencies of large businesses are government agencies, and suppliers and vendors. The indirect interdependency is with the consumer. Small businesses are interdependent with consumers and with suppliers. The *impact on the business* is ultimately a financial concern and all actions emerge from that concern. Large business operations can transfer the risk by purchasing insurance, but smaller businesses may not be able to afford the insurance premiums to cover all of their losses and therefore bear the risk of the major part of the damage. Since the concerns of the private industry cannot be heard through a single voice, it is extremely difficult to determine who's standing should count.

Perhaps a dual approach is necessary. Small businesses should be housed in seismically retrofitted structures as serious damage to these structures, impacts their business significantly. This needs to be achieved through regulations. The impact on larger businesses results not only from disruptions to their own operations but the consequent impact on the community. The opinion of large businesses in the community towards acceptable risk should be counted. Aggregation of small businesses in the community should be made and overall impact on the small business community in relation to the large businesses should be considered in counting the standing of small businesses.

Financial Institutions

Financial institutions operate in a competitive market environment. Their business is to lend money and derive returns on their loans. Large financial institutions can absorb more financial risk due to their large and diversified asset base. Smaller financial institutions on the other hand tend to be local and more conservative. They also take pride in being recognized as part of the community and are likely to develop close relations with business owners. Their lending practices tend to be based on trust and relationships in addition to the ability to borrow. Previous experience of repayment of loans with the business owner is important in determining future lending. For physical property improvement, the loans are secured by collateral of the property. It is therefore in the interest of the lender that there be minimal damage to the structure housing the business.

In California currently, it is not unusual for a lending institution to ask for a probable maximum loss report by an expert, before loans are committed. If the loan is for business operations or for building inventories, continuation of the business after a major seismic event is even more important. Financial institutions do have standing in determining acceptable risk. The insurance industry has a dual function, on one hand they are financial institutions because of their activity in lending money, and on the other hand they are like private industry in trying to protect their assets.

The opinions of the controllers of financial resources are important and must be considered. Business owners and the homeowners are impacted directly in major earthquakes and therefore their opinions need also to be taken into account.

POLITICAL DECISION MAKERS

This group of actors comprises of executive branch represented by political appointees as administrators, legislators, local government, and the federal government.

The discussion in this section is focused on political action rather than control of financial resources. The motivation for these actors to act is *"self interest rightly understood"*, as stated by Tocqueville in the nineteenth century.

Since the interdependencies of legislators are electorate and the executive branch, the decision-making process for seismic risk is based on the theory of exchange. According to this theory, an exchange takes place only when parties to the exchange perceive that they have benefited by exchange. When rewards exceed the costs by at least a minimum level of expectation, exchange takes place (Kelly, 1980).

Federal government under the disaster emergency plan bails out the local and state governments after a major disastrous event. This assistance has created a benevolent exchange where only the recipient benefits. The Federal government has realized, that the cost of assistance has grown dramatically in recent years (PEER, 1998). Recently the Federal Emergency Management Agency (FEMA) has undertaken a strategy to redefine the seismic risk as a responsibility to be borne by all those involved and impacted by it. A public/private partnership concept (FEMA, 1997) is being promoted.

All participants, who have political decision making authority and responsibility, need to act with a common notion approach. We need to develop a "common goods" approach, wherein the individual good is inextricable bound up with the community good as a whole (EERI, 1997). There needs to be a cooperative behavior and a common platform for a plan of action. Arguably, when the number of actors is large, when information on participants is lacking and when there is no repetition of interactive actions, cooperation is difficult to sustain (North, 1996).

To account for the standing of this group, economic capacity of a community which partly depends upon government assistance should be taken into account, bigger the capacity to absorb seismic risk, bigger the acceptable seismic risk for that community. Political decisions could be based on a 'community specific' needs.

PHYSICAL PROPERTY OWNERS

The focus here is the group of people who are physical property owners. The homeowners are not considered under this group. These are investors in physical properties, including business real property. This group is important because physical property represents a significant portion of assets of a community. Revenues for a community are also generated as 'property tax' from these properties. Perhaps more importantly, severe damage to properties will result in economic dislocations beyond the immediate damage aspect, due to in-operability of businesses, temporary housing for renters and lack of income for those who work in the buildings affected by an earthquake event.

Behavior of these investors varies with the size, the location, the type of property and the remaining economic life of the property under consideration. This group has very little interdependency with others for decision-making purposes. The utility function of each owner is different, as owners attach different weights to different property specific variables. How can these diverse utility functions be aggregated? Perhaps one way to aggregate the risk that the community may be faced with, is to determine the non-insured part of the assets. Aggregation of these amounts will indicate total acceptable risk by this group in a community.

LIFE LINE SUPPORT SYSTEMS PROVIDERS

This category of stakeholders includes utility companies providing services in water, waste water, gas & electricity, communications and the transportation network. This group represents a combination of private utility providers and public entities responsible for transportation network. Because the privately owned utility companies are regulated by government agencies, their structure and hierarchy of decision making tends to be similar to those in the public sector. However, the two operate under different sets of rules regulations and policies.

Most utility companies are not locally owned and usually service a wide geographical area, however, their distribution network in a community may be locally owned, particularly in case of water systems. A community may be adversely impacted due to inoperable utilities, even though the earthquake effects may not be locally felt, because of damage to the transmission network at some distant location from the affected community. Similar situations exist in the case of transportation network. The state highways are under the transportation department control, but the operations and maintenance of local roads is left to cities and counties. The surface inaccessibility could result from damage to the network anywhere along its various routes.

The interdependence of utility providers and transportation system providers is heavy at various levels of government. The acceptable seismic risk has two components in this case. *First*, the amount of risk these providers can absorb and *second*, the amount of risk a community should accept due to in-operability of these systems. The first one is decided by each provider and the community does not exert much influence on that decision. However, the decisions taken by these providers impact the economic and social life of a community. The tolerable level of service interruptions ought to be determined in a community through public information and debate, in conjunction with the providers of these services.

ENGINEERING AND SCIENTIFIC EXPERTS COMMUNITY

Engineers and scientists have been studying the problem of earthquake risk for quite some time. Through laboratory research and observations of actual behavior of buildings and other structural systems in major earthquake events, considerable advances have been made in understanding the technological component of seismic risk. The laboratory research though is concentrated primarily in the technical disciplines. A systematic study of economic risk is yet to be undertaken. At the present, the economic risk is quantified as a direct consequence of technological risk and is limited primarily to physical structures. The society in general, public policy makers and business owners in particular, depend on the engineering and scientific experts to determine seismic risk and to write regulatory provisions in the model codes to mitigate the risk.

From an organizational perspective, engineers and scientists operate as individual technical experts. Although some professional associations like Earthquake Engineering Research Institute (EERI) and Structural Engineers Association of California (SEAOC) are engaged in promoting seismic safety, the seismic engineering discipline is practiced on an individual technical expertise basis.

The behavioral aspect is primarily related to satisfying the needs of clients and giving them expert technical advice. Due to the individualistic professional nature of the discipline many different opinions exist on seismic risk, although technical disagreements are hammered out in meetings of the professional bodies. The interdependencies are limited to client-professional relationship and the interaction of the professionals with professional associations.

Engineers and scientists have considerable standing in defining seismic risk. At present they have defined seismic risk as "life safety". In engineering definition "life safety" means, that during the most probable major seismic event, the structure will perform adequately for occupants to exit safely. The life safety concept is not related to the building damage and recognizes that although the structure may be damaged significantly, it will remain standing. Lately, efforts have been made to define the structural performance objectives different than life safety (SEAOC, 1994). The concept is, that based upon the requirements by the owner, a structure can be designed to meet the desired level of performance objective. The concept is powerful, but has problems in real life applications.

From a community viewpoint, engineers and scientists should be called upon to estimate the probable damage levels to various structures and consequent costs associated with the repair or replacement, but the acceptable magnitude of damage ought to be left to the community. Engineers and scientists have considerable standing in determining technological component of the risk.

RESCUE AND RELIEF AGENCIES

This group of actors comes into play after a major seismic event occurs. They are, thus not involved in determining the acceptable seismic risk, but suffer from the consequences of acceptable seismic risk as determined by others. Although it would appear that greater the acceptable risk the lesser the demand on rescue and relief agencies, quite the contrary is the case. Because property owners and the community as a whole are prepared to accept larger risk, a greater degree of damage to the facilities and a greater overall impact on the community ensue. The demand on rescue and relief agencies therefore, increases.

The organizational behavior of these agencies is driven by the ethical and moral considerations and dedication to help others in need. Many of the workers are volunteers. Some of these relief agencies are supported financially by the state or federal government. Their interdependencies are with other relief agencies to co-ordinate the efforts and with government agencies that provide funding. Those who receive funding from the government tend to restrict their rescue and relief efforts due to constraints associated with the grant or the amount available for relief and rescue operations.

Other groups that are involved in these operations are: police and fire services, and medical facilities. However, since fire and police services are usually a part of the local government, they are not discussed separately. Their mission is to provide the services within their capacity, irrespective of immediate cost. The cooperative arrangements with other fire service agencies and the police departments are also common, boosting their service capacity.

Medical facilities though deserve a separate discussion. The majority of these facilities are privately owned. They behave as immediate caretakers, but eventually collect a fee for their services. The overall capacity of medical facilities to service the injured is important. By law, they are designed to a higher safety standard and are expected to be in service during a seismic event. Their input is important in establishing the serviceability capability.

Although the rescue and relief agencies play a major role ex-post the event, their standing in determining acceptable seismic risk is weak and is not likely to be considered with any seriousness.

FEDERAL GOVERNMENT

The agency, which is responsible for determining seismic policy at the federal level, is FEMA. This body influences policy decisions in two distinct ways: generating 'building code type' documents and providing financial assistance after a major seismic event, e.g. after the 1994 Northridge earthquake in California, FEMA provided nearly $12 b. funding to various owners (EERI,1997).

The body, which creates "building code type" documents, is comprised of nationwide seismic experts and is called Building Seismic Safety Council (BSSC). Documents prepared by this body influence building codes in the nation. Thus, acceptable performance of structures is addressed indirectly, influencing the technological component of risk.

Because FEMA provides direct funding after a declared major disaster, acceptable risk by the communities is also directly influenced. The more the funding given by FEMA, the lesser is the acceptable risk by a community. Recently, however, FEMA has reformulated its disaster assistance strategy. It is promoting the concepts of public/private partnership and incentives, so that the financial exposure of FEMA is reduced. Communities would have to bear more risk in future major events, as less funding for assistance will be available from FEMA. Federal government thus influences the acceptable seismic risk indirectly through its funding mechanism.

ACCEPTABLE SEISMIC RISK - DISCUSSION

I have identified the stakeholders and the standing they have in different components of acceptable risk. How should these standings be accounted? It is clear that the motivation for each group of stakeholders is different and ranges from economic to political to technological aspects. It is not possible to propose a uniform method to combine these disparate weightings. I have attempted in Table 1 to describe the relative impact of each group on the three components of risk. The extent of impact (weight) is defined in qualitative rather than quantitative terms. Table 1 allows us to identify the importance of standing of different groups, when attempting to define acceptable risk.

I propose, that the acceptable risk be further discussed along ethical/moral, economic value, and societal value dimensions, as not all decisions related to acceptable risk can be made with economic rationality only.

Table 1: IMPACT OF STAKEHOLDERS ON RISK COMPONENTS

Stakeholder	Technological	Economic	Societal
Controllers of Financial Resources	Weak	Strong	Strong to Modest
Political Decision Makers	Modest	Modest	Strong
Physical Property Owners	Modest	Strong	Weak
Lifeline Support System Providers	Modest	Modest to Strong	Modest
Engineering and Scientific Experts	Strong	Modest	Weak
Rescue and Relief Agencies	Weak	Weak	Modest

<u>Ethical / Moral</u>

Certain aspects within a community can be described and hopefully agreed by the majority as moral/ethical obligations, e.g. taking care of children, elderly and the sick. Such issues cannot be rationally discussed along economic value dimension only. It is also the responsibility of the local and state governments to enact laws and regulations to effect actions within a community. As a civil society, it is our obligation to take care of certain sections of the population, facilities, and support structure. This obligation goes beyond the norms of economic rationale. I consider these to be ethical/moral values of a civil society.

In a community we need to identify the aspects which need to be addressed on moral/ethical grounds. A list of critical facilities and infrastructure must be made. To protect these facilities in a major seismic event, provisions must be made by enacting laws, creating an implementation structure and monitoring the actions. Such critical facilities could include housing for the elderly, community nursing care facilities, childcare centers, and schools and hospitals, to name a few.

Since there is no economic incentive to have the critical facilities remain functional during a major seismic event, the best course of action is enacting regulations. These regulations must go beyond the normal structural safety aspects and need to address non-structural components, building contents, and utility support systems. It is important that these facilities remain functional during an earthquake, because of their critical nature.

<u>Economic Value</u>

Almost everything in a community can be deemed to have an economic value. The list includes physical property, building contents, infrastructure, business losses etc. I have discussed at length, various stakeholders who would be impacted during a major seismic event. The acceptable risk depends upon who owns what, economic value and the tolerable levels of in-operability of the lifeline support systems.

In the case of homeowners, a certain minimum level of structural safety should be provided in the building codes. In case of other physical property owners, the acceptable risk to them is the deductible amount in the insurance policy. In the case of financial institutions the acceptable risk may be zero, because they would want insurance to protect their investment.

From the lifeline support system providers like utilities, the acceptable risk to the community would be the economic cost due to the unavailability of their services for a limited period of time. Similarly for the transportation network, it is the acceptable inoperable time, which is of importance to a community.

Societal Value

Certain aspects and features of a community cannot be quantified in economic terms, e.g. a beautiful coastline, historic structures that are not replaceable etc. How should these be protected in a major seismic event? How many deaths and serious injuries are acceptable? These are complex and difficult issues to debate and resolve. However, such aspects of societal value need to be addressed and a debate within a community needs to occur and decisions by the majority need to be taken. Different communities may decide to put different values on aspects of a similar nature. The decisions, although different in different communities, determines the extent of societal value that is important for the majority. There is no reason to universalize the issue. What is acceptable to the community should be taken as the community value.

A list of those items which have societal value to the community needs to be made, a debate in the community needs to be held and a majority decision needs to be taken. From these decisions, an economic cost to preserve certain aspects may be decided based upon ethical/moral consideration.

RESOURCE CAPACITY OF A COMMUNITY

After the acceptable seismic risk is determined, the cost to bear that risk has to be weighed against the resource capacity of a community. Acceptable seismic risk is an independent as well as a dependent variable and therefore difficult to establish without an iterative process. The resource capacity of a community has two dimensions: *financial and human resources*. The total capacity is a combination of the two.

Since the focus of this paper is to determine the standing of shareholders, the resource capacity aspect is not expanded further except to emphasize that the resource capacity aspect will impact the acceptable risk decision and vice versa.

SUMMARY AND CONCLUSIONS

Total seismic risk is defined as comprising of three components: technological, economic, and societal. Current models on loss estimation due to a major seismic event focus primarily on technological and economic consequences arising out of technological weaknesses. They are weak in considering indirect economic effects or societal effects.

Beyond the concept of total seismic risk, a concept of acceptable seismic risk is presented. However, the issue of acceptable seismic risk is not universalized. It is proposed that acceptable seismic risk should be based on community by community considering the particular characteristics of that community and should be discussed along ethical/moral, economic value and societal value dimensions.

To determine acceptable seismic risk, we need to identify the actors who are stakeholders and consider the importance of their standing. Decisions about acceptable seismic risk policy should go beyond an economic analysis, based upon the potential Pareto optimality principle. Policy analysts must develop a dialogue with other professions and the public to consider ethical grounds and distribution effects to develop policy recommendations.

Finally, acceptable risk as an independent variable and as a dependent variable will have to be assessed against the resource capacity of a community. Based upon the resource capacity, acceptable risk may have to be be modified through an iterative process. A general framework of total seismic risk, acceptable risk and the stakeholders, who have standing on different components of risk, has been presented.

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