# EVALUATION OF SEISMIC RISK THROUGH TOTAL ACCEPTABLE COST MODEL

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## SUMMARY

In summary, it is important that all three components, i.e. technological, economic, and societal be considered to determine total risk and therefore the total acceptable cost based upon total risk.

Once total acceptable cost is assessed, the community needs to decide what is acceptable and what it is capable of sustaining. Such decisions are best taken by stakeholders in the community. Selection of stakeholders is guided by their area of expertise and impact of their opinion in at least two areas of importance. While technological and economic data can be assessed quantitatively, qualitative statements for societal risk are converted into quantitative data using analytic hierarchy process model.

Finally, the quantitative data from all three components of seismic risk is added which represents an index of total acceptable cost.

## INTRODUCTION

The purpose of this paper is to present a total acceptable cost model for seismic risk evaluation. Total cost is comprised of technological, economic and societal components. Current seismic loss estimation models do not account for total loss (cost) assessments due to a major seismic event.

A community faces many types of risks. Some are man-made, while others result from natural hazards. To reduce the overall cost of a particular hazard risk, one needs to account for all components of the total risk and develop methodologies to evaluate them.

Major seismic events have a low probability of occurrence, but result in high consequences. Due to the low probability nature of seismic events, their effects are generally measured by immediate losses to physical facilities and infrastructure, which leaves a gap in overall loss assessment.

The determination of seismic risk is technologically driven which is then incorporated into building codes. The building codes are written primarily for new buildings and very little guidance is available for retrofitting existing buildings and facilities. The biggest potential loss is faced by the inherent risks in existing structures and infrastructure and the direct and indirect effects on the community in general.

In the current socio-economic environment, designing for only life safety is not a sufficient, overall risk assessment must extend to business interruptions, economic losses, disruption of social systems and long term effects on the community

The total cost a particular community can bear as a consequence of a major seismic hazard depends on the economic capacity and composition of the community. The community should decide acceptable risk (cost) after considering the experts' opinions and rank ordering of various risks by stakeholders in the community. Qualification of opinions can be achieved through an analytical hierarchy process.

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Without taking community preferences into account, total acceptable cost cannot be dictated by technical experts. A total acceptable cost model approach is presented in the paper. SOCIAL & ECONOMIC ISSUES:

## CONTROLLERS OF FINANCIAL RESOURCESCONTROLLERS OF FINANCIAL RESOURCESINTRODUCTION

This paper discusses the concept of total acceptable cost to a community as a result of a major seismic event. The magnitude and probability of a natural hazard such as a major seismic event are dependent on geologic conditions and cannot be controlled by human beings. On the other hand man-made hazards by their very nature are created by human beings and as such their probability and magnitude are controllable.

Although natural hazard occurrence is not in the hands of human beings, the response to the risk posed by such a hazard is controllable by human beings. Such a response determines the magnitude of risk and its effects. Risk thus is an independent as well as a dependent variable. Risk becomes a dependent variable because its magnitude varies with the response provided by a community to a hazard.

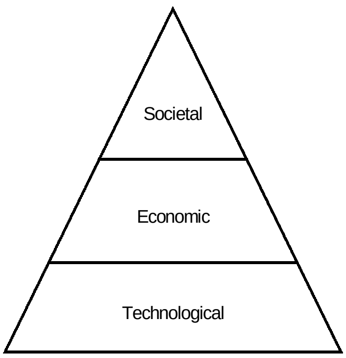
The basic premise in this paper is that a community is responsible to decide the response to a seismic risk based upon its capability to deal with the hazard. A community is thus responsible to determine the total cost of damages due to a hazard.

## TOTAL COST

It is proposed that the total cost of damages due to a major seismic event should comprise of three components: Technological; Economic; and, Societal.

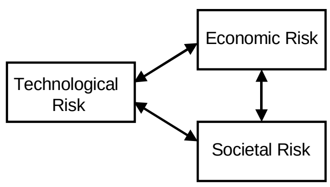
Currently, risk analysis and cost of damages consider primarily the technological component and resulting economic costs. The indirect and long-term economic costs are poorly accounted for and societal costs, direct and indirect, are ignored in current loss estimation models. It is not that the total cost including all three components is not understood properly but rather is a result of how seismic risk is perceived. Seismic risk is currently dominated by considerations of technical risk. Because of this dominance other risk components, i.e. economic and societal are de-emphasised. One of the difficulties in incorporating these other components is lack of data and lack of quantification methods. However, unless the three risk components are considered in the damage model, total damage estimate is incomplete.

Total risk components and their interdependencies are shown in Figures 1 and 2.




Components of Total Seismic Risk

Figure 1



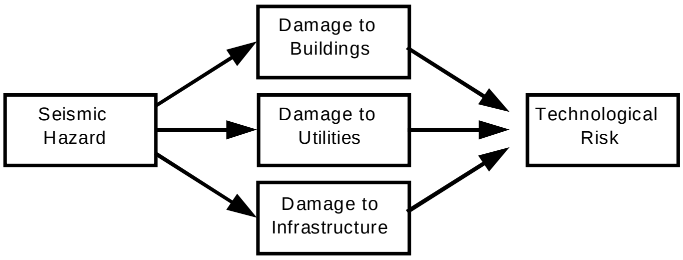

Interdependence of Risk Components

Figure 2

### Technological Risk

Technological risks arise out of three areas: *buildings, utilities, and infrastructure*. When the physical structures are incapable of withstanding seismic forces without major damage, technological risk is deemed to be present.

In buildings, the damage may result in partial or total failure of structures with significant repair costs and potential life safety hazards. In utilities, damage may result in breakage of pipelines or dislocation of utilities, causing gas, water, or electricity services to be disrupted. Similarly, in infrastructure, roads, bridges and other transportation structures may be damaged rendering the infrastructure unusable. Figure 3 shows the composition of technological risk graphically.




Technological Risk

Figure 3

The probability of the magnitude of damage to a particular physical structure can be calculated once the structural characteristics, the site characteristics and the magnitude of the hazard causing the damage are known.

It is possible to assess with reasonable accuracy, the technological component of total risk under a given seismic event scenario because sufficient knowledge now exists in this field.

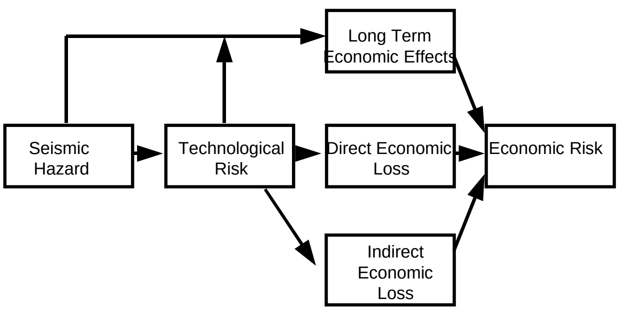
**Economic Risk**

This component of total risk is partly dependent on the technological risk component. The bigger the technological risk the bigger the economic risk. However, total economic impact goes beyond damage to physical facilities and infrastructure. Losses due to business interruptions and the indirect effects on the economy of the community need to be accounted for to determine overall economic impact.

Economic risk, in current loss estimation models is quantified as a direct consequence of technological risk and is limited primarily to damage to physical structures.

A business owner can estimate the magnitude of potential economic loss due to interruption of a limited duration to his business. Such individual business losses within a community can then be aggregated. This aggregation would provide an estimate of the direct economic impact on the community due to business interruptions.

Indirect economic effects are difficult to quantify. Repairing and rebuilding infrastructure and utilities require a massive infusion of capital; this may create an unacceptable debt burden on the community. Economic effects from such occurrences fall into the indirect economic category. Services, which cannot be provided due to damages to utilities and infrastructure, cannot be quantified accurately due to the many uncertainties that need to be taken into account. Figure 4 depicts different components of economic risk.




Economic Risk

Figure 4

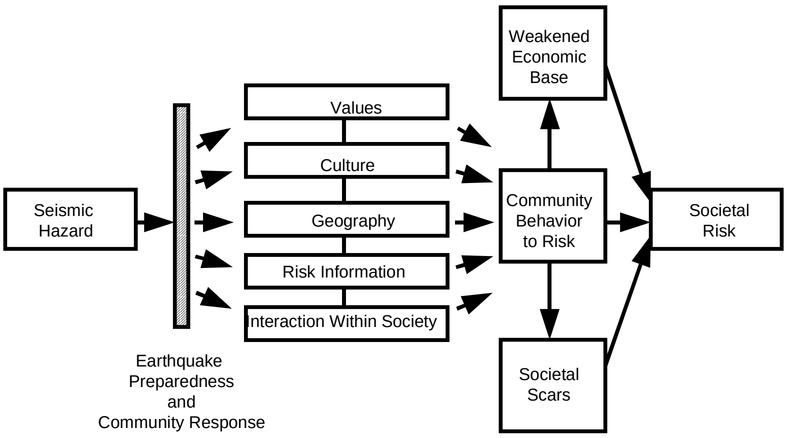
Currently available loss estimation models do not have the ability to quantify long term economic losses to a community (King ET al, 1997).

A systematic study of economic risk has yet to be undertaken.

**Societal Risk**

This risk component is more widespread and of greater magnitude than the technological and economic components and is extremely difficult to quantify (Tierney and Nigg, 1993). Societal risk has multiple dimensions: *values, culture, geography, risk information, and interaction with other members of the society*. Community response and earthquake preparedness also influences the magnitude of risk to a community. Societal risk includes the reduced ability to attract future businesses and citizens, and a weakened economic base. Societal scars left on the community due to the inability of a local government to provide needed services after a major seismic event, and the impact of personal tragedies and traumas on the long term health of citizens are also a part of societal risk component.

Societal risk also depends on the composition of a community; *i.e.* whether a community is comprised of younger families or retirees, a bedroom community or a vibrant business community etc. Figure 5 shows various aspects of societal risk.




Societal Risk

Figure 5

Each community will respond differently to a major seismic event and therefore the societal risk for each community will be different. Unless the societal risk component is integrated into the overall damage evaluation, total seismic risk assessment is not complete.

**Challenges**

One of the primary difficulties in incorporating societal component and indirect economic component is the inherent lack of quantification of data. If these components cannot be quantified readily, they cannot be accounted for in the overall cost model.

Another challenge presented in determining societal components is who should decide this component of risk? Who speaks for the community and how can the diverse opinions of various stakeholders in the community be aggregated?

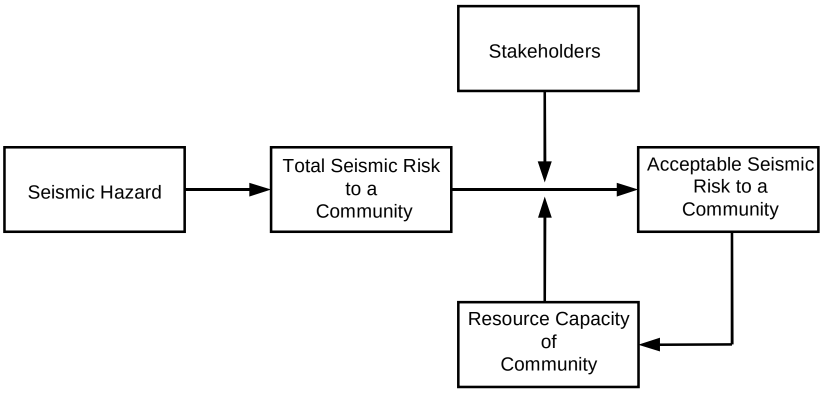
**Acceptable Risk**

Since the basic premise of this paper is that risk is a social and cultural construct, it is necessary to have community input in determining an acceptable level of risk. Although the magnitude and probability of occurrence of a natural hazard such as seismic event cannot be controlled by human beings, responses to mitigate the effects of hazard are controllable.

Since acceptable risk leads naturally to ask Questions such as: Acceptable to whom? and, What is the criteria for acceptance? The following definition of acceptable risk is proposed.

> *Acceptable risk is defined here as that amount of risk, which could be estimated and voluntarily accepted by an individual, a family, a group, a business, a community or society based upon economic, technological, social and political considerations.*

Total acceptable cost to a community is a proxy for acceptable risk. To determine acceptable risk in a community, we need to seek he expert opinion of stakeholders in the community. How should the stakeholders be selected. How should their opinions be weighted? These are difficult questions to answer. In this paper, a methodology is proposed and proposed model for total acceptable cost is shown in Figure 6.




Acceptable Risk Decision Process Model

Figure 6

**Methodology & Proposed Model**

Seven stakeholders and six criteria are identified. Categories of stakeholders may vary from community to community depending upon its composition.

To be a stakeholder, one must score “high” in one of the categories and “medium” in at least one other category. Depending upon the strength of the expert opinion in a particular category, stakeholders’ opinions are weighted.

To convert the qualitative opinions into a quantitative useable date, Analytical Hierarchy Process (AHP) is proposed.

REGULATORY AGENCIESTo overcome the challenges a methodology to select stakeholders is presented in Table 1.

**Table 1: DECISION TABLE FOR STAKEHOLDER SELECTION**

| CRITERIA | STAKEHOLDERS | | | | | | |
|---|---|---|---|---|---|---|---|
| | CONTROLLERS OF FINANCIAL RESOURCES | POLITICAL DECISION MAKERS | REGULATOR Y AGENCIES | PHYSICAL PROPERTY OWNERS | LIFELINE SUPPORT SYSTEM PROVIDER S | ENGINEERING AND SCIENTIFIC EXPERTS | RESCUE & RELIEF AGENCI ES |
| **Control of Community Infrastructure** | ***Low*** | ***High*** | ***Medium*** | ***Low*** | ***High*** | ***Low*** | ***Medium*** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Financial & Non-Financial Ability** | High | Medium | Low | Medium | Medium | Medium | High |
| **Physical Property Control** | ***Medium*** | Low | Low | High | Medium | Low | Low |
| **Expertise in Damage Assessment** | Low | Low | Medium | Low | High | High | Medium |
| **Control of Community Economic Base** | High | High | Low | Medium | Medium | Low | Low |
| **Protection of Societal Interests** | Low | High | High | Medium | High | Medium | High |

Costs due to technological risk component should be assessed with expertise of engineers and seismologists. Economic costs are best determined by a combined opinion of engineers, economists and financial institutions. The cost of the societal risk component is best determined by these stakeholders in the community who are political decision-makers and regulatory agencies.

A combined index incorporating these three components provides a relative total acceptable cost index.

## CONCLUSIONS

Seismic risk from major earthquake events must include economic and social components along with technological ones. Unless all three components are evaluated, the total cost of damage cannot be assessed comprehensively.

To formulate effective public policy, such total cost information is essential. Resource allocation, by necessity, is a rank ordering process. Total acceptable cost to a community will help determine equitable allocation of resources.

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