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INCLUDING EARTHQUAKE RISK PERCEPTION IN RISK REDUCTION MODELING

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CUREE-Kajima Joint Research Program
Phase IV

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We thank the participants in the Workshop, both those from the U.S. and from Japan.

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Finally, we thank Dennis Miletti, Paul Slovic, and other colleagues for their ideas and suggestions.

TABLE OF CONTENTS

INTRODUCTION

Resistance to investing in earthquake hazard mitigation, such as strengthening or replacing existing buildings and facilities, is common in both Japan and the U.S. The challenge is to find effective ways to change values and processes so loss prevention becomes an important organizational and community goal that results in decision-makers giving higher priority and greater resources to mitigation.

Researchers in both the U.S. and Japan are developing methodologies for Performance-Based Earthquake Engineering (PBEE), a relatively new concept that facilitates the design of structures and systems for specific earthquake performance levels. However, the more rigorous PBEE formulation for the "engineering benefit" is only one of the inputs to the decision process for specific mitigation action. Other inputs to the decision process come from the social, economic, and political issues that affect those making the decision. Therefore, a multidisciplinary approach is needed to understand mitigation actions and therefore overall risk reduction.

In this collaborative, multidisciplinary research project funded by Kajima Corporation through the CUREE-Kajima research program, investigators from the fields of engineering, social science, and statistics are trying to develop qualitative, and hopefully quantitative, models for earthquake hazard mitigation decision process. Investigators of this project on the CUREE (U.S.) side are Robert Nigbor, Robert Olson, and John Adams. On the Kajima (Japan) side, investigators are Masamitsu Miyamura, Kaoru Mizukoshi, and Narito Kurata.

Our work focused on defining the decision process of key decision-makers in responsible and authoritative positions in moderate to large private companies (the "unit of analysis"). Their decisions include investing in earthquake loss prevention strategies and technologies as part of new construction or retrofitting/rehabilitation projects. We then propose a more generalized framework for a "Community Earthquake Risk Reduction Model (CERRM)," based upon the multiple and varied inputs to decision and action. The CERRM could provide a framework for the evaluation of the relative effects of different engineering, social, economic, or political actions on the earthquake risk of a community. Such a model could be useful in benefit-cost assessment of investment in physical mitigation versus investment in earthquake risk education, for example.

Approach

Our approach to this study consisted of:

- Review of past and present studies of risk perception, mitigation decisions, social and political issues, and decision modeling applicable to earthquake-related decision-making;
- Key person interviews in both the U.S. and Japan to collect information about risk perception, the decision process, and the mitigation action process from experts and decision-makers;
- Development of a qualitative model for the earthquake mitigation decision process;
- Development of a general quantitative framework model for the decision process applicable to more general risk reduction modeling integrated over a community or region;
- Critique of these models at a focused Workshop;
- Development of final models and examples.

Report Overview

This report documents the efforts within the approach described above. Chapters are:

- Introduction
- Risk Perception Background
- Initial Hypothesis
- Key Person Interviews
- Workshop
- Proposed Framework Model
- Conclusions

Also part of this project output is the separate document *Proceedings of the 15 May 2002 CUREE-Kajima Workshop on a Community Earthquake Risk Reduction Model* (Miyamura and Nigbor, ed., 2002). This document contains more details regarding both the Workshop and the Key Person Interviews.

RISK PERCEPTION BACKGROUND

This project began with an extensive search of the literature within the specific area of earthquake risk perception, earthquake mitigation policy, and earthquake mitigation modeling. Conversations with researchers familiar with the literature suggested that to meet the needs of this project the team should expand its search for information related to hazard education and how knowledge of risk affects decision-making behaviors. Therefore, our study was necessarily broadened to include more general social and political areas of risk perception and risk mitigation.

The team discussed these subjects with representatives of, and where available, explored materials from the Natural Hazards Research and Applications and Information Center, University of Colorado; National Information Service for Earthquake Engineering; Applied Technology Council; Disaster Research Center, University of Delaware; Hazard Reduction and Recovery Center, Texas A&M University; and others.

The References section contains a collection of some of the more useful literature relevant to this study. Appendix A summarizes several of the most pertinent references.

Paul Slovic's recent book *The Perception of Risk* is a good place to start [Slovic(2000)]. In the first chapter Slovic attempts to answer the question "How Can We Improve Adjustment to Natural Hazards?" by providing a discussion of a Decision Analysis approach to the problem. He concludes the following:

- *Convergent evidence from psychological, business, government policy-making and geography documents the usefulness of bounded rationality as a framework for conceptualizing decision processes.*
- *An understanding of the workings of bounded rationality can be exploited to improve adjustment to natural hazards*
- *Decision analysis, though still in the early stage of developments, promises to be a valuable aid for the important decisions man must make regarding natural hazards.*

At the heart of this entire issue is the difficulty in understanding and even defining the concept of risk. Fischhoff et al. (1984) state that *"… an explicit and accepted definition of the term risk is essential. Creation of that definition is a political act, expressing the definers' values…"* Indeed, difficulties in a uniform definition of risk are the beginning of our problem of modeling the mitigation decision process.

Further insight into this process can come from studying the way people and society categorize and miscategorize risks. Morgan et al. (2000) look at this issue in a semi-quantitative way to come up with a process for "correct" risk ranking.

The recent development of formal performance-based earthquake engineering methodologies in the U.S. [Deierlein(2002)] and in Japan [Akiyama et al. (2000)] provides a framework for discussing and developing specific engineering aspects of mitigation. While this PBEE framework addresses the technical concerns, the implementation of mitigation strategies still depends upon organizational and societal considerations that perhaps more directly impact the decision process.

May (2001) provides an excellent and thorough discussion of these issues in his recent PEER report. May proposes that a PBEE framework should "recognize differences among individuals in time horizons, tolerance for risk, and weights attached to different aspects of safety." He states that such a PBEE framework should:

- *Treat seismic safety and risk as explicit considerations*
- *Expand the choices to be considered*
- *Allow for consideration of different dimensions of safety or risk*
- *Expose consequences and trade-offs among different levels of safety (or risk)*
- *Express safety and risk consequences for different alternatives in terms of relative safety improvements or risk reductions*
- *Consider externalities*

Among the research needs May states at the end of his discussion is "*understanding of how performance-based earthquake engineering contributes to more rigorous methods for making decisions*…" There is clearly a need for more explicit consideration of the decision-making process as an extension of PBEE technical analysis.

A recent effort by Geohazards International [Geohazards International(2001)] in the quantification of relative risk at a city level is proving to be a useful tool. This semi-quantitative model produces a single "Risk Index" value for an urban area based mainly on life loss potential. It includes engineering, social, and governmental inputs. It is narrow in focus and not very rigorous, but it does demonstrate the usefulness of such a tool for aiding the mitigation process.

Findings from Literature Review

There is a lack of a comprehensive model of the earthquake risk mitigation process that includes both engineering and socio-economic inputs to the process. While certainly the inclusion of both quantitative engineering inputs and qualitative/semi-quantitative socio-economic inputs into an integrated model is problematic, it may provide a useful tool for studying tradeoffs and optimization of resource allocation for mitigation.

Based partially upon Olson's work with Tsunami Hazards [Olson, 2001)] and on other reviewed literature, we have divided the process of mitigation into six general steps:

- **Perception/Knowledge**
- **Commitment to influence the decision-making process**
- **Putting mitigation action on a decision agenda**
- **Making a "Yes" decision for action**
- **Allocation of resources**
- **Implementing actions**

We used these steps to focus our initial modeling, information gathering, and key person interview process.

INITIAL MITIGATION DECISION MODEL

Based upon the perceived need for a comprehensive model of the earthquake risk mitigation process, we focused on the development of an initial model for an individual mitigation decision process. Discussed below are an initial qualitative model and a quantitative model for this decision process.

Initial Qualitative Model

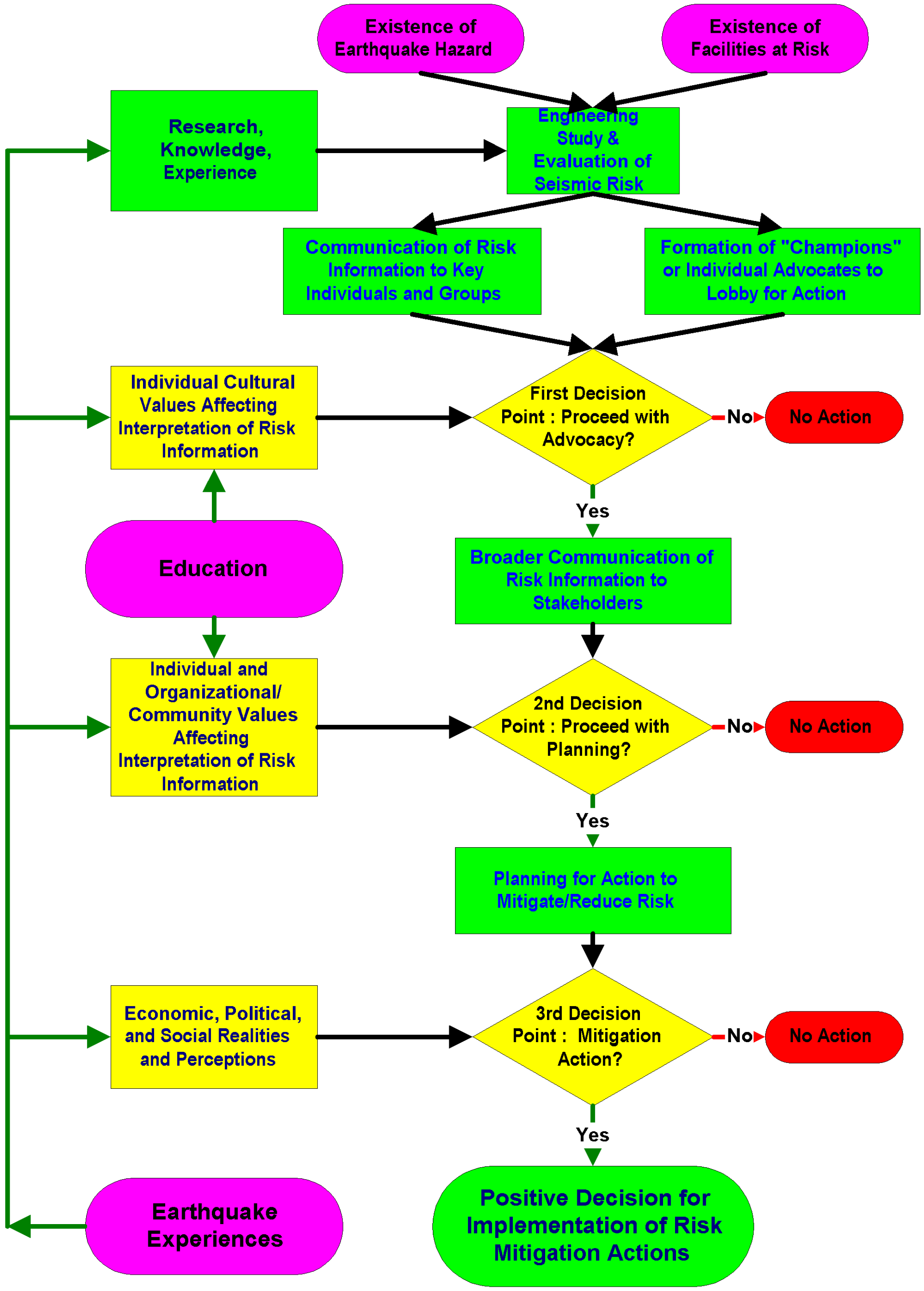
Following is an assumed path for mitigation actions:
perception/knowledge-->commitment-->on decision agenda-->decision-->allocation of resources-->action

Linking risk perception with the decision to invest in specific mitigation actions is not new. This important link has been studied for decades and longer in the social and political science arenas and more recently in the earthquake engineering arena. Alesch and Petak (2001) are a recent example of the use of this linkage.

Based on our review of the literature we have developed a qualitative, flow-chart style model of a specific mitigation decision process shown in Figure 1. This might represent a single decision process within a single company or other organization. It is based upon the assumption that the decision process starts with a single (or multiple/group) “champion” who is responsible for initiating the mitigation process. This may be more typical for the process in the U.S. than in Japan or other countries; however, this model could be modified for other social situations.

We have divided the mitigation decision process into three “Decision Points.” Each of these decision points has inputs from technical, social, economic, and political sources. Included in these inputs would be the technical inputs from engineering analyses or studies, including PBEE “Decision Variables.” The outputs of the first two Decision

Points feed into the next. The output of the final Decision Point is specific mitigation action.



RISK PERCEPTION AND DECISION-MAKING PROCESS MODEL FOR EARTHQUAKE HAZARDS

Robert Olson & Robert Nigbor, 2002

FIGURE 1: Initial Mitigation Decision Model

Initial Quantitative Model

Many researchers have discussed the need for more quantitative models of the earthquake risk mitigation decision process (May (2001) for example). However, due to the complexity and uncertainty of the issues influencing this decision process, to our knowledge no quantitative model has been proposed for the earthquake mitigation decision process.

Certainly any attempt at modeling the decision process will contain potentially large uncertainties both in the choice of parameters and in the quantification of those parameters. It is likely that such a model cannot be validated in any formal sense and therefore may not be useful as a predictive model. However, this does not mean that such a model is useful. Hodges and Dewar (1992) state the following in this regard:

> *"If a model is unvalidated or unvalidatable, it may not be used to predict, but that does not mean it is useless. There are at least seven distinct nonpredictive uses for models:*
>
> 1. *As a bookkeeping device, to condense masses of data or to provide a means or incentive to improve data quality;*
> 2. *As an aid in selling an idea of which the model is but an illustration;*
> 3. *As a training aid, to induce a particular behavior;*
> 4. *As part of an automatic management system whose efficacy is not evaluated by using the model as if it were a true representation;*
> 5. *As an aid to communication;*
> 6. *As a vehicle for a fortiori arguments; and*
> 7. *As an aid to thinking and hypothesizing, e.g. as a stimulus to intuition in applied research or in training or as a decision aid in operating organizations."*

Several of these uses, particularly #5 and #7, would apply to the problem of earthquake mitigation decision-making.

The PEER PBEE Framework Model (Deierlein(2002)) is a general probabilistic model that distills the various components into a probabilistic Decision Variable. This is proving to be a useful framework for use in further development of the engineering concepts of PBEE.

We propose a similar Mitigation Decision Model based on the qualitative model given in Figure 1 of the previous section.

Define the following Bernouli random variables:

D_1 = Yes decision at first decision point
D_2 = Yes decision at second decision point
D_3 = Yes decision at third decision point
D = Yes decision overall (same as D_3)

We can express the probability of a positive overall decision for mitigation as:

$$P(D \mid X) = P(D_3 | D_2, X) P(D_2 | D_1, X) P(D_1 | X)$$

where ***X*** is a vector of information that supports any of the three decisions. ***X*** contains all of the deterministic or stochastic decision inputs to all three decision steps. This includes PBEE outputs, cultural values, community values, and perceptions of all types.

Note the altered conditioning. The ultimate probability is still conditional on the facts. Also note that ***X*** is the same for all three conditional probabilities, although the relative importance of the elements of ***X*** will change across the three. The appearance of the full information set (***X***) in all three conditional probabilities admits two important features. First, the probability that you pass a latter decision point can depend upon the margin by which you passed earlier decision points. For example, barely choosing Yes for D_1 can negatively affect the probability of Yes at D_2 or D_3.

Secondly, the probability of choosing Yes at D_1 can be negatively affected by low probabilities at D_2 or D_3. Researchers, advocates, and policy makers may elect to allocate their efforts elsewhere if the chances of passing later stages in the decision process are small.

If we then define the random variable C as the quantitative reduction of earthquake risk by this action (as defined by engineering or other quantities; may be deterministic or random), then we can define in a probabilistic sense the expected reduction of risk E(R) by this action and its decision to be:

$$E(R) = C^* P(D|X)$$

This initial model is decidedly very general and crude, and needs further refinement. The following two stages of our project (Key Person Interviews and Workshop) address this need.

KEY PERSON INTERVIEWS

The team used formal interviews with a small group of practitioners, researchers, and decision-makers to yield valuable insights into the factors influencing decisions to invest in mitigation actions. Of particular interest for this study is the opportunity to study the difference in these factors between the U.S. and Japan. Interview results were used in the definition of the Mitigation Decision Models described elsewhere in this report.

Interview Method

A “Project Interview Guide” was developed and used to guide individual discussions with interview subjects in both the U.S. and Japan. The “Project Interview Guide” is included in Appendix A.

A small number of ”Key People” were interviewed in both the U.S. and in Japan. These Key People were all involved in earthquake mitigation decision-making. Eight people were interviewed in the U.S, and six in Japan.

We should point out that these interviews were not meant to represent any sort of rigorous statistical survey. The interview subjects were “opportunity sampled” and therefore do not represent a statistical sampling of the population.

Detailed interview results are provided in Appendix A. The following two sections summarize and discuss the U.S. and Japan interviews.

Summary of U.S. Interviews

A total of eight persons were interviewed by the CUREE team. Of these, six completed the questionnaire. The other two provided partial responses and qualitative discussions.

Table 1 below describes these eight interview subjects, denoted Subject A – Subject H. Subjects G and H did not adequately complete the questionnaire but provided good comments about the process useful as input into this development.

Table 1: CUREE (U.S.) Interview Subjects

Subject	Profession	Expertise
A	President of Small Structural Engineering Consultancy	Is involved in seismic retrofit projects for small and medium-size organizations, largely in California.
B	Property Owner	Owner of several apartment buildings and commercial buildings in Los Angeles. Faces seismic retrofit issues often. Is also a mechanical and structural building contractor.
C	Vice President of a very large nationwide engineering company	Is involved with seismic projects, both new and retrofit, for medium and large clients.
D	Principal of a medium-size engineering firm	Is involved in seismic retrofit projects for small and medium-size organizations, largely in California. Is also very involved in earthquake engineering research.
E	Principal of a small engineering consultancy	Is involved in seismic issues for small projects, largely in California where seismic issues dominate.
F	Principal of a large earthquake engineering company	Is involved with hazard mitigation, including all natural and man-made hazards. Is very involved with seismic code development.
G	Architect and individual consultant	Is a noted expert in seismic issues, but more from the development side than the engineering side
H	Principal of geotechnical engineering firm	Is involved with seismic retrofit projects for a variety of clients, many government.

Details of the U.S. interview results are included in Appendix A. Following are tabulations of the features considered “Most Important” or “Important” by the interviewees:

Risk Perception/Knowledge

Most important or important:

- Understand concept of “low probability-high consequence” events.
- Understand impacts of earthquakes on own facilities and operations.
- Understand general earthquake risk.
- Sources of risk information.

Commitment

Most important or important

- Know if organization is required to take action.
- Know consequences of not taking actions.
- Know practical alternatives.
- Know if competitors taking similar measures.
- Know if organization is willing to change and innovate.
- Know what similar organizations have done.

Place on Decision Agenda

Most important or important:

- Present a plan for the work showing its scope, cost, and time.
- Organize and present risk information that leads to decisions.
- Influential person needed to get hazard mitigation on decision agenda.
- Understand other subjects may not be considered.
- Realize loss prevention may be deferred or assigned further study.
- Realize external factors might affect decisions.

“YES” Decision Assumed

Most important or important:

- Assign a program/project manager or leader.
- Have necessary financial and organizational capacities.
- Project manager access to decision-makers during program.
- Know how loss prevention supports multiple goals.

Allocation of Resources

Most important or important:

- Resources must support policy decisions.
- Use available incentives or subsidies to offset the project costs.
- Have accurate cost estimates during the entire project.
- Know if loss prevention benefits exceed expected losses.

Implementation Actions

Most important or important:

- Set priorities where multiple locations or facilities are involved.
- Demonstrate how loss prevention actions support organizational goals.
- Have the needed technical expertise.
- Develop detailed plans to ensure accomplishment.
- Keep decision-makers regularly informed of progress.
- Be able to explain unexpected complications.

Summary of Japan Interviews

A total of six persons were interviewed by the Kajima team. Of these, six completed the questionnaire. The other two provided partial responses and qualitative discussions. Table2 below describes these eight interview subjects, denoted Subject JA – Subject JF.

Table 2: Kajima (Japan) Interview Subjects

Subject	Profession	Expertise
JA	a large department store	Chief of the facility safety management section of the general affairs department
JB	a large beer company	Executive producer of the quality planning department
JC	a large shopping center	Manager in charge of large-scale disaster prevention
JD	an electric power development company	Deputy manager of the construction group of the nuclear electric power business department
JE	a large car company	Section chief of the general affairs department
JF	a electric power company	Group manager of the seismic design group of the Engineering R&D Division

Details of the Japan interview results are included in Appendix A. Following are tabulations of the features considered “Most Important” or “Important” by the interviewees:

Risk Perception/Knowledge (Most important or important):

- Understand concept of “low probability-high consequence” events.
- Understand impacts of earthquakes on own facilities and operations.

Commitment

Most important or important:

- Know if organization is willing to change and innovate.

Place on Decision Agenda

Most important or important:

- Influential person needed to get hazard mitigation on decision agenda.
- Organize and present risk information that leads to decisions.

“YES” DECISION ASSUMED

Most important or important:

Allocation of Resources

Most important or important:

- Know if loss prevention benefits exceed expected losses.

Implementation Actions

Most important or important:

- Set priorities where multiple locations or facilities are involved.

Interview Synthesis

This interpretive section summarizes the similarities and differences between the interviews completed in Japan by Kajima researchers and in the U.S. by CUREE researchers. The Interview Guide contained in Appendix B is based on a simple multiple-step decision process:
Risk Perception/Knowledge>Commitment>Place on Decision Agenda>Decision>Allocation of Resources>Action.

As expected, there are common and different results. It is important to recognize that the interviews were conducted with a very small number of people in both countries strictly for the purpose of gaining some preliminary understandings of what kinds of subjects are important to communicating and deciding to reduce earthquake risk in private companies in both countries. These results, while very tentative, provide a basis for further research to support the development of a broader "Community Earthquake Risk Reduction Model."

From both sets of interviews, common outcomes regarding the earthquake mitigation decision process were:

- Decision-makers need to understand concept of "low probability-high consequence" events and impacts of earthquakes on own facilities and operation
- Someone must have sufficient influence to get the subject of hazard mitigation on the organization's decision agenda and be responsible for organizing and presenting the risk information that lead to a decision
- Implementers must ensure that the prospective benefits of investing in loss prevention actions exceed the expected losses and set priorities where multiple locations or facilities are concerned

Outcomes were different in the U.S. and Japan interview results as follows:

- In Japan, decision-makers does not need to know what similar organizations are doing or have done, and if their competitors are taking measures to prevent losses. In US, decision-makers need this information.
- In Japan, the company which takes measures to prevent losses does not depend on similar organizations and competitors.
- In US, implementers must ensure that organizational resources are made available to support the policy decisions.
- In Japan, implementers must ensure that the prospective benefits of investing in loss prevention actions exceed the expected losses.
- In US, loss prevention action is considered in the policy decision.
- In Japan, the prospective benefit of investing in loss prevention action is concerns.
- In Japan, implementers must ensure that feedback is provided regularly so the program remains visible to the decision-makers.
- In Japan, feedback and communication to decision-makers are important for implementers.

Detailed discussion of the results for the six steps of the mitigation decision process follow.

Step 1: Risk Perception/Knowledge

Decision-makers in both countries should have a general understanding of earthquake risk, but more importantly they need to understand the concept of “low probability—high consequence events and how such events, such as major damaging earthquakes, will impact their companies’ facilities and operations. Company staff and its consultants are more important sources of earthquake risk information in both countries than are external sources of such information.

Step 2: Commitment

Compared to the U.S. it is more important to Japanese decision-makers to understand how receptive their companies are to change and innovation, such as investing in an earthquake hazard mitigation program. Decision-makers in both countries believe it is moderately important to understand the range of alternatives available to them for preventing losses.

However, it is more important to U.S. decision-makers to know what similar organizations are doing or have done to lessen earthquake risk, and it is far more important to U.S. decision-makers to know if others, such as government regulatory agencies, require them to take action and what the consequences might be of their not acting to reduce earthquake risk than it is to Japanese decision-makers. Also, it is more important to U.S. decision-makers to know if their competitors are taking mitigation actions than it is to Japanese decision-makers.

Step 3: Place on Decision Agenda

In both Japan and the U.S. it is important that someone involved must have sufficient influence to get the subject of earthquake hazard mitigation on their company's decision agenda and that someone be responsible for organizing and presenting the risk information in ways that lead to decisions. It seems more important in the U.S. that those managing the hazard mitigation decision process understand that getting on their companies' decision agenda may mean that other matters are not considered. While probably well understood, it does not seem important in either country that a proposed hazard mitigation program decision might be deferred or assigned to further study."

Step 4: Decision

The interview assumed that a "yes" decision is made to invest in earthquake hazard mitigation. Except for one point, there is remarkable consistency between Japanese and U.S. decision-makers. Both see it as very important to designate a "program/project manager or leader," that this person or group has continuing access to decision-makers, and that their companies have the financial and organizational capabilities to invest in hazard mitigation. It seems a little more important in the U.S. that decision-makers understand how their commitment to mitigation "fits" into other company strategies and commitments.

Step 5: Allocation of Resources

Differing views regarding the allocation of company resources to accomplish hazard mitigation program goals are apparent between Japanese and U.S. decision-makers. It is important in both contexts that those responsible for implementing the program have the resources to accomplish the goal. Somewhat surprising, however, is that knowledge of available incentives, while showing about the same importance, is not of great importance. It is more important in Japan that those implementing the decision ensure that the prospective benefits of investing in loss prevention exceed the expected losses. As might be expected, "good" estimates of project costs are important in both cases.

Step 6: Action

There are strong similarities regarding implementers' responsibilities for demonstrating how their actions support their companies' plans and goals, needs for technical expertise, use of detailed project work plans, setting of priorities where multiple locations or facilities are concerned, and being able to explain why adjustments may be needed because unexpected complications. It appears more important in Japan than in the U.S. that implementers ensure that regular feedback be provided to decision-makers.

Using the Interview Results

Results of the Key Person Interviews in both the U.S. and Japan provide an interesting and useful background for this attempt at the modeling of the decision process. These results provided assistance to the Investigators in the further refinement of the initial qualitative model.

Further interviews, perhaps with more breadth of subjects and an attempt at randomness in subject selection, would be useful in the next step of model refinement.

WORKSHOP

The CUREE-Kajima Workshop on a Community Earthquake Risk Reduction Model was held on May 16, 2002 at Kajima Corporation's KI Building in Tokyo. The purpose of this workshop was threefold: 1) to discuss earthquake risk perception in the U.S. and Japan; 2) to discuss a proposed model framework for community earthquake risk reduction; and 3) to obtain "expert opinion" on key modeling issues to assist with further model development.

The Workshop and its results are briefly described below, and some details are included in Appendix C. Further details can be found in the Workshop Proceedings (Miyamura and Nigbor, 2002).

Workshop Participants

Invited participants of this one-day workshop were:

Kajima Staff and Guests
Akira Endoh, Kajima Technical Research Institute
Taichi Goto, Avant/ComPus
Yasufumi Iseki, Engineering and Risk Services Corporation
Hiroshi Ishida, Kajima Technical Research Institute
Takuji Kobori, Kobori Research Complex
Narito Kurata, Kobori Research Complex
N. Kusano, Engineering and Risk Services Corporation
Masamitsu Miyamura, Kobori Research Complex; co-Chair
Kaoru Mizukoshi, Kajima Technical Research Institute
Y. Sasaki, Kajima Corporation
Y. Takahashi, Kajima Corporation
Kazuaki Torisawa, Kajima Technical Research Institute

CUREE Representatives and Guest
John Adams, RAND Corporation
Wilfred Iwan, CUREE Board Member, Caltech
Robert Nigbor, University of Southern California, co-Chair
Robert Olson, Robert Olson Associates

Workshop Venue and Agenda

The workshop was held in the Kajima KI Building in Akasaka on May 16, 2002. Prior to the workshop, on May 15, was a planning meeting attended by the project investigators. A post-workshop investigators' meeting was also held on May 16 to help summarize the results.

Following is the workshop agenda:

10:00	Introductions
10:15	Opening remarks by Mizukoshi and Nigbor
10:30	Earthquake Risk Perception Background: Olson
11:00	Results of Interviews in US: Nigbor/Olson
11:30	Results of Interviews in Japan: Kurata
12:00	Lunch
13:00	Case Study of Community Management: Goto
13:15	Statistical Modeling of Social Issues: Adams
14:00	The GHI Model for Community Earthquake Safety: Iwan
14:00	The PEER Framework Model for PBEE: Nigbor
14:15	A Framework Model for Earthquake Risk Perception: Nigbor/Olson
15:00	Break
15:15	Guided group exercise/discussion using the RAND Method
17:00	Summary and closing comments
17:30	Close Workshop

Workshop Results and Recommendations

The Workshop provided excellent discussion of earthquake risk perception in the U.S. and in Japan based upon the results of the Key Person Interviews. A key finding here was that Japanese decision-makers tend to focus on projects and specific project needs while their U.S. counterparts tend to address broader policy and strategy issues related to earthquake risk.

The Workshop provided a useful critique of the general and specific aspects of the initial Framework Model for Community Earthquake Risk Reduction presented by Nigbor and Olson. Specific recommendations of the Workshop regarding this initial model were:

- The purpose and uses of the model are not yet clear. This must be better defined.
- Likewise, we should make it clear who could use and benefit by this model.
- The structures of both the qualitative (flow chart) and quantitative (equation) framework models should be generalized further to be more applicable.
- In the qualitative (flow chart) model, the decision-maker should be explicitly identified at each decision point.
- One or more simple examples of the use of such a model will be very important.

The results of the brief RAND/UCLA Appropriateness Method ("the RAND Method") exercise in the afternoon of the Workshop provided initial "expert opinion" guidance regarding the relative importance of different inputs to a mitigation decision model. This exercise was focused by providing the following scenario:

> *Assume you are responsible for a high-rise steel office building owned and used by your own company in your home country. Below is a list of types of information that might be useful to support your decisions to reduce seismic risk.*

Appendix C contains detailed results of the polling. Focusing on the “Importance” polling (the “Feasibility” polling was confused by poor definition of the term), we can make the following observations regarding the final exercise results:

- Engineering Information: all information is relatively important, with average Importance factors of 7 or higher. However, the most important information was 4) specific building condition and 5) information on mitigation technologies.
- Business Economics: again all information was considered to be of relative importance, with average Importance factors 7 or above. The most important information (with average scores of 8) were 6) retrofit option costs, 7)retrofit option performance, 9)estimated damage repair costs, 11)estimated lost business cost during repair.
- Legal/Political: again all information was considered important, with average Importance factors 7 or higher. The most important was 16) current seismic mitigation regulations.
- Social: here corporate pressure outweighed both worker pressure and community pressure for mitigation action.

The RAND method is often used by researchers to quantify model parameters for social, political, or economic issues that cannot be explicitly defined. It and other “Modified Delphi” methods are common in the social sciences, less common in the “hard” sciences. However, for the modeling of risk perception and other parts of the mitigation decision process, this is the only way to obtain semi-quantitative model parameters.

The brief exercise at the Workshop did provide some useful results that will be applied to the refinement of the Mitigation Decision Model described in the next section. It also served as a demonstration on how this method could be used for the modeling problem at hand. However, a much more complete and careful exercise would be required to obtain high-quality “expert opinion” parameter values for future modeling of risk perception, mitigation decisions, or community risk reduction.

PROPOSED FRAMEWORK MODEL

Based upon our initial hypothesis, the Key Person Interviews, the Workshop, and on discussions within the project team, the Risk Mitigation Decision model was modified into the following general framework model. A framework model for mitigation decision-making, intended to be a general model that can be modified to fit different situations within a general schema, can be a vehicle for understanding the decision-making process at the individual level and the accompanying effect on risk reduction.

Such a model for individual risk mitigation decisions can then become a basic unit ("quanta") for integration over a set of potential actions to help understand the aggregate effect of engineering, social, and economic inputs on earthquake risk reduction within a "community" (defined herein as a town or small city such as Pasadena in California or Akasaka in Tokyo). This aggregated model can be called

We acknowledge that this effort is only providing a framework for future efforts and is therefore incomplete in both its definition and its details. It should be considered as a seed for further research and development.

Hypothesis

We propose the following hypothesis for integrated earthquake risk mitigation modeling:

> ***The process of earthquake risk mitigation is a combination of: 1) decision processes with many different types of inputs and 2) risk reduction of individual actions. It is therefore useful to attempt both qualitative and quantitative modeling of single mitigation actions using a probabilistic framework. This can then be extended by integration over spatially and/or temporally-distributed sets of possible mitigation actions to provide a probabilistic "earthquake risk reduction model" for a community or other vulnerable groupings. Such a model can enhance understanding of the effect of various***

and diverse engineering, social, or economic inputs on overall earthquake risk reduction.

The proposed qualitative and quantitative models below follow from this hypothesis. The construction of these models benefited greatly from results of the Key Person surveys and from the discussions at the Workshop.

Qualitative Decision Tree

The initial qualitative "decision tree" model shown in Figure 1 had a specific focus: an earthquake risk mitigation decision within a private company having a single "champion" who is interested in the promotion of earthquake risk mitigation. This is often the way decisions are made in a U.S. company, but may not reflect the correct decision tree for other types of organizations or in other cultures. Specifically, it may not be applicable to the social fabric of Japan, where decisions are mostly made in a group venue.

Nevertheless, the concept presented in Figure 1 is one of a discrete number of intermediate decision points (two in Figure 1) leading to a final decision to execute the mitigation action. Each of these decision points is influenced by a wide array of external inputs, from engineering (PBEE "decision variables" for example) to social to political to economic. Ignoring any of these possible inputs will result in an incomplete model.

The construction of a "complete" decision tree for a specific or a generalized mitigation decision could easily get very complicated and could then obscure its purpose as a tool for studying the relative importance and effect of major inputs. We must acknowledge up front that what we are producing is not a rigorous predictive model but is a tool for what Hodges and Dewar (1992) denote as "*an aid to thinking and hypothesizing, e.g. as a stimulus to intuition in applied research or in training or as a decision aid in operating organizations."*

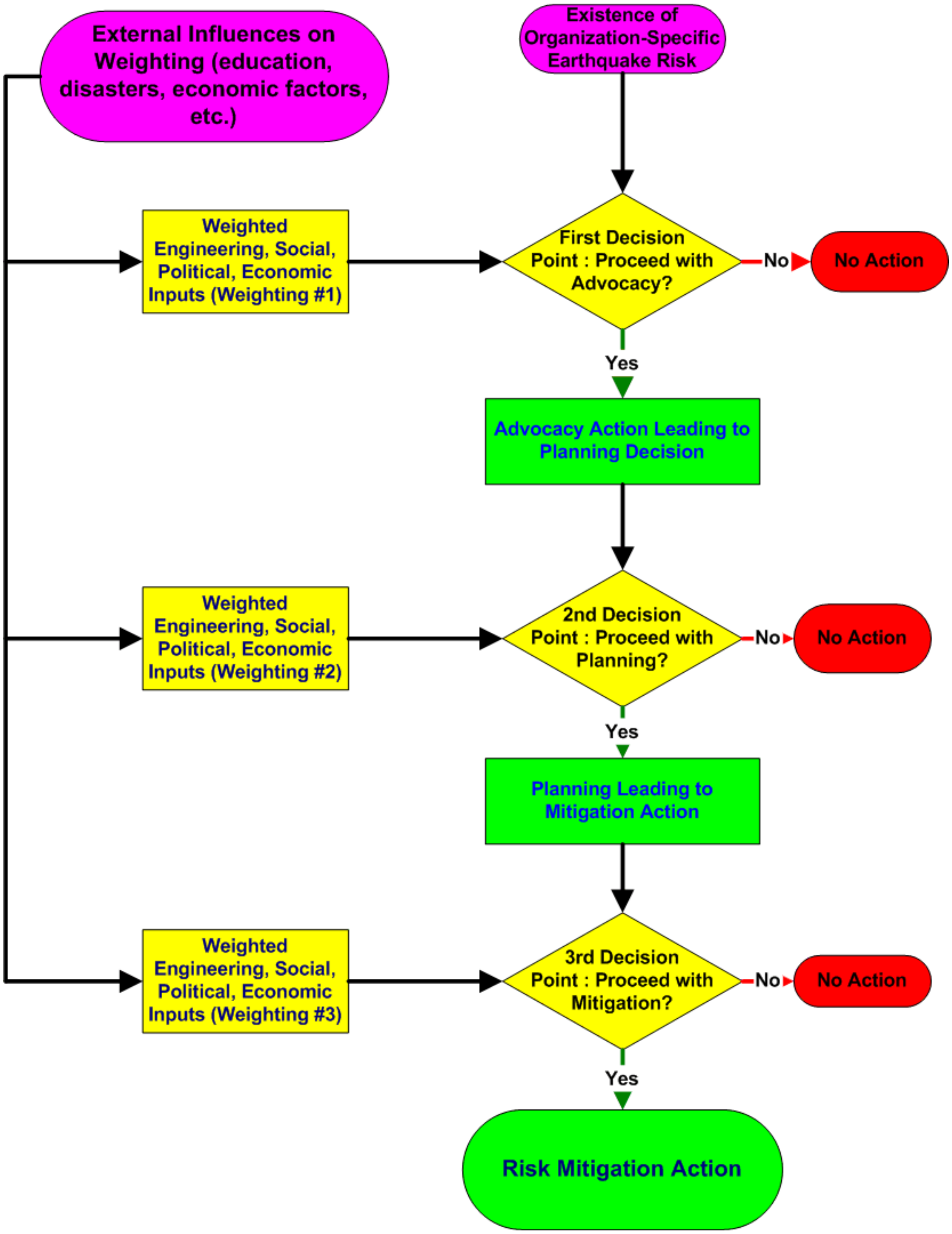
With this in mind, the generalized decision tree model in Figure 2 is proposed as a simplified qualitative framework model for earthquake mitigation decision making. This model again contains three "decision points." The first is the decision to advocate, or encourage, the mitigation action. This may be done by one internal person (a "champion") or an internal group. It may be prompted by external or internal political or social forces. Inputs to this decision are weighted engineering, social, political, and economic variables.

The second decision point is the decision to proceed with detailed planning, leading to recommendations to management or other controlling decision-making individuals or groups. This decision will be initiated by the actions following from the first decision, and will be influenced by weighted engineering, social, political, and economic inputs. The weighting will differ from that in the first decision.

The last decision is the decision for mitigation action by an internal decision-making individual or group, leading to the execution of the mitigation action. This decision will be initiated by actions following from the second decision, and will be influenced by weighted engineering, social, political, and economic inputs. The weighting will differ from that in the first two decisions.

In general, we must acknowledge that the weighting of the various engineering, social, political, and economic variables will vary from person-to-person, organization-to-organization, geographically, and temporally. Weighting can be affected by external stimuli from education, recent earthquakes or other disasters, economic conditions, and many other variables; these external effects may often be of interest.

This is indeed a very complex issue even in a qualitative sense. To be useful this model will need to be simplified greatly, with only a sparse number of most important inputs being considered.



Generalized Decision Model
for Earthquake Risk Mitigation Action

FIGURE 2: Proposed Qualitative Decision Tree Model

Quantitative Framework Model for a Single Mitigation Action

An abstract probabilistic model of the generalized mitigation action shown in Figure 2 can be assembled as follows:

Let the inputs be represented by a vector *X*. Elements of this vector are random variables representing the engineering, social, political, and economic quantities that are considered significant to a particular decision or group of decisions.

Define a weighting vector *W*, of the same size as *X*, that contains the relative weights of the input variables in *X*. Further define W_1 as the weights for Decision Point 1, W_2 as the weights for Decision Point 2, and W_3 as the weights for Decision Point 3.

As was done in the Initial Model, define the following Bernouli random variables:

D_1 = Yes decision at Decision Point 1
D_2 = Yes decision at Decision Point 2
D_3 = Yes decision at Decision Point 3
D = Yes decision overall (same as D_3)

We can express the probability of a positive overall decision for mitigation as:

$$P(D \mid X, W) = P(D_3 \middle| D_2, X \times W_{31}^T) P(D_2 \middle| D_1, X \times W_2^T) P(D_1 \middle| X \times W_1^T)$$

This model has two important implied features. First, the probability that you pass a latter decision point can depend upon the margin by which you passed earlier decision points. For example, barely choosing Yes for D_1 can negatively affect the probability of Yes at D_2 or D_3.

Secondly, the probability of choosing Yes at D_1 can be negatively affected by low probabilities at D_2 or D_3. Researchers, advocates, and policy makers may elect to allocate their efforts elsewhere if the chances of passing later stages in the decision process are small.

If we then define the random variable C as the quantitative reduction of earthquake risk R by this action (as defined by engineering or other quantities; may be deterministic or random), then we can define in a probabilistic sense the expected reduction of risk E(R) (a random variable) by this action and its decision to be:

$$E(R) = C * P(D \mid X, W)$$

This is admittedly a very general probabilistic model. It is intended to be a framework for future research in this hybrid engineering/social science arena.

Application to a specific mitigation action will require the following steps:

1. Definition of important inputs (components of X)
2. Definition of the three weighting vectors (for the assumed decision tree model)
3. Definition of the probability density functions (PDF) for each decision point
4. Definition of the conditional relationships between the three PDF's

Appendix D contains a simple, hypothetical model of the usage of this quantitative model of the mitigation decision process. Accurate creation of a model for a specific scenario would require obtaining values for parameters through a method such as the RAND method.

Extension to a Community Risk Reduction Model

In an abstract sense, earthquake risk mitigation for a community can be modeled as the aggregation of a set of discrete mitigation actions.

Within this abstraction, one can easily extend the single-action model above to the risk reduction for a community as follows.

Define *R_c* as the random variable representing the reduction of risk in a community. Implicit in the definition of this variable are limits in both time and area (temporal and spatial)

For the sake of simplicity, assume that the discrete mitigation actions are independent. One can then simply sum the risk reductions of the individual actions to get the aggregate risk reduction, or

$$R_c = \sum_i R_i = \sum_i C_i P(D_i | X, W_i)$$

This assumption of independence may not be valid, especially where external political, social, or economic factors are weighted high in the input vector *X*. This possible dependence should be considered in a more refined probabilistic model.

CONCLUSIONS

The purpose of this project was to study the perception of earthquake risk and to fold this into a generalized model of mitigation decision-making and of earthquake risk reduction. To do this, we have studied the literature, formulated an initial model, interviewed key people, held a workshop, and then formulated a hypothesis and a framework model for qualitative and quantitative modeling of the decision to perform earthquake mitigation. A simple example of the use of this model is provided in Appendix D. This mitigation decision then becomes the quanta of a framework model for Community Earthquake Risk Reduction, defined as the reduction of risk aggregated over a town-level (e.g. Pasadena, California or Akasaka, Tokyo) grouping of people and infrastructure.

This modest effort is a seed for further work on more quantitative combination of engineering, social, economic, political, and other inputs to the decision process for earthquake mitigation and then to the aggregate effect of these decisions on the reduction of earthquake risk within a community or other groupings of people or assets. Such quantitative modeling is lacking in past and present studies of earthquake risk reduction, but is a logical extension of developing PBEE methodologies.

REFERENCES

Akiyama, H., M. Teshigawara, and H. Fukuyama (2000), *A Framework of Structural Performance Evaluation System for Buildings in Japan*, *Proc. 12th World Conference on Earthquake Engineering*, Aukland, NZ.

Alesch, D. and W. Petak (2001) *Overcoming Obstacles to Implementation: Addressing Political, Institutional and Behavioral Problems in Earthquake Hazard Mitigation Policies*. Multi-Disciplinary Center for Earthquake Engineering Research(MCEER), http://mceer.buffalo.edu.

Arnold, C. (2001), *Communicating Risk to and Within the Business Community (The ATC-56 Project)*, 2001 Western States Seismic Policy Council Annual Meeting, Sacramento, CA (presentation).

California Seismic Safety Commission (1993). *The Commercial Property Owner's Guide to Earthquake Safety (SSC Report 93-01)*, CSSC, Sacramento, CA.

California Seismic Safety Commission (1999a). *Incentives to Improve California's Earthquake Safety: An "Agenda in Waiting" (SSC Report 99-02),CSSC,* Sacramento, CA.

California Seismic Safety Commission (1999b). *Earthquake Risk Management: A Toolkit for Decision-Makers (SSC Report 99-04)*, Sacramento, CA.

Clark, B. (2001), *Earthquake Risk Communications Between Consultant and Client*, 2001 Western States Seismic Policy Council Annual Meeting, Sacramento, CA (presentation).

Deierlein, G., (2002), *Overview of PEER PBEE Methodology*, *2002 PEER Annual Meetin Proceedings*, Oakland, CA, http://peer.berkeley.edu/2002annualmtg/index.html.

EERI (1998), *Incentives and Impediments to Improving the Seismic Performance of Buildings,* Earthquake Engineering Research Institute, Oakland, CA.

EERI (2000a), *Investigating Incentives to Improve the Implementation of Performance-Based Seismic Design in New and Existing Buildings: Report of a Workshop.* Earthquake Engineering Research Institute, Oakland, CA.

EERI (2000b), *Financial Management of Earthquake Risk*. Earthquake Engineering Research Institute, Oakland, CA.

FEMA (1998a), *Planning for Seismic Rehabilitation: Societal Issues (FEMA 275).* Federal Emergency Management Agency, Washington, DC

FEMA (1998b) *Second Report on Costs and Benefits of Natural Hazards Mitigation (FEMA 331)*. Federal Emergency Management Agency, Washington, DC.

Fischhoff, B., S. Watson, and C. Hope (1984), *Defining Risk*, *Policy Sciences* Vol. 17.

Flynn, J., P. Slovic, C. Mertz, and C. Carlisle (1999), *Public Support for Earthquake Risk Mitigation in Portland, Oregon*, *Risk Analysis*, Vol. 19, No. 2.

Geohazards International (2001), *Global Earthquake Safety Initiative Pilot Project*, Geohazards International, Palo Alto, CA.

Hodges, J. and J. Dewar (1992), *Is it You or Your Model Talking? A Framework for Model Validation*, Rand Corporation Report R-4114-AF/A/OSD.

May, P. (2001), *Organizational and Societal Considerations for Performance-Based Earthquake Engineering*, Pacific Earthquake Engineering Research Center Report PEER 2001/04.

May, P. (2002), *Thinking Ahead: Issues for Adoption of PBEE*, *PEER Annual Meeting Research Digest*, PEER Publication 2002-5.

Mileti, D., C. Fitzpatrick, and B. Farhar (1992), *Lessons from the Parkfield Earthquake Prediction*, *Environment*: 34:3, 16-39.

Mileti, D. and C Fitzpatrick (1993), *The Great Earthquake Experiment: Risk Communication and Public Action*. Westview Press, Boulder, CO.

Mileti, D., D. Cress, and J. Darlington (1998). *Earthquake Culture and Corporate Action.* Report by Department of Sociology, University of Colorado, Boulder, CO.

Miyamura, M. and R. Nigbor (ed.), Proceedings of the 16 May 2002 CUREE-Kajima Workshop on a Community Risk Reduction Model, Tokyo, Japan, May 2002, USC Report CE-2002-N-2, December, 2002.

Morgan, M., H. Florig, M. DeKay, and P. Fischbeck (2000), *Categorizing Risks for Risk Ranking*, *Risk Analysis*, Vol. 20, No. 1.

Nathe, S., P. Gori, M. Greene, E. Lemersal and D. Mileti (1999), *Public Education for Earthquake Hazards*, *Natural Hazards Informer*: 2, 1-8.

Olson, R., (1987), *Data Processing Facilities: Guidelines for Earthquake Hazard Mitigation*. VSP Associates, Inc. (now Robert Olson Associates, Inc.). Folsom, CA.

Olson, R. et al. (2001), *Designing for Tsunamis: Seven Principles for Planning and Designing for Tsunami Hazards*, National Tsunami Hazard Mitigation Program/California Office of Emergency Services*,* Oakland, CA.

Slovic, P. (2000), *The Perception of Risk*, Earthscan Publications, London and Sterling, VA.

Spangle Associates (1999), *Decisions to Demolish: Case Studies of the Fate of Earthquake-Damaged Buildings, Spangle Associates,* Portola Valley, CA.

Turner, R., J. Nigg, and D. Paz (1986). *Waiting for Disaster: Earthquake Watch in California*. University of California Press, Berkeley, CA.

APPENDIX A: Abstracts of Selected References

- **Akiyama et al. (2000)**
- **Deierlein (2002)**
- **Fischhoff et al. (1984)**
- **Geohazards Int'l (2001)**
- **May (2001)**
- **Morgan et al. (2000)**
- **Slovic (2000)**

Author:	Akiyama, Hiroshi; Teshigawara, Masaomi; Fukuyama, Hiroshi
Title:	A framework of structural performance evaluation system for buildings in Japan
Citation:	12th World Conference on Earthquake Engineering [Proceedings], New Zealand Society for Earthquake Engineering, Upper Hutt, New Zealand, 2000, Paper No. 2171
Abstract:	This paper introduces an outline of a new framework for a structural performance evaluation system for buildings developed by the Japanese national project on "Development of a New Engineering Framework for Building Structures," a three-year project completed in 1998. The flow of the proposed framework of structural performance evaluation consists of establishment of target performance, verification of performance, and statement of the evaluated performance. Safety, repairability, and serviceability, which correspond to the protection of human life, property, and functions and comfort, respectively, are provided as basic structural performances for the establishment of target performance. Performance evaluation items, which are combinations of three basic structural performances and five evaluation objects, structural frame, building elements, equipment, furniture, and the ground, should then be determined. Limit states should be prescribed for every performance evaluation item. Performance levels are expressed as combinations of load and/or external force intensity and limit state. The limit state expresses the condition in which each evaluation object is required to be in terms of each basic structural performance. Performance verification should be conducted to check whether the responses are reached at the limit states according to the principle of performance verification. In this paper, the principle of performance verification is the engineered response value, which expresses the response of a building or a part of a building caused by load and/or external forces that should not exceed the engineered limit values, a threshold value expressing the corresponding limit state. Finally, every estimated performance of the building is stated. The significance of this design system is summarized as: (a) introduction of market principles into the field of structural engineering, (b) promotion of the development of building structural engineering technologies, (c) possibility of a more flexible design, and (d) international harmonization of structural engineering.

Author:	Deierlein, Greg
Title:	Overview of PEER PBEE Methodology
Citation:	2002 PEER Annual Meeting [Proceedings], Oakland, CA, http://peer.berkeley.edu/2002annualmtg/index.html
Abstract:	This presentation summarizes the current status of PEER;s Framework Model for performance-based earthquake engineering ("PBEE"). It describes the components of this model: Intensity Measure, Engineering Demand Parameters, Damage Measure, and Decision Variable. It then assembles these components into the PEER PBEE Probability Framework Equation, which expresses the impact of earthquake shaking in terms of hazard and performance models. The components of the model are then discussed, down to the level of damage estimation of structures, systems, and components. General application of the Framework Equation to the mitigation decision process is then discussed.

Author:	Fischhoff, Baruch; Watson, Stephen; Hope, Chris
Title:	Defining risk
Citation:	Policy Sciences, Vol. 17, pp. 123-139, Elsiver, 1984
Abstract:	Risk is the focal topic in the management of many activities and technologies. For that management to be successful, an explicit and accepted definition of the term "risk" is essential. Creation of that definition is a political act, expressing the definer's values regarding the relative importance of different possible adverse consequences for a particular decision. Those values, and with them the definition of risk, can change with changes in the decisionmaker, the technologies considered, or the decision problem. After a review of the sources of controversy in defining risk, a general framework is developed, showing how these value issues can be systematically addressed. As an example, the approach is applied to characterizing the risks of six competing energy technologies, the relative riskeness of which depends upon the particular definition used.

Author:	Geohazards International
Title:	GESI – global earthquake safety initiative pilot study
Citation:	Geohazards International, Palo Alto, California USA, www.geohaz.org, 2001
Abstract:	This report summarizes an effort by Geohazards International and the United Nations Centre for Regional development to define urban earthquake risk. The Pilot Study of this Global Earthquake Safety Initiative tested a method of assessing community earthquake safety. The objective of the method is to: • Express urban earthquake risk in lay terms; • Measure trends in the urban earthquake risk of the world's major cities; • Evaluate the effectiveness of various means of reducing earthquake casualties; and • Highlight the increasing earthquake risk of schools of developing countries and the potential for reducing that risk. This method focuses on the risk of only life loss in earthquakes. The possible users of this method are primarily city, national, and international decision makers.

Author:	May, Peter
Title:	Organizational and societal considerations for performance-based earthquake engineering
Citation:	PEER-2001/04, Berkeley: Pacific Earthquake Engineering Research Center, University of California, Apr. 2001, 52 pages
Abstract:	Decisions about seismic performance are the underpinnings of a rigorous approach to performance-based earthquake engineering and should specifically consider the decision variables within the PEER framing equation. This report considers the decision-making process for seismic safety from the perspective of organizations -- building owners, investors, and others concerned with single facilities or a collection of facilities -- and from the perspective of society. The dominant mode of seismic performance decision making, "risk and safety as by-products of design," falls short in not allowing trade-offs or choices in decisions concerning seismic risks. The opposite mode, "performance-optimized decisions," focuses on desired performance levels but masks relevant choices and trade-offs. Only an "investment-based" approach provides a framework consistent with the variables of the PEER framing equation for making explicit trade-offs in seismic performance and their costs. Decisions about desired levels of seismic performance should allow for explicit consideration of trade-offs associated with investment in seismic safety and in other forms of risk management. Particular attention should be given to public safety, to repairability of a structure, and to usability of a structure, each as separate dimensions of performance objectives. Seismic safety is a matter of public welfare for which governmental regulation is necessary for establishing minimum standards for seismic performance. Such standards at least implicitly involve the controversial notion of "acceptable risks" to society. Determining acceptable levels of risk is a value judgement that requires collective choices about minimum standards. Knowledge of relevant risk considerations, technical details, and costs and benefits is crucial to establishing these standards. Finding the appropriate compromise between public processes and technical expertise in determining safety goals is a serious challenge. Recasting acceptable risk into a discussion of desired safety goals, the costs involved in achieving these, and the trade-offs imposed could address some of the limitations of the concept of acceptable risk.

Author:	Morgan, M. Granger; Florig, H. Keith; DeKay, Michael; Fischbeck, Paul
Title:	Categorizing risks for risk ranking
Citation:	Risk Analysis, Vol. 20, No. 1, pp. 49-57, 2000
Abstract:	Any practical process of risk ranking must group hazards into a manageable number of categories. Defining such categories requires value choices that can have important implications for the rankings that result. Most risk-management organizations will find it useful to begin defining categories in terms of environmental loadings or initial events. However, the resulting categories typically need to be modified in light of other considerations. Risk-ranking projects can benefit from considering several alternative categorization strategies and drawing upon elements of each in developing their final categorization of risks. In principle, conducting multiple ranking exercises by using different categorizations could be interesting and useful. In practice, agencies are unlikely to have either the resources or patience to do this, but other groups in society might. Done well, such additional independent rankings could add valuable inputs to democratic risk-management decision making.

Author:	Olson, Robert
Title:	Designing for tsunamis: seven principles for planning and designing for tsunami hazards
Citation:	National Tsunami Hazard Mitigation Program, California Office of Emergency Services, Sacramento, California, USA, March 2001
Abstract:	This publication describes and details a planning methodology for tsunami hazard mitigation. The purpose of these guidelines is to help coastal communities in the five Pacific states – Alaska, California, Hawaii, Oregon, and Washington – to understand their tsunami hazards, exposure, vulnerability, and to mitigate the resulting risk. This methodology contains seven major principles: • Know your communities tsunami risk • Avoid development in tsunami run-up areas • Locate and configure new development in run-up areas to minimize future losses • Design and construct new buildings to minimize tsunami damage • Protect existing development from losses • Take special precautions in locating and designing critical infrastructure and facilities • Plan for evacuation. While it was written for U.S. communities but is applicable to other countries as well.

Author:	Slovic, Paul
Title:	The perception of risk
Citation:	Earthscan Publishers, London and Sterling, VA, USA, 2000
Abstract:	This publication is the result of 25 years of the author's research on perception of risk. It is a collection of chapters, written by the author and/or other collaborators, dealing with decision processes, the psychology of risk perception, societal risk taking, specific risks, the value of human life, and risk-benefit evaluation. The discussions are done within the context of a general approach and theoretical framework embedded as the "psychometric paradigm," that assumes risk is subjectively defined by individuals who may be influenced by a wide array of psychological, social, institutional, and cultural factors.

APPENDIX B: Key Person Interviews

PROJECT INTERVIEW GUIDE FOR CUREE-KAJIMA PROJECT

EARTHQUAKE RISK UNDERSTANDING AND MITIGATION DECISION-MAKING

Instructions

Provide the person(s) to be interviewed with a copy of this guide before the interviews so they can think about their answers. If advance time permits, ask them to return the completed guide before the interview. The interview then can focus on understanding their answers, talking about their additional ideas, and gathering other information that may come from the discussions. If advance time is not available, use this guide during the interview. In every case, carefully listen for and make note of other ideas or experiences.

Purpose and Goal of Project

Resistance to investing in earthquake hazard mitigation, such as strengthening or replacing existing buildings and facilities, is common in both Japan and the U.S. The challenge is to find effective ways to change values so hazard prevention becomes an important social goal that results in decision-makers giving higher priority and greater resources to mitigation.

The project's goal is to develop qualitative and quantitative models for portraying earthquake risk perceptions and knowledge at the individual, group/company, and community levels that demonstrate how the various elements of risk perception and education and/or knowledge affect decisions to take or invest in mitigation actions, especially the strengthening or replacing of existing buildings and facilities.

The important questions we are interested in answering as a result of the interviews and other project work include: (1) Why do some decision-makers adopt or reject new technologies? (2) Who is involved in these decisions, and what are their roles and responsibilities? (3) What strategies are used in promoting commitments to loss prevention? and (4) What barriers must be overcome so investments are made in mitigation?

Purpose of This Interview

We are interviewing a small group of practitioners and researchers to help us identify and rate the relative importance of the many factors/variables that affect decisions to prevent future earthquake losses. The answers will help us develop ideas for strategies, techniques, and materials that could be developed to increase a commitment to loss prevention.

Structure of This Interview

We will follow a set of simple steps important to mitigation decision-making. They are:

RISK PERCEPTION/KNOWLEDGE>COMMITMENT>PLACE ON DECISION AGENDA>DECISION>ALLOCATION OF RESOURCES>ACTION.

For each step we will ask you to comment first on the validity of each statement we make. If you consider it valid, then we will ask you to rate its importance to decision-making by answering “Very Important,” “Important,” or “Not Very Important.” If you consider any statement to be not valid, we skip to the next statement. At the end of each step we will ask you for other ideas so we get a complete list as possible of factors that influence mitigation decision-making.

STEP 1: RISK PERCEPTION/KNOWLEDGE

a. Decision-makers need to understand the concept of “low probability-high consequence” events.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

b. Decision-makers should understand earthquake risk in general terms.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

c. Decision-makers depend primarily on staff and consultants for risk information.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

d. Decision-makers depend primarily on external sources of risk information and then bring it to their organization for consideration.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

e. Decision-makers need to understand how the potential impacts of earthquakes will affect their organization’s facilities and operations.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

Notes:

STEP 2: COMMITMENT

a. Decision-makers need to understand how receptive the organization is to change and innovation in general.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

b. Decision-makers need to know what similar organizations are doing or have done.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

c. Decision-makers need to know if their organization is required by others to take action.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

d. Decision-makers need to know the consequences of their not taking actions to prevent losses.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

e. Decision-makers need to know if their competitors are taking measures to prevent losses.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

f. Decision-makers need to know the practical range of alternatives available for preventing losses.

Valid____ or not valid____? If valid, is this statement: Very Important____ Important_____Not Very Important______ to decision-making?

Notes:

STEP 3: PLACE ON DECISION AGENDA

a. Someone must have sufficient influence to get the subject of hazard mitigation on the organization's decision agenda.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

b. Someone must be responsible for organizing and presenting the risk information in ways that lead to a decision (not just interesting information).

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

c. Someone must manage the process and understand that getting loss prevention on the agenda may mean that other subjects may not be considered.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

d. Someone must present a "plan" to show what work will be accomplished, how, by whom, for how much money, and over what length of time.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

e. Someone must realize that the item may be deferred or assigned further study that could lead to later consideration.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

f. Someone should realize that external factors unknown to them might affect decisions.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

Notes:

STEP 4: DECISION (ASSUME "YES" FOR INTERVIEW PURPOSES)

a. Decision-makers need to assign a "program/project manager or leader."

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

b. The assigned project manager must have access to decision-makers during the entire length of the program.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

c. Decision-makers should see how this commitment "fits" into other strategies and commitments so multiple goals can be achieved efficiently.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

d. Decision-makers must ensure their organization has the financial and organizational capacities to invest in hazard mitigation

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

Notes:

STEP 5: ALLOCATION OF RESOURCES

a. Implementers must ensure that organizational resources are made available to support the policy decisions.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

b. Implementers should know about and use any available incentives or subsidies to help offset the costs of mitigation.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

c. Implementers must ensure that, however measured, the prospective benefits of investing in loss prevention actions exceed the expected full range of losses.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

d. Implementers must have “good” estimates of project costs over the life of the project.

Valid____ or not valid____? If valid, is this statement: Very Important____
Important_____Not Very Important______ to decision-making?

Notes:

STEP 6: ACTIONS

a. Implementers should be able to demonstrate how their actions support their organization's plans and goals.

Valid____ or not valid____? <u>If valid, is this statement</u>: Very Important____
Important_____Not Very Important______ to decision-making?

b. Implementers must ensure the needed technical expertise is available.
Valid____ or not valid____? <u>If valid, is this statement</u>: Very Important____
Important_____Not Very Important______ to decision-making?

c. Implementers must develop detailed plans to ensure the work is accomplished.

Valid____ or not valid____? <u>If valid, is this statement</u>: Very Important____
Important_____Not Very Important______ to decision-making?

d. Implementers must ensure that feedback is provided regularly so the program remains visible to the decision-makers.
Valid____ or not valid____? <u>If valid, is this statement</u>: Very Important____
Important_____Not Very Important______ to decision-making?

e. Implementers must set priorities based on project needs, especially where multiple locations or facilities are concerned.

Valid____ or not valid____? <u>If valid, is this statement</u>: Very Important____
Important_____Not Very Important______ to decision-making?

f. Implementers must be able to explain the unexpected complications that may arise so adjustments can be made.

Valid____ or not valid____? <u>If valid, is this statement</u>: Very Important____
Important_____Not Very Important______ to decision-making?

<u>Notes:</u>

CUREE (U.S.) Team Interview Subjects

Subject	Profession	Expertise
A	President of Small Structural Engineering Consultancy	Is involved in seismic retrofit projects for small and medium-size organizations, largely in California.
B	Property Owner	Owner of several apartment buildings and commercial buildings in Los Angeles. Faces seismic retrofit issues often. Is also a mechanical & structural building contractor.
C	Vice President of a very large nationwide engineering company	Is involved with seismic projects, both new and retrofit, for medium and large clients.
D	Principal of a medium-size engineering firm	Is involved in seismic retrofit projects for small and medium-size organizations, largely in California. Is also very involved in earthquake engineering research.
E	Principal of a small engineering consultancy	Is involved in seismic issues for small projects, largely in California where seismic issues dominate.
F	Principal of a large earthquake engineering company	Is involved with hazard mitigation, including all natural and man-made hazards. Is very involved with seismic code development.

CUREE-Kajima Risk Perception Project
Results of U.S. Interviews
R. Nigbor and R. Olson, 10 May 2002

(VI= very important, I = important, NI = not very important)

Question	Subject A					Subject B				
	Valid	Not Valid	VI	I	NI	Valid	Not Valid	VI	I	NI
1a	1			1		1		1		
1b	1			1		1			1	
1c	1			1		1		1		
1d	1			1		1			1	
1e	1			1		1		1		
2a		1					1			
2b	1				1	1		1		
2c	1			1		1		1		
2d	1			1		1		1		
2e	1				1	1		1		
2f	1		1			1				1
3a	1		1			1			1	
3b	1		1				1			
3c	1		1			1			1	
3d	1		1			1			1	
3e				1		1				1
3f	1			1		1				1
4a	1		1			1			1	
4b	1			1		1		1		
4c	1			1		1			1	
4d	1			1		1		1		
5a	1			1		1		1		
5b	1		1			1			1	
5c	1			1		1			1	
5d	1			1		1			1	
6a	1			1		1			1	
6b	1		1			1		1		
6c	1			1		1			1	
6d	1			1		1		1		
6e	1		1			1			1	
6f	1		1			1			1	

CUREE-Kajima Risk Perception Project
Results of U.S. Interviews
R. Nigbor and R. Olson, 10 May 2002

(VI= very important, I = important, NI = not very important)

Question	Subject C					Subject D				
	Valid	Not Valid	VI	I	NI	Valid	Not Vali	VI	I	NI
1a	1		1			1		1		
1b	1		1			1			1	
1c	1		1			1				1
1d	1			1		1				1
1e	1		1			1		1		
2a	1		1			1			1	
2b	1			1		1			1	
2c	1		1			1		1		
2d	1		1			1		1		
2e	1			1		1			1	
2f	1		1			1		1		
3a	1		1			1		1		
3b	1		1			1		1		
3c	1		1			1			1	
3d	1		1			1			1	
3e	1			1		1				1
3f	1				1	1				1
4a	1		1			1		1		
4b	1		1			1			1	
4c	1		1			1				1
4d	1			1		1		1		
5a	1		1			1		1		
5b	1		1			1				1
5c	1			1		1				1
5d	1			1		1			1	
6a	1		1			1			1	
6b	1		1			1				1
6c	1		1			1				1
6d		1				1				1
6e	1		1			1		1		
6f	1		1			1				1

CUREE-Kajima Risk Perception Project
Results of U.S. Interviews
R. Nigbor and R. Olson, 10 May 2002

(VI= very important, I = important, NI = not very important)

Question	Subject E					Subject F				
	Valid	Not Valid	VI	I	NI	Valid	Not Valid	VI	I	NI
1a	1		1			1				1
1b	1			1		1				1
1c	1			1		1			1	
1d		1					1			
1e	1		1			1		1		
2a	1			1		1			1	
2b	1		1			1			1	
2c	1		1			1		1		
2d	1		1			1		1		
2e	1			1		1			1	
2f	1			1		1		1		
3a	1			1		1			1	
3b	1		1			1		1		
3c	1			1		1		1		
3d	1		1			1		1		
3e	1			1		1			1	
3f	1			1		1				1
4a	1			1		1			1	
4b	1		1			1			1	
4c	1			1		1			1	
4d	1			1		1		1		
5a	1			1		1		1		
5b	1			1		1			1	
5c		1				1			1	
5d	1			1		1			1	
6a	1			1		1		1		
6b	1			1		1			1	
6c	1			1		1			1	
6d	1			1		1			1	
6e	1		1				1			
6f	1			1		1			1	

CUREE-Kajima Risk Perception Project
Results of U.S. Interviews
R. Nigbor and R. Olson, 10 May 2002

(VI= very important, I = important, NI = not very important)

Question	TOTALS				
	Valid	Not Valid	VI	I	NI
1a	6	0	4	1	1
1b	6	0	1	4	1
1c	6	0	2	3	1
1d	4	2	0	3	1
1e	6	0	5	1	0
2a	4	2	1	3	0
2b	6	0	2	3	1
2c	6	0	5	1	0
2d	6	0	5	1	0
2e	6	0	1	4	1
2f	6	0	4	1	1
3a	6	0	3	3	0
3b	5	1	5	0	0
3c	6	0	3	3	0
3d	6	0	4	2	0
3e	5	0	0	4	2
3f	6	0	0	2	4
4a	6	0	3	3	0
4b	6	0	3	3	0
4c	6	0	1	4	1
4d	6	0	3	3	0
5a	6	0	4	2	0
5b	6	0	2	3	1
5c	5	1	0	4	1
5d	6	0	0	6	0
6a	6	0	2	4	0
6b	6	0	3	2	1
6c	6	0	1	4	1
6d	5	1	1	3	1
6e	5	1	4	1	0
6f	6	0	2	3	1

Kajima (Japan) Team Interview Subjects

Subject	Organization	Profession
JA	a large department store	Chief of the facility safety management section of the general affairs department
JB	a large beer company	Executive producer of the quality planning department
JC	a large shopping center	Manager in charge of large-scale disaster prevention
JD	an electric power development company	Deputy manager of the construction group of the nuclear electric power business department
JE	a large car company	Section chief of the general affairs department
JF	a electric power company	Group manager of the seismic design group of the Engineering R&D Division

TABLE : KAJIMA Interview Data

(VI= very important, I = important, NI = not very important)

Step	Question	Subject A					Subject B				
		Valid	Not Valid	VI	I	NI	Valid	Not Valid	VI	I	NI
1	1a	1		1			1			1	
	1b	1		1			1			1	
	1c		1				1			1	
	1d	1			1		1				1
	1e	1		1			1		1		
2	2a	1		1			1			1	
	2b		1				1				1
	2c	1				1	1			1	
	2d	1		1			1			1	
	2e		1				1				1
	2f	1			1		1				1
3	3a	1				1	1		1		
	3b	1		1			1		1		
	3c	1			1		1				1
	3d	1		1			1			1	
	3e	1			1		1				1
	3f	1			1		1			1	
4	4a	1		1			1			1	
	4b	1		1			1			1	
	4c	1		1			1			1	
	4d	1			1		1		1		
5	5a	1			1		1			1	
	5b	1			1		1				1
	5c	1		1			1			1	
	5d	1		1			1			1	
6	6a	1			1		1			1	
	6b	1		1			1		1		
	6c	1		1			1			1	
	6d	1		1			1			1	
	6e	1		1			1			1	
	6f	1			1		1			1	

TABLE : KAJIMA Interview Data

(VI= very important, I = important, NI = not very important)

Step	Question	Subject C					Subject D				
		Valid	Not Valid	VI	I	NI	Valid	Not Val	VI	I	NI
1	1a	1		1			1		1		
	1b	1				1	1				1
	1c	1		1			1			1	
	1d	1				1	1				1
	1e	1		1			1		1		
2	2a	1		1			1		1		
	2b		1				1			1	
	2c	1		1			1			1	
	2d	1			1		1		1		
	2e		1				1			1	
	2f	1		1			1		1		
3	3a	1		1			1		1		
	3b	1		1			1		1		
	3c	1		1			1				1
	3d	1		1			1		1		
	3e		1				1				1
	3f	1				1	1				1
4	4a	1		1			1			1	
	4b	1		1			1		1		
	4c	1		1			1		1		
	4d	1		1			1			1	
5	5a	1		1			1			1	
	5b	1		1			1		1		
	5c	1		1			1		1		
	5d	1		1			1			1	
6	6a	1		1			1			1	
	6b	1		1			1			1	
	6c	1				1	1			1	
	6d	1			1		1		1		
	6e	1		1			1		1		
	6f	1		1			1				1

TABLE : KAJIMA Interview Data

(VI= very important, I = important, NI = not very important)

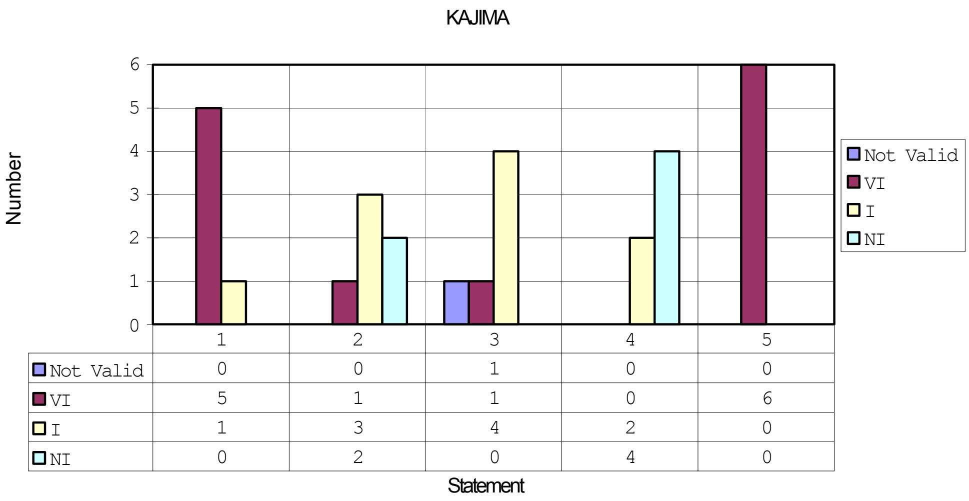
Step	Question	Subject E					Subject F				
		Valid	Not Valid	VI	I	NI	Valid	Not Valid	VI	I	NI
1	1a	1		1			1		1		
	1b	1			1		1			1	
	1c	1			1		1			1	
	1d	1			1		1				1
	1e	1		1			1		1		
2	2a	1				1	1		1		
	2b	1				1	1			1	
	2c	1				1	1			1	
	2d	1			1		1		1		
	2e	1				1	1			1	
	2f	1			1		1		1		
3	3a	1			1		1		1		
	3b	1			1		1			1	
	3c	1			1		1			1	
	3d	1			1		1			1	
	3e	1			1		1			1	
	3f	1			1		1			1	
4	4a	1			1		1		1		
	4b	1			1		1			1	
	4c	1			1		1			1	
	4d	1			1		1			1	
5	5a	1				1	1			1	
	5b	1			1		1		1		
	5c	1		1			1		1		
	5d	1			1		1		1		
6	6a	1			1		1		1		
	6b	1				1	1			1	
	6c	1			1		1			1	
	6d	1			1		1		1		
	6e	1		1			1			1	
	6f	1			1		1			1	

TABLE : KAJIMA Interview Data

(VI= very important, I = important, NI = not very

Step	Question	TOTALS				
		Valid	Not Valid	VI	I	NI
1	1a	6	0	5	1	0
	1b	6	0	1	3	2
	1c	5	1	1	4	0
	1d	6	0	0	2	4
	1e	6	0	6	0	0
2	2a	6	0	4	1	1
	2b	4	2	0	2	2
	2c	6	0	1	3	2
	2d	6	0	3	3	0
	2e	4	2	0	2	2
	2f	6	0	3	2	1
3	3a	6	0	4	1	1
	3b	6	0	4	2	0
	3c	6	0	1	3	2
	3d	6	0	3	3	0
	3e	5	1	0	3	2
	3f	6	0	0	4	2
4	4a	6	0	3	3	0
	4b	6	0	3	3	0
	4c	6	0	3	3	0
	4d	6	0	2	4	0
5	5a	6	0	1	4	1
	5b	6	0	3	2	1
	5c	6	0	5	1	0
	5d	6	0	3	3	0
6	6a	6	0	2	4	0
	6b	6	0	3	2	1
	6c	6	0	1	4	1
	6d	6	0	3	3	0
	6e	6	0	4	2	0
	6f	6	0	1	4	1

Comparison of U.S. and Japan Results:
Step 1 Risk perception/knowledge



	1	2	3	4	5
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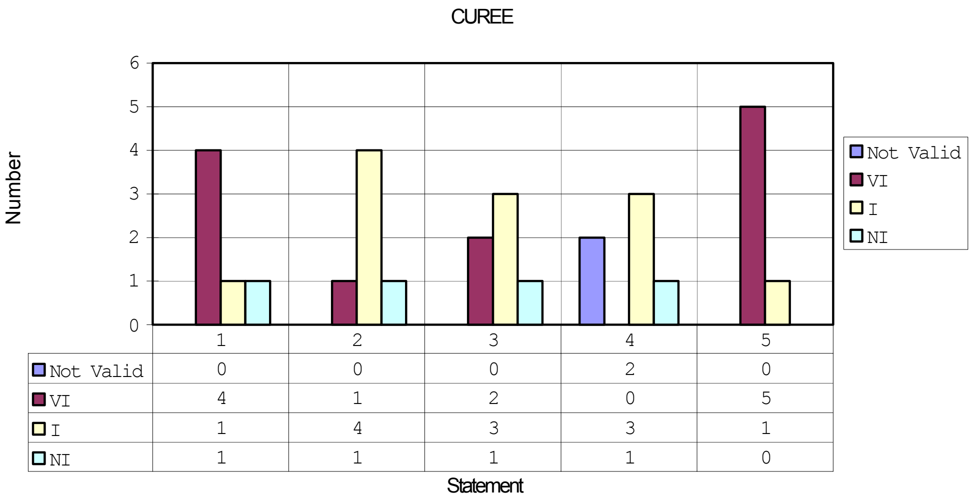
VI	5	1	1	0	6
I	1	3	4	2	0
NI	0	2	0	4	0



	1	2	3	4	5
Not Valid	0	0	0	2	0
VI	4	1	2	0	5
I	1	4	3	3	1
NI	1	1	1	1	0

Remarkable points : Same tendency between Japan and US can be seen

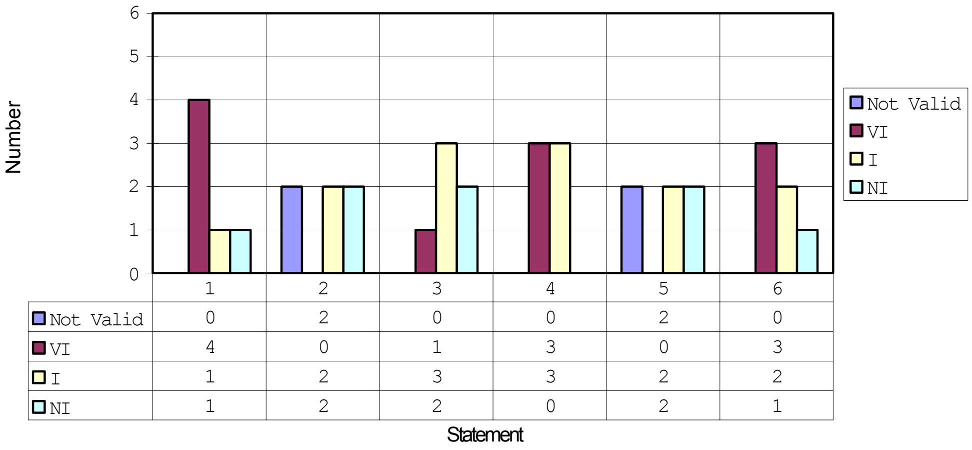
・In Japan and US, DMs need to understand concept of "low probability-high consequence" events (1)

・In Japan and US, DMs does not depend primarily on external sources of risk information (4)

・In Japan and US, DMs need to understand impacts of earthquakes on own facilities and operation (5)

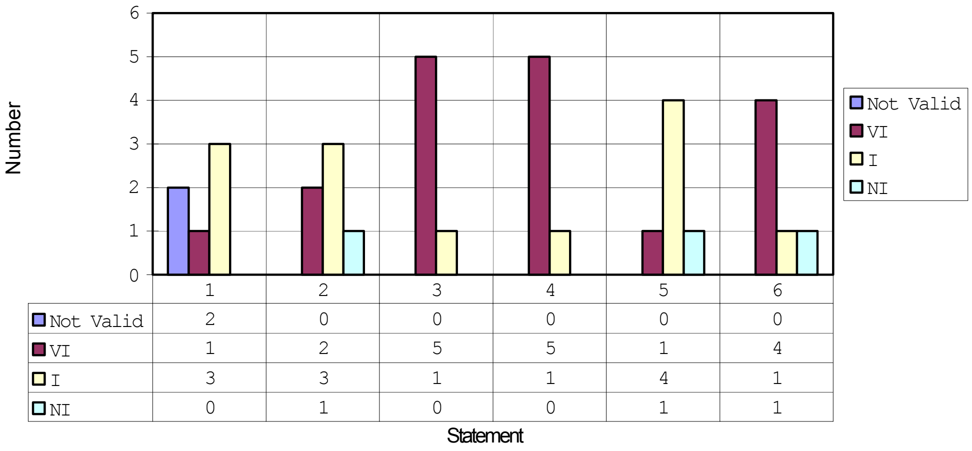
Comparison of U.S. and Japan Results:
Step 2 Commitment

KAJIMA



	1	2	3	4	5	6
Not Valid	0	2	0	0	2	0
VI	4	0	1	3	0	3
I	1	2	3	3	2	2
NI	1	2	2	0	2	1

CUREE



	1	2	3	4	5	6
Not Valid	2	0	0	0	0	0
VI	1	2	5	5	1	4
I	3	3	1	1	4	1
NI	0	1	0	0	1	1

Remarkable points : Different points can be seen

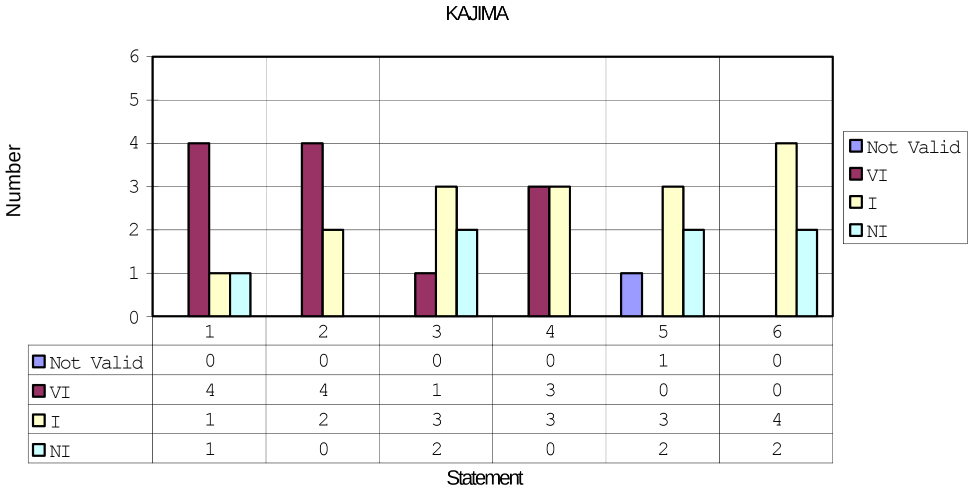
・In Japan, DMs need to understand how receptive the organization is to change and innovate. In US, DMs do not need it (1)

・In Japan, DMs does not need to know what similar organizations are doing or have done. In US, DMs need it. (2)

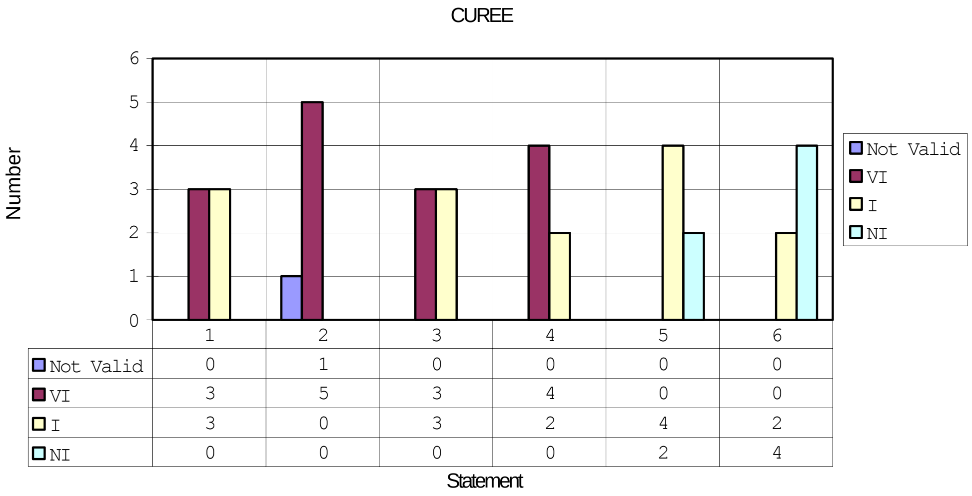
・In US, DMs need to know if their organization is required by others to take action and the concequences of their not taking actions to prevent losses. (3,4)

・In Japan, DMs does not need to know if their competitors are taking measures to prevent losses (5)

Comparison of U.S. and Japan Results:
Step 3 Place on decision agenda


KAJIMA

	1	2	3	4	5	6
Not Valid	0	0	0	0	1	0
VI	4	4	1	3	0	0
I	1	2	3	3	3	4
NI	1	0	2	0	2	2


CUREE

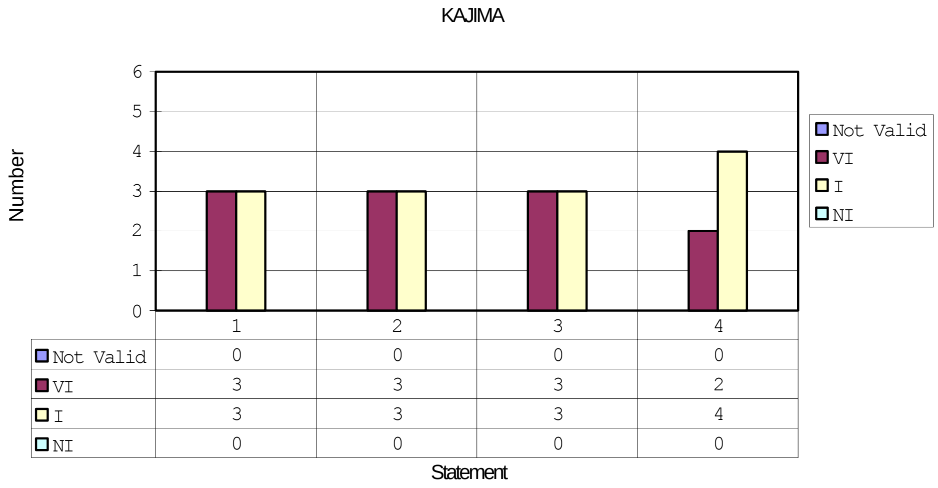
	1	2	3	4	5	6
Not Valid	0	1	0	0	0	0
VI	3	5	3	4	0	0
I	3	0	3	2	4	2
NI	0	0	0	0	2	4

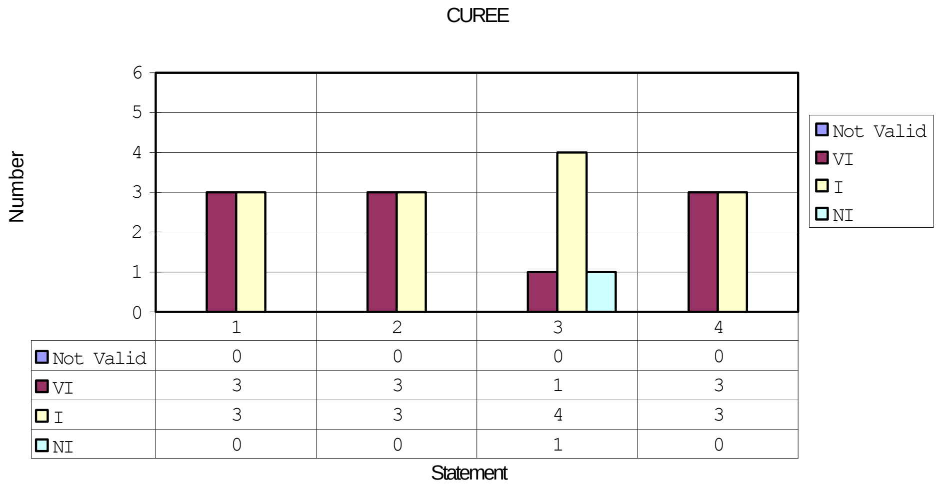
Remarkable points : Same tendency between Japan and US can be seen

・In Japan and US, someone must have sufficient influence to get the subject of hazard mitigation on the organization's decision agenda (1)

・In Japan and US, someone must be responsible for organizing and presenting the risk information that lead to a decision (2)
・In US, someone must manage the process and understand that getting loss prevention on the agenda may mean that other subjects may not be considered (3)
・In Japan and US, someone does not need to realize that loss prevention may be deferred or assigned further study (5)

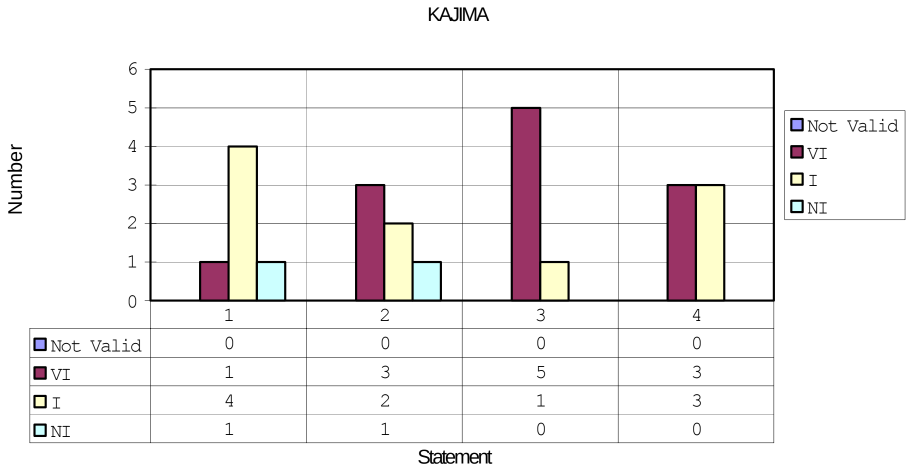
Comparison of U.S. and Japan Results:
Step 4 Decision



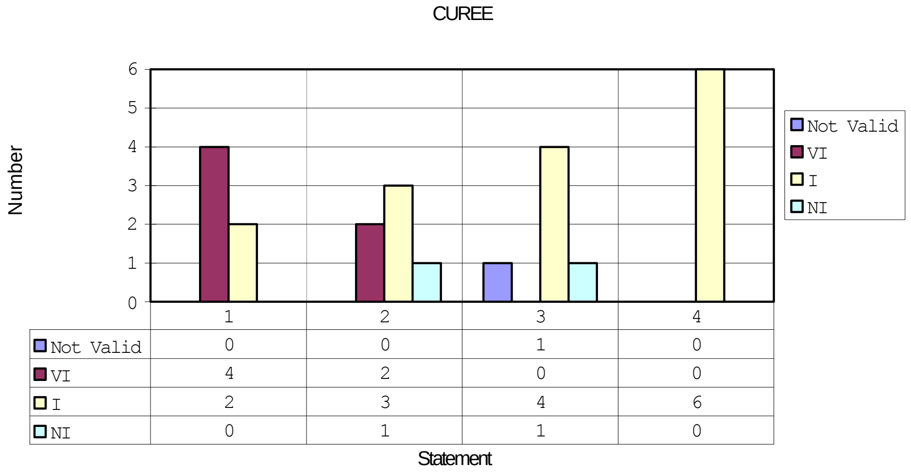


No remarkable points

Comparison of U.S. and Japan Results:
Step 5 Allocation of resources



	1	2	3	4
■ Not Valid	0	0	0	0
■ VI	1	3	5	3
■ I	4	2	1	3
■ NI	1	1	0	0



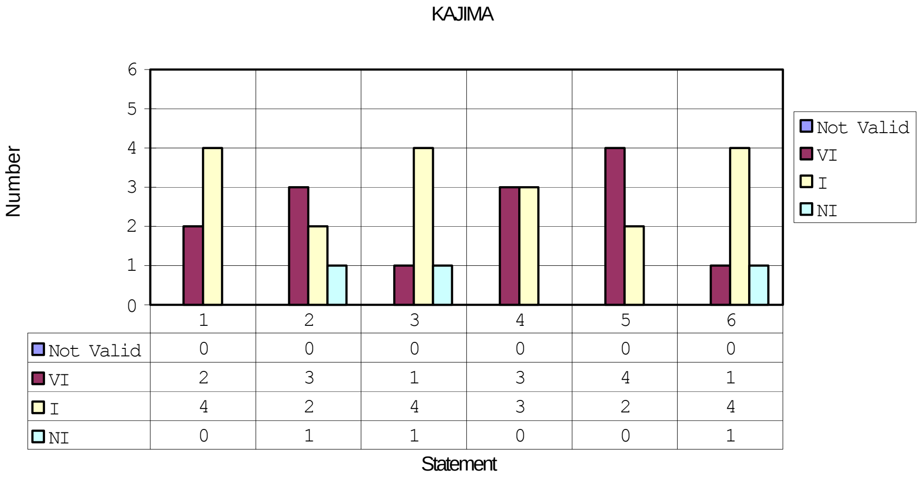
	1	2	3	4
■ Not Valid	0	0	1	0
■ VI	4	2	0	0
■ I	2	3	4	6
■ NI	0	1	1	0

Remarkable points : Different points can be seen

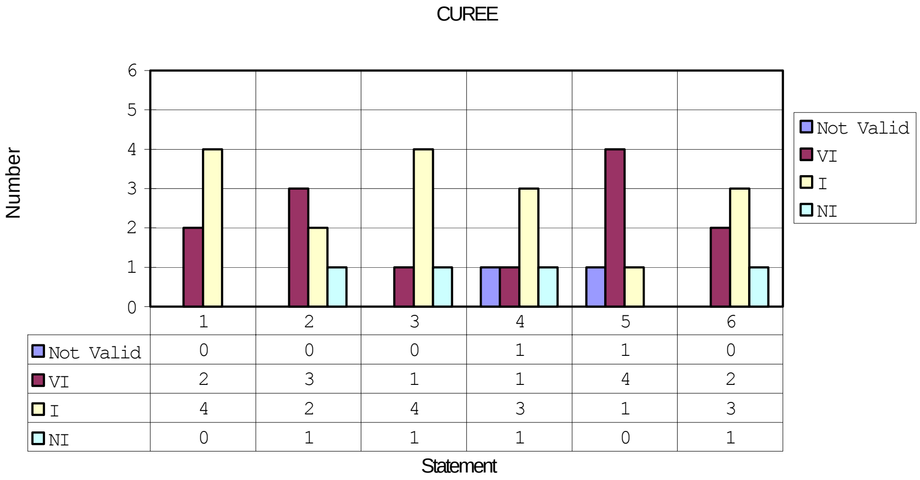
・In US, implementers must ensure that organizational resources are made available to support the policy decisions (1)

・In Japan, implementers must ensure that the prospective benefits of investing in loss prevention actions exceed the expected losses (3)

Comparison of U.S. and Japan Results:
Step 6 Action



Statement	1	2	3	4	5	6
Not Valid	0	0	0	0	0	0
VI	2	3	1	3	4	1
I	4	2	4	3	2	4
NI	0	1	1	0	0	1



Statement	1	2	3	4	5	6
Not Valid	0	0	0	1	1	0
VI	2	3	1	1	4	2
I	4	2	4	3	1	3
NI	0	1	1	1	0	1

Remarkable points : Common and different points can be seen

・In Japan, implementers must ensure that feedback is provided regularly so the program remains visible to the DMs (4)

・In Japan and US, implementers must set priorities where multiple locations or facilities are concerned (5)

APPENDIX C: Workshop Summary and Results

The CUREE-Kajima Workshop on a Community Earthquake Risk Reduction Model was held on May 16, 2002 at Kajima Corporation's KI Building in Tokyo. The purpose of this workshop was threefold: 1) to discuss earthquake risk perception in the U.S. and Japan; 2) to discuss a proposed model framework for mitigation decisions and community earthquake risk reduction; and 3) to obtain "expert opinion" on key modeling issues to assist with further model development.

Workshop Participants

Kajima Corporation and Guests

Akira Endoh, Kajima Technical Research Institute
Taichi Goto, Avant/ComPus
Yasufumi Iseki, Engineering and Risk Services Corporation
Hiroshi Ishida, Kajima Technical Research Institute
Takuji Kobori, Kobori Research Complex
Narito Kurata, Kobori Research Complex
N. Kusano, Engineering and Risk Services Corporation
Masamitsu Miyamura, Kobori Research Complex; co-Chair
Kaoru Mizukoshi, Kajima Technical Research Institute
Y. Sasaki, Kajima Corporation
Y. Takahashi, Kajima Corporation
Kazuaki Torisawa, Kajima Technical Research Institute

CUREE Representatives

John Adams, RAND Corporation
Wilfred Iwan, CUREE Board Member, Caltech
Robert Nigbor, University of Southern California, co-Chair
Robert Olson, Robert Olson Associates

Workshop Venue and Agenda

The workshop was held in the Kajima KI Building in Akasaka on May 16, 2002. Prior to the workshop, on May 15, was a planning meeting attended by the project investigators. A post-workshop investigators meeting was also held on May 16 to help summarize the results.

Following is the workshop agenda:

10:00	Introductions
10:15	Opening remarks by Mizukoshi and Nigbor
10:30	Earthquake Risk Perception Background: Olson
11:00	Results of Interviews in US: Nigbor/Olson
11:30	Results of Interviews in Japan: Kurata
12:00	Lunch
13:00	Case Study of Community Management: Goto
13:15	Statistical Modeling of Social Issues: Adams
14:00	The GHI Model for Community Earthquake Safety: Iwan
14:00	The PEER Framework Model for PBEE: Nigbor
14:15	A Framework Model for Earthquake Risk Perception: Nigbor/Olson
15:00	Break
15:15	Guided group discussion using the Rand Method
17:00	Summary and closing comments
17:30	Close Workshop

Guided Group Discussion Using a Modified Delphi Method

Dr. Adams led the group in an "expert opinion" exercise to explore some aspects of the Framework Model proposed by Prof. Nigbor. This discussion used a "Modified Delphi" method for extracting expert opinion from groups through a process of repeated anonymous polling/questioning and discussions.

The group was provided with a scenario as follows:

> *Assume you are responsible for a high-rise steel office building owned and used by your own company in your home country. Below is a list of types of information that might be useful to support your decisions to reduce seismic risk. Please score the information in two dimensions:*
>
> *Importance: How important would this information be to your decision making if it were available? Score the information on a 1-9 scale with 1="very unimportant" and 9="very important."*
>
> *Feasibility: How feasible do you think it would be to obtain this information in a usable form? Score the information on a 1-9 scale with 1="not feasible" and 9="very feasible."*

A series of 21 questions was then posed in writing, and the participants were asked to respond individually and anonymously. In the brief time period for this discussion, there was time for only an initial polling, discussions, and a final polling. Appendix B contains the questionnaire used in this guided discussion and plots of the results of the final polling.

More than half of the 21 information types in the survey were considered to be important (importance >7) in the final polling. These are the variables that should be considered in modeling of a decision-making process for this scenario.

The final questionnaire for this exercise and the results of the final polling are included in this Appendix below.

Appropriateness Information Survey
CUREE-Kajima Community Risk Reduction Model Project
16 May 2002

Final Workshop Survey

Scenario:
Assume you are responsible for a high-rise steel office building owned and used by your own company in your home country. Below is a list of types of information that might be useful to support your decisions to reduce seismic risk.

Please score the information in two dimensions:

Importance: How important would this information be to your decision making if it were available? Score the information on a 1-9 scale with 1=”very unimportant” and 9=”very important.”

Feasibility: How feasible do you think it would be to obtain this information in a usable form? Score the information on a 1-9 scale with 1=”not feasible” and 9=”very feasible.”

Please do not confer with your colleagues before answering. This survey is anonymous. Responses will not be identified by respondent.

Scales:

Importance:

1 <-very unimportant <-------neutral-------→very important-> 9

Feasibility:

1 <-not feasible <-------neutral-------→very feasible-> 9

What is your home country?

Japan- US (circle one)

Engineering information

1) General information about potential seismic events in your region (expected frequency of occurrence and magnitude.)

___ Importance (1-9) ___ Feasibility (1-9)

2) General information about the potential earthquake damage to buildings of this type.

___ Importance (1-9) ___ Feasibility (1-9)

3) Detailed information about the potential damage to buildings of this type by magnitude of earthquake.

___ Importance (1-9) ___ Feasibility (1-9)

4) Specific information about the condition of your building.

___ Importance (1-9) ___ Feasibility (1-9)

5) Information about available technologies for steel building seismic retrofit.

___ Importance (1-9) ___ Feasibility (1-9)

Business Economics

6) Costs of various retrofit options.

___ Importance (1-9) ___ Feasibility (1-9)

7) Performance of various retrofit options.

___ Importance (1-9) ___ Feasibility (1-9)

8) Estimated loss of life at various levels of damage.

___ Importance (1-9) ___ Feasibility (1-9)

9) Estimated costs of repairing various levels of damage.

___ Importance (1-9) ___ Feasibility (1-9)

10) Estimated costs of temporary space during repair.

___ Importance (1-9) ___ Feasibility (1-9)

11) Estimated costs of lost business during repair.

___ Importance (1-9) ___ Feasibility (1-9)

12) Availability and cost of insurance for losses by category of loss (e.g. Capital, business interruption.)

___ Importance (1-9) ___ Feasibility (1-9)

13) Future cost of capital.

___ Importance (1-9) ___ Feasibility (1-9)

14) Value of alternative investments.

___ Importance (1-9) ___ Feasibility (1-9)

Legal/Political

15) Estimated legal liability for potential injury and loss of life during future earthquakes.

___ Importance (1-9) ___ Feasibility (1-9)

16) Current regulations requiring seismic mitigation.

___ Importance (1-9) ___ Feasibility (1-9)

17) Future regulations requiring seismic mitigation.

___ Importance (1-9) ___ Feasibility (1-9)

18) Expected government financial relief at various levels of damage.

___ Importance (1-9) ___ Feasibility (1-9)

Social

19) Community pressures for mitigation action.

___ Importance (1-9) ___ Feasibility (1-9)

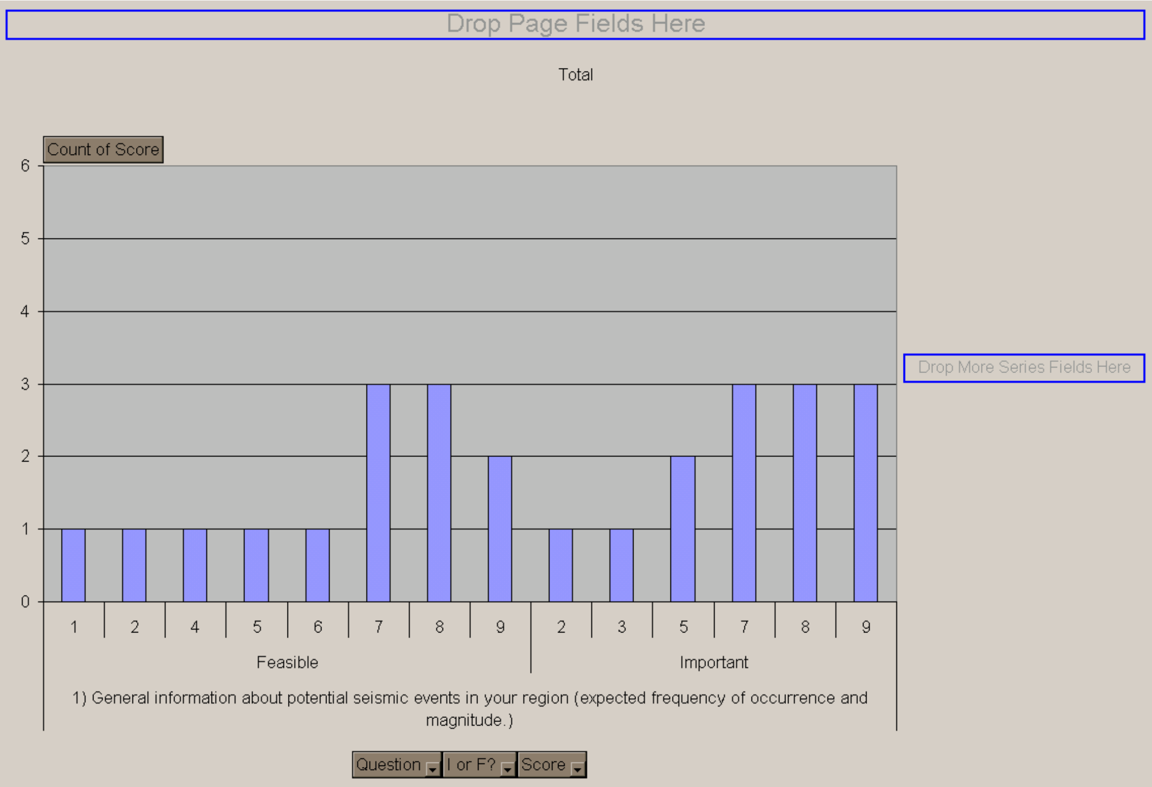
20) Worker pressures for mitigation action.

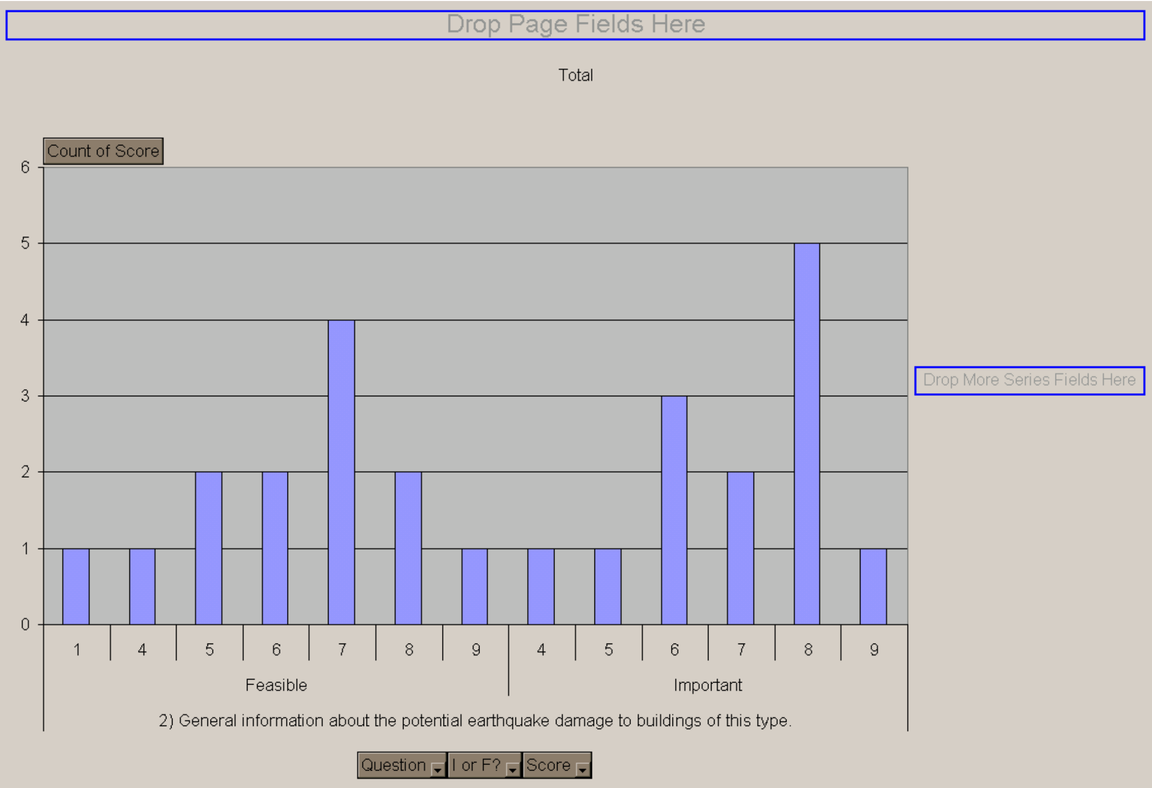
___ Importance (1-9) ___ Feasibility (1-9)

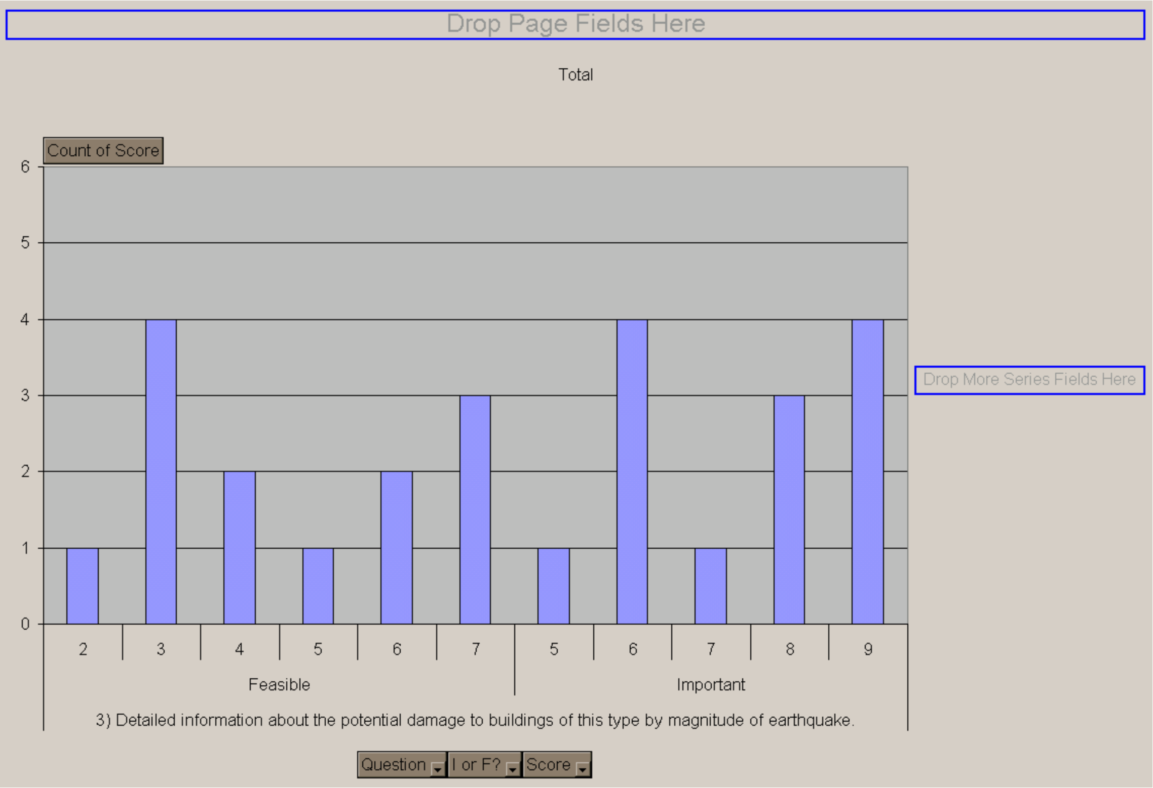
21) Corporate pressures for mitigation action.

___ Importance (1-9) ___ Feasibility (1-9)

RESULTS OF FINAL MODIFIED DELPHI METHOD SURVEY



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3) Detailed information about the potential damage to buildings of this type by magnitude of earthquake.
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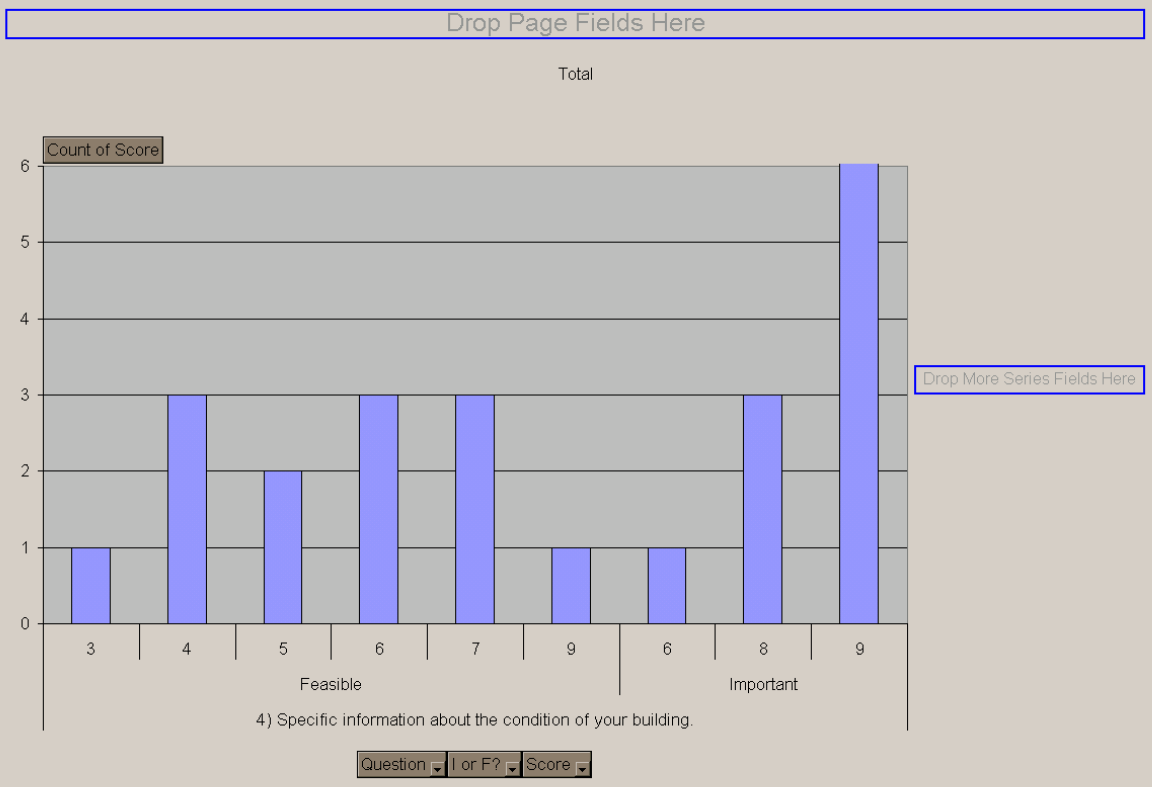
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4) Specific information about the condition of your building.
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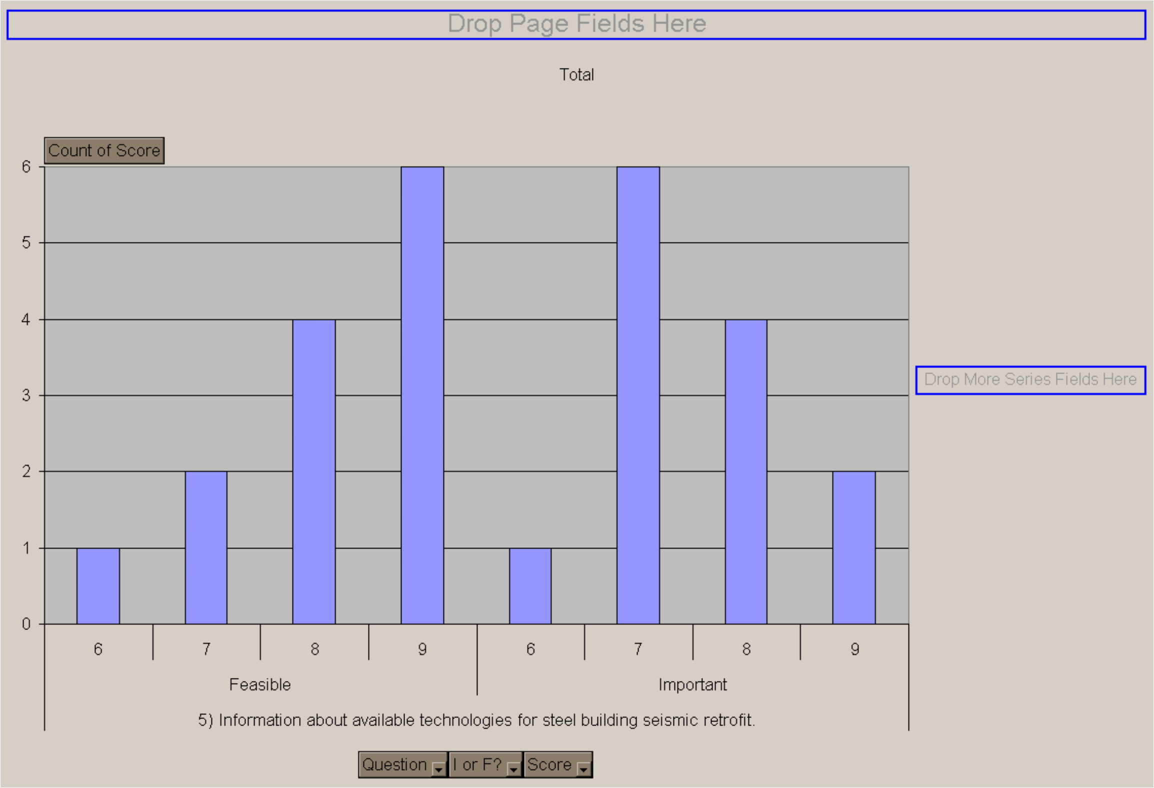
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5) Information about available technologies for steel building seismic retrofit.
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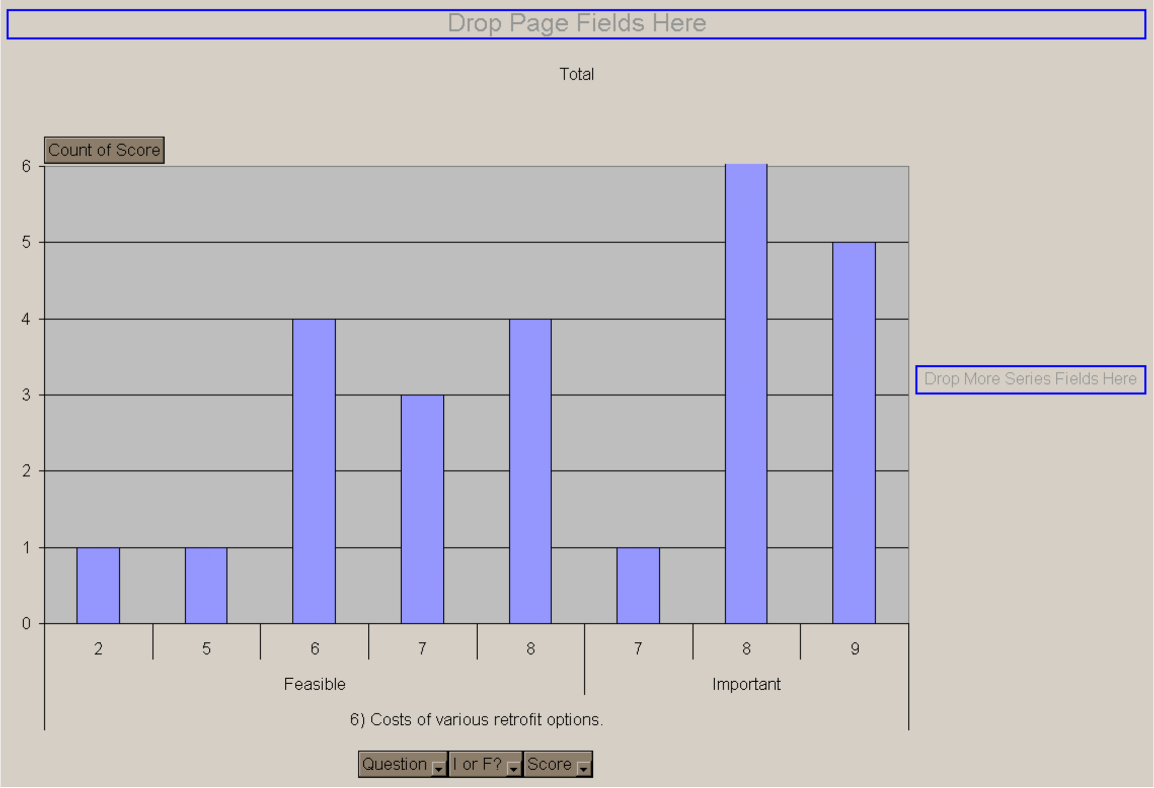
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6) Costs of various retrofit options.
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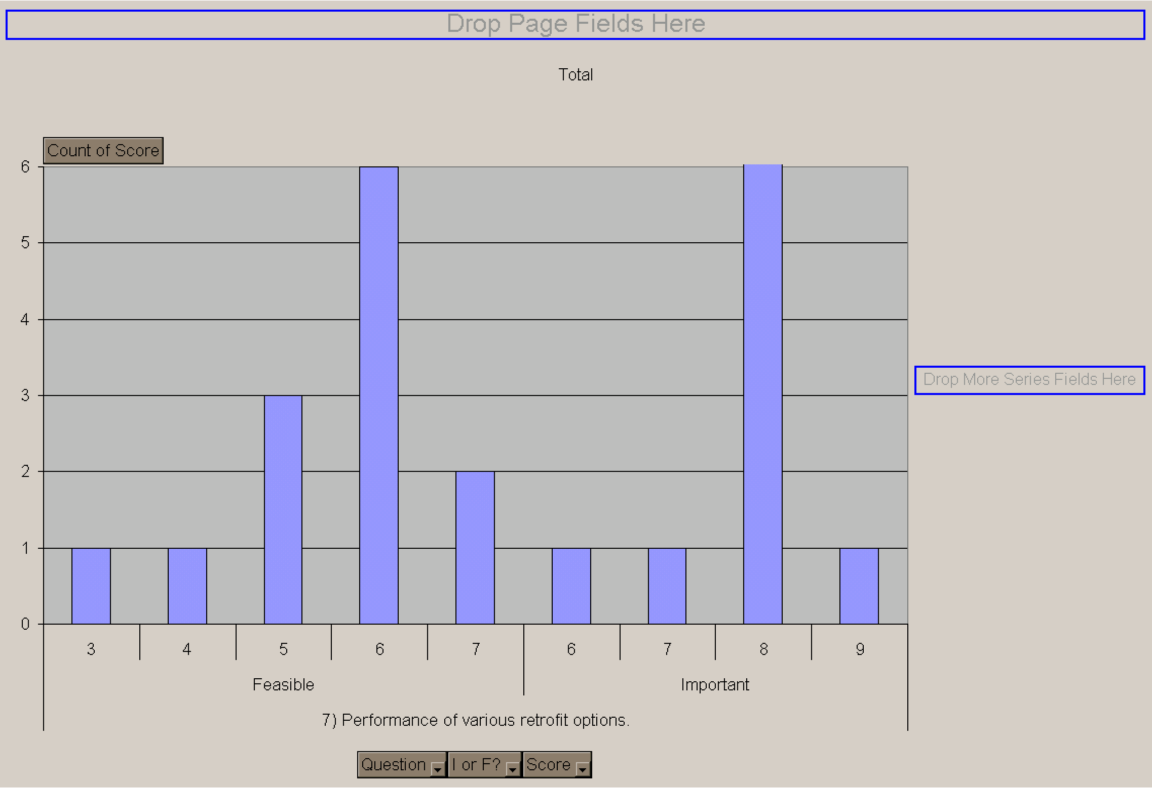
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7) Performance of various retrofit options.
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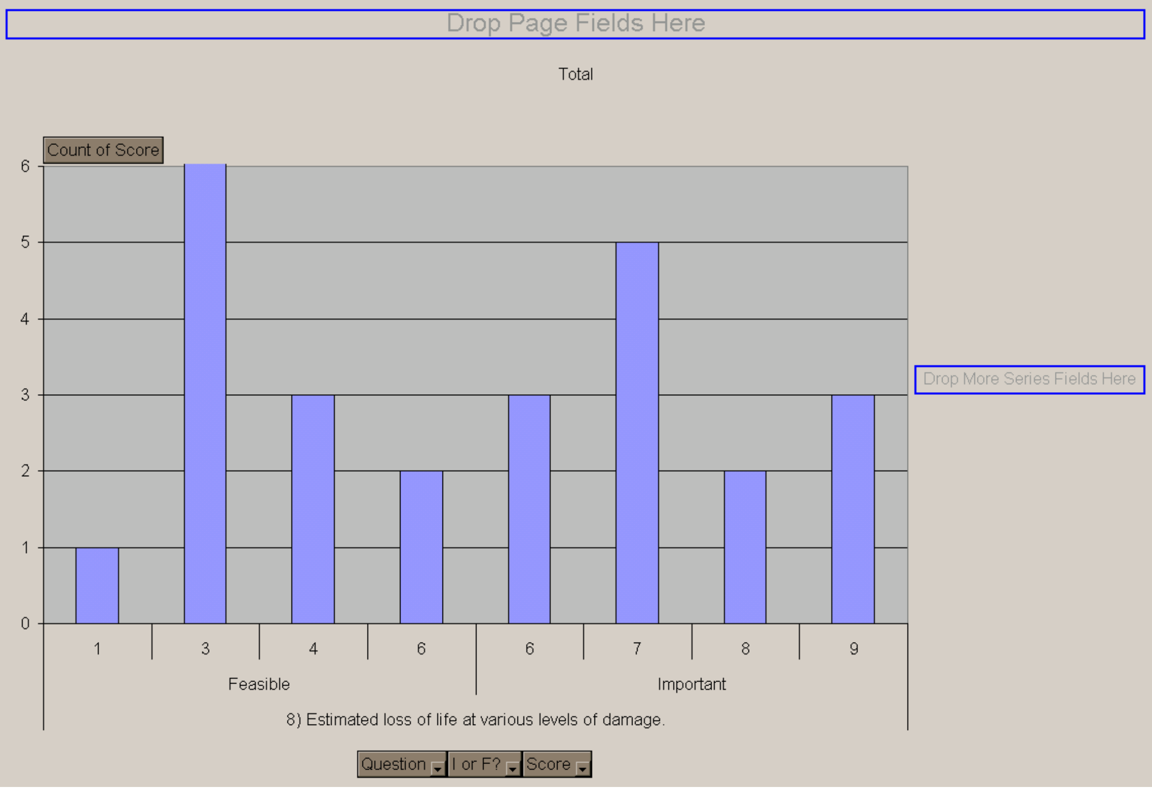
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8) Estimated loss of life at various levels of damage.
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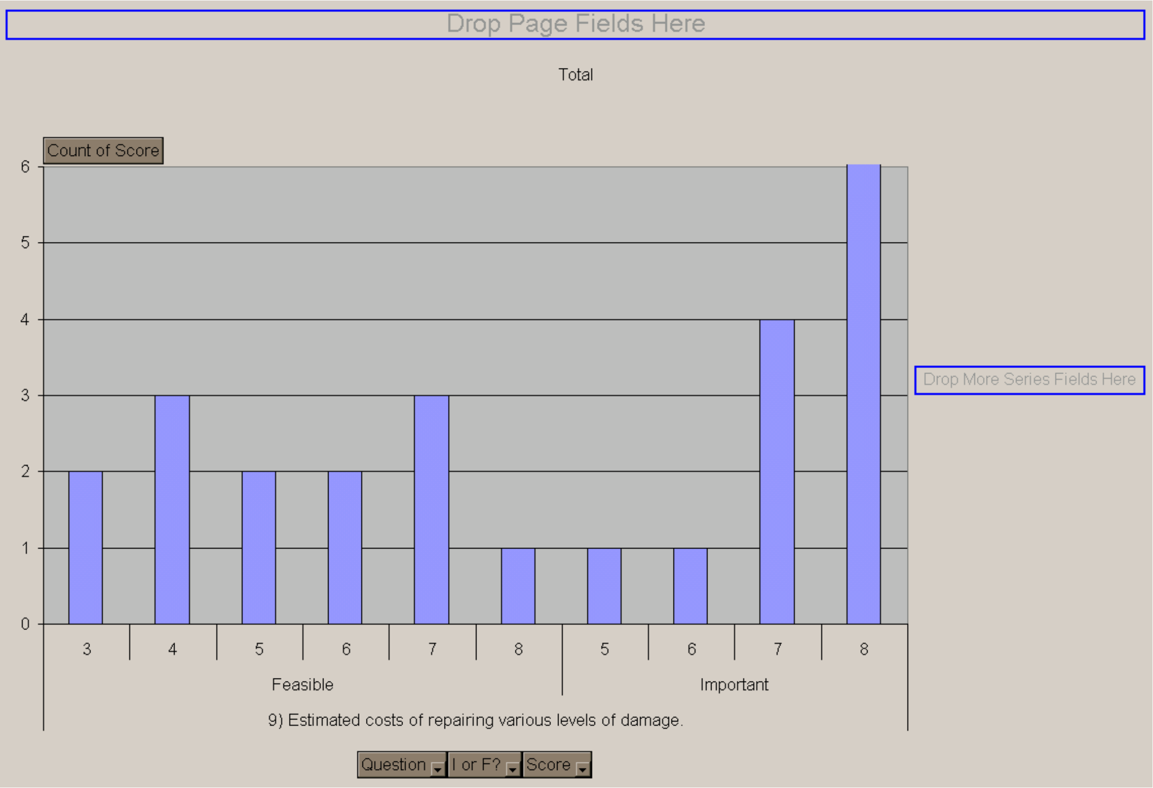
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9) Estimated costs of repairing various levels of damage.
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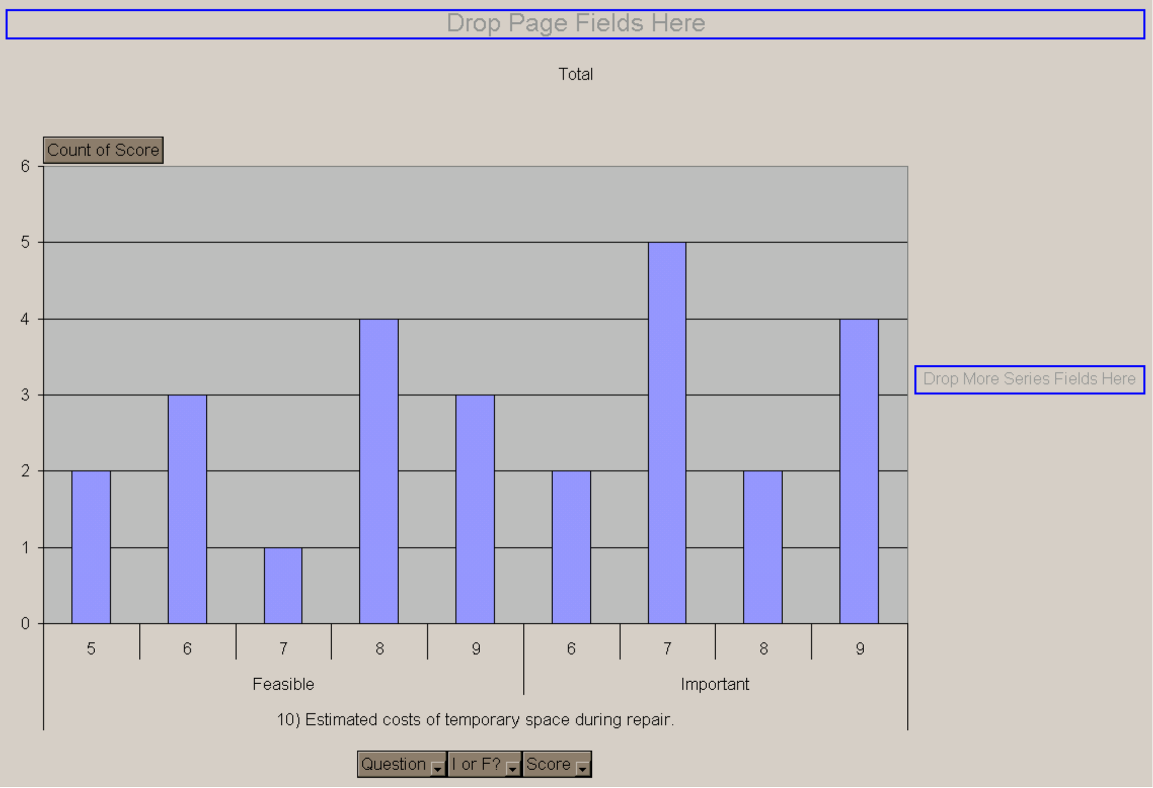
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10) Estimated costs of temporary space during repair.
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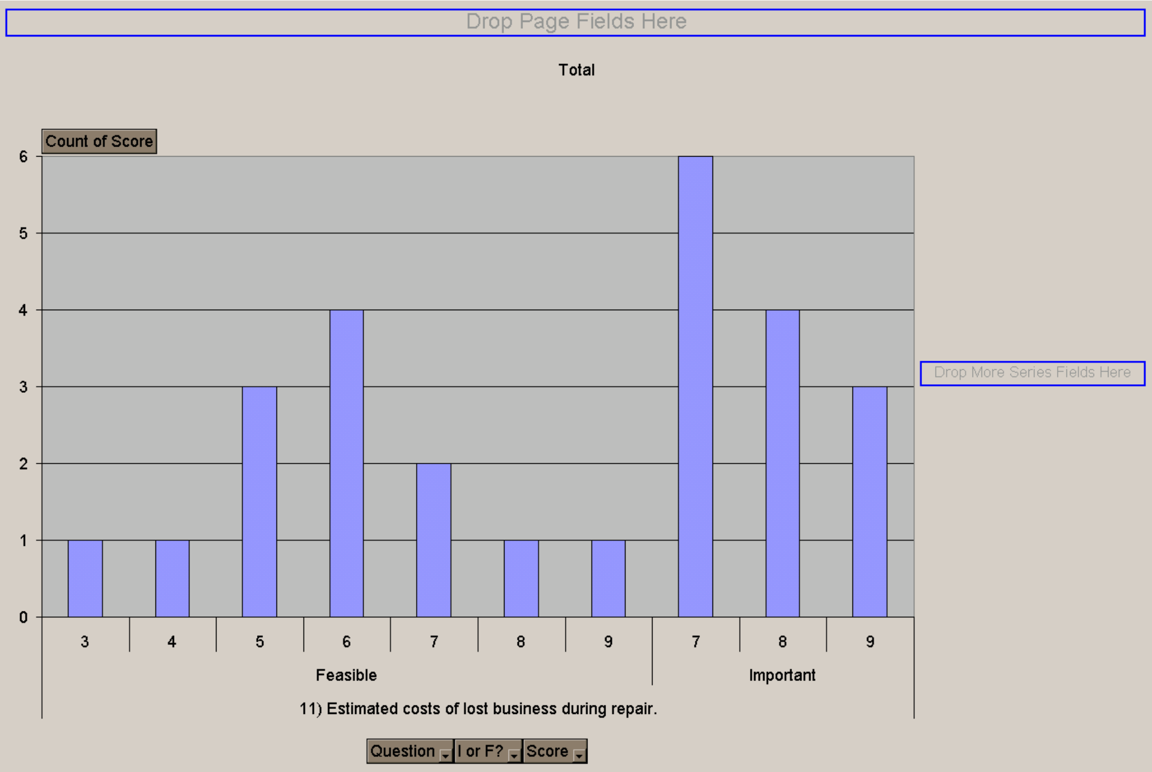
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11) Estimated costs of lost business during repair.
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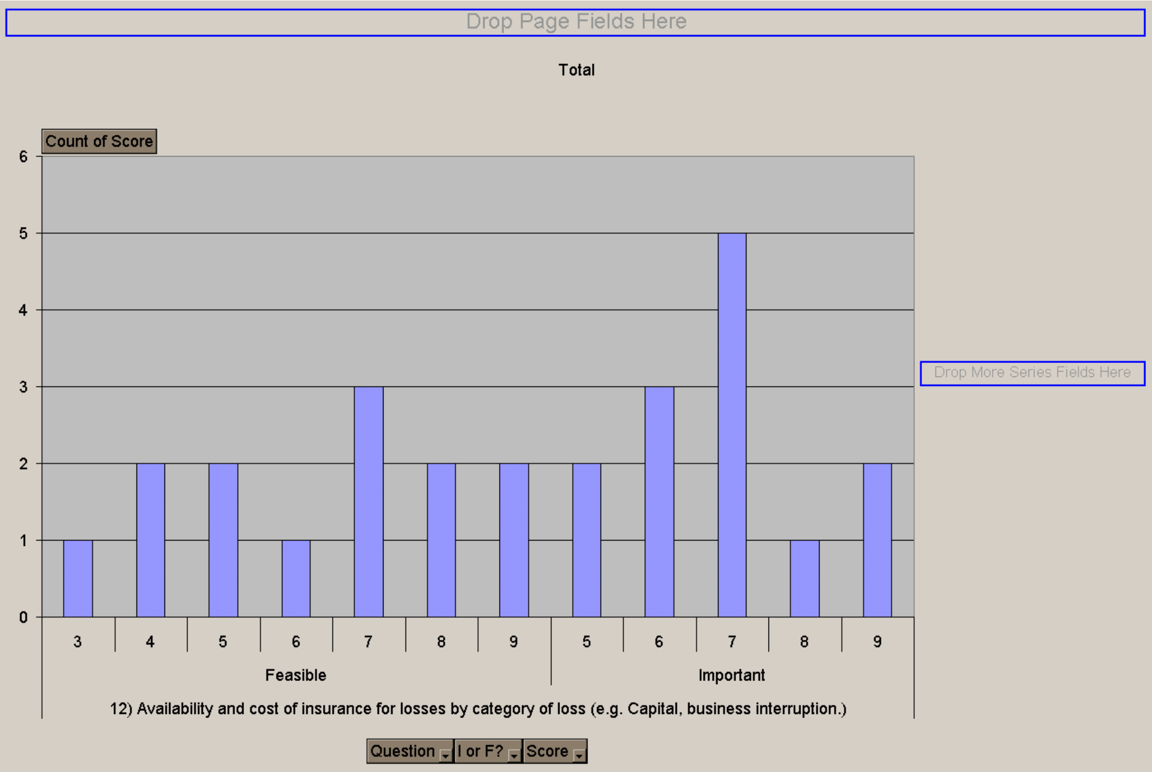
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12) Availability and cost of insurance for losses by category of loss (e.g. Capital, business interruption.)
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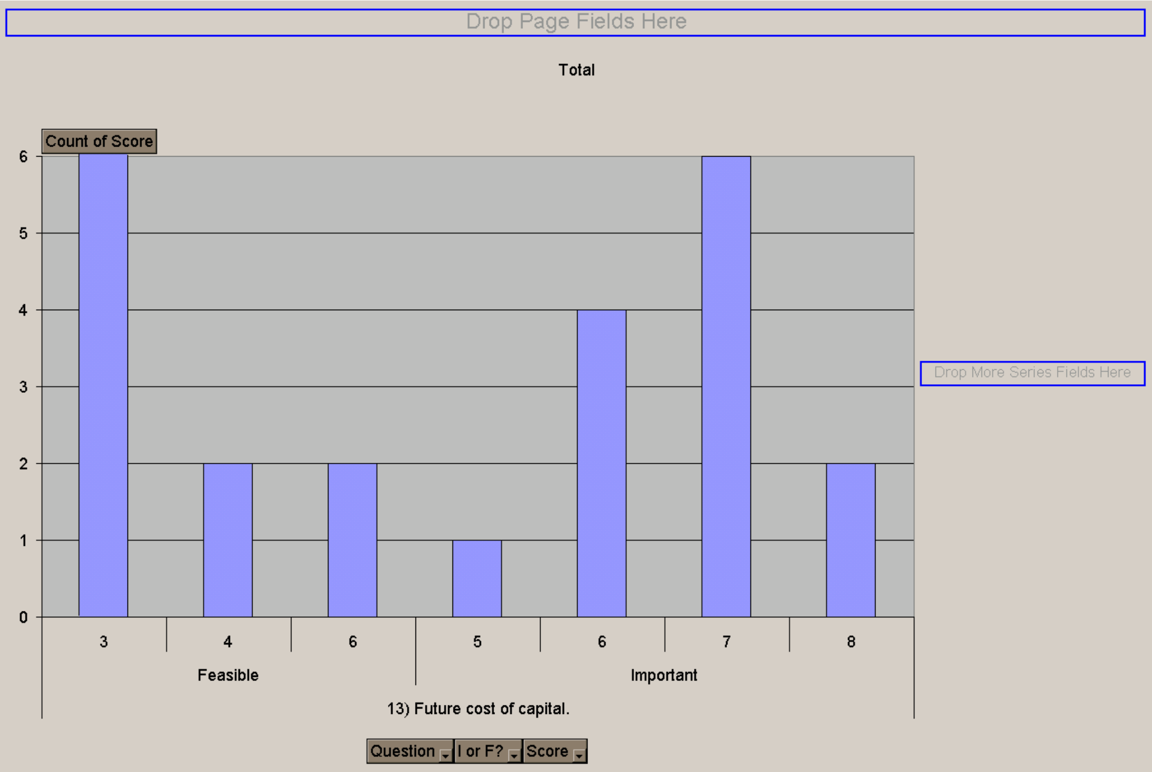
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13) Future cost of capital.
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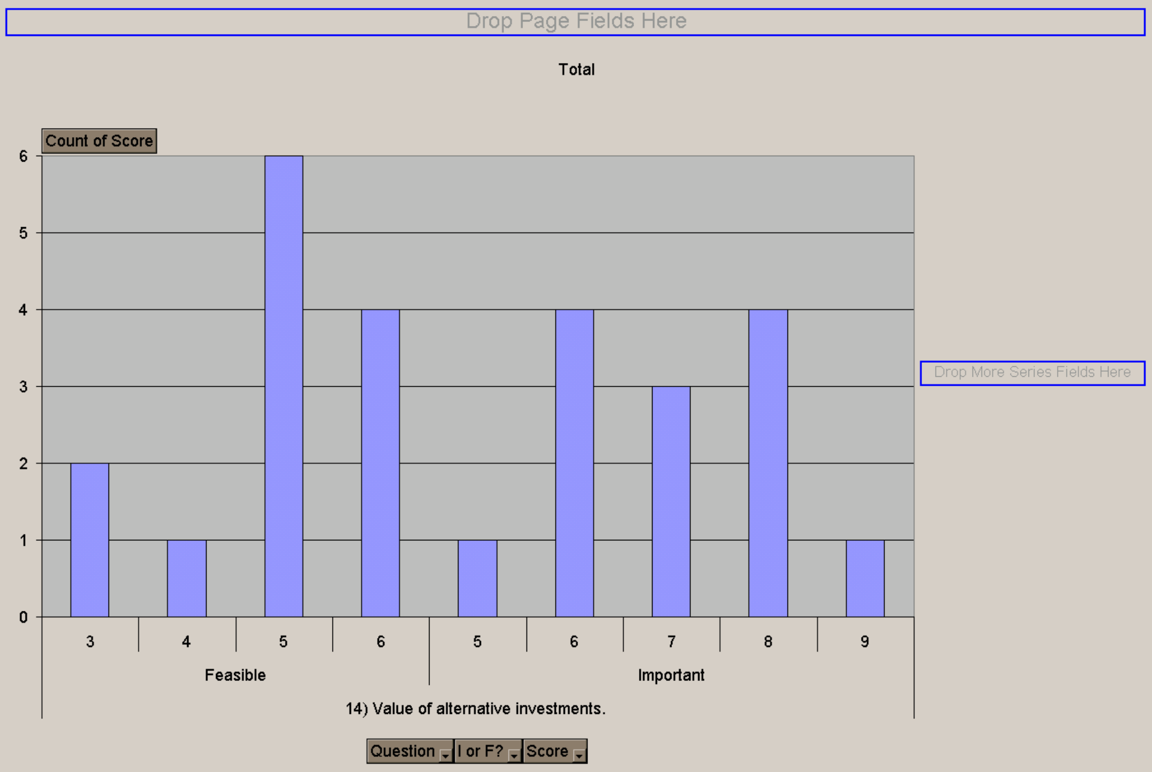
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14) Value of alternative investments.
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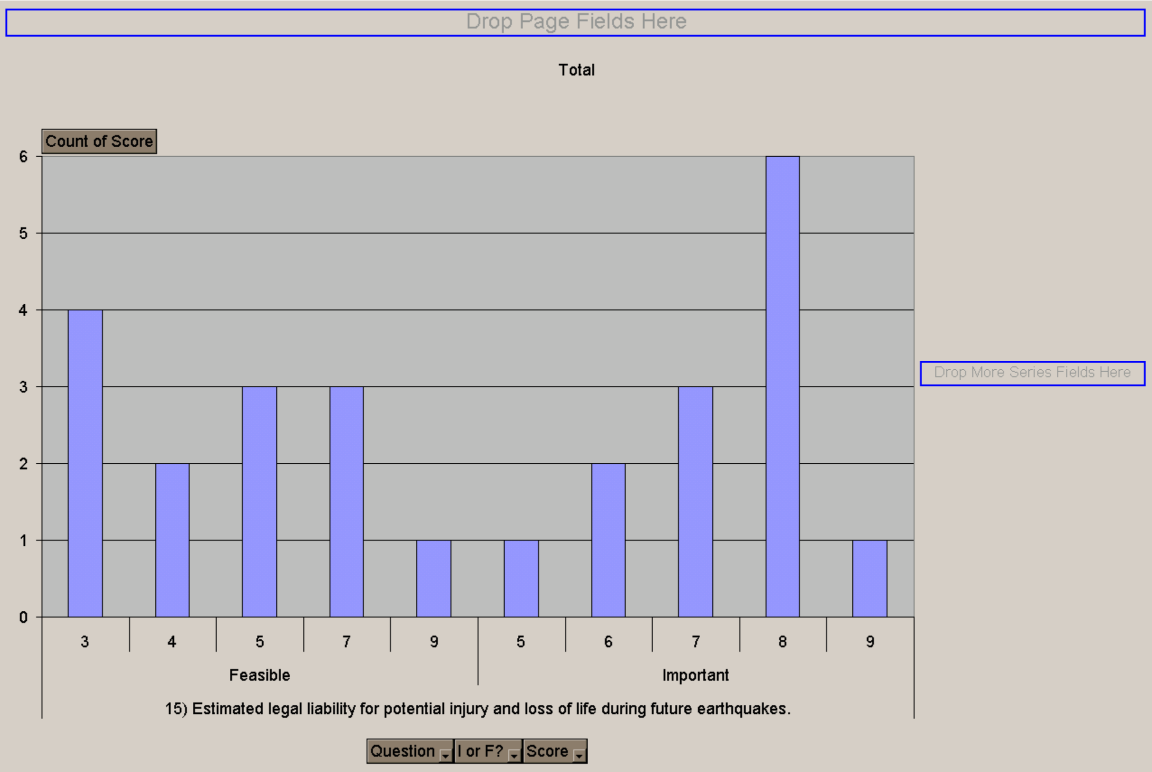
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15) Estimated legal liability for potential injury and loss of life during future earthquakes.
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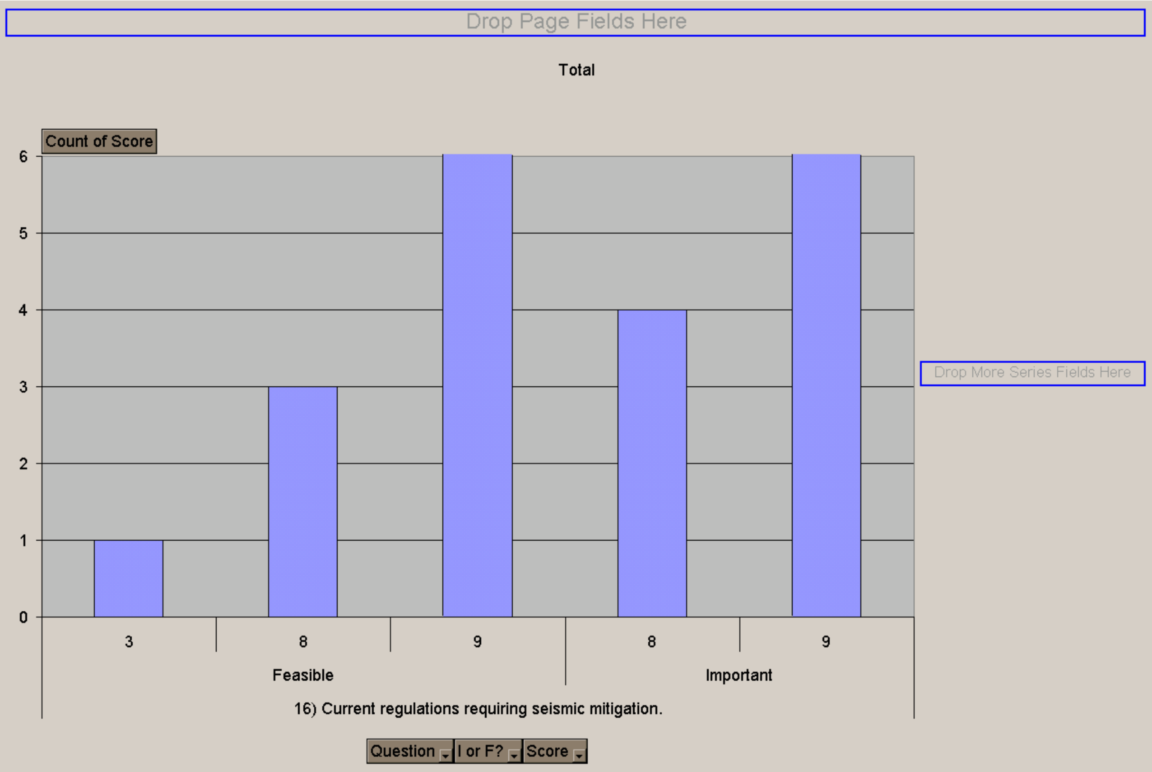
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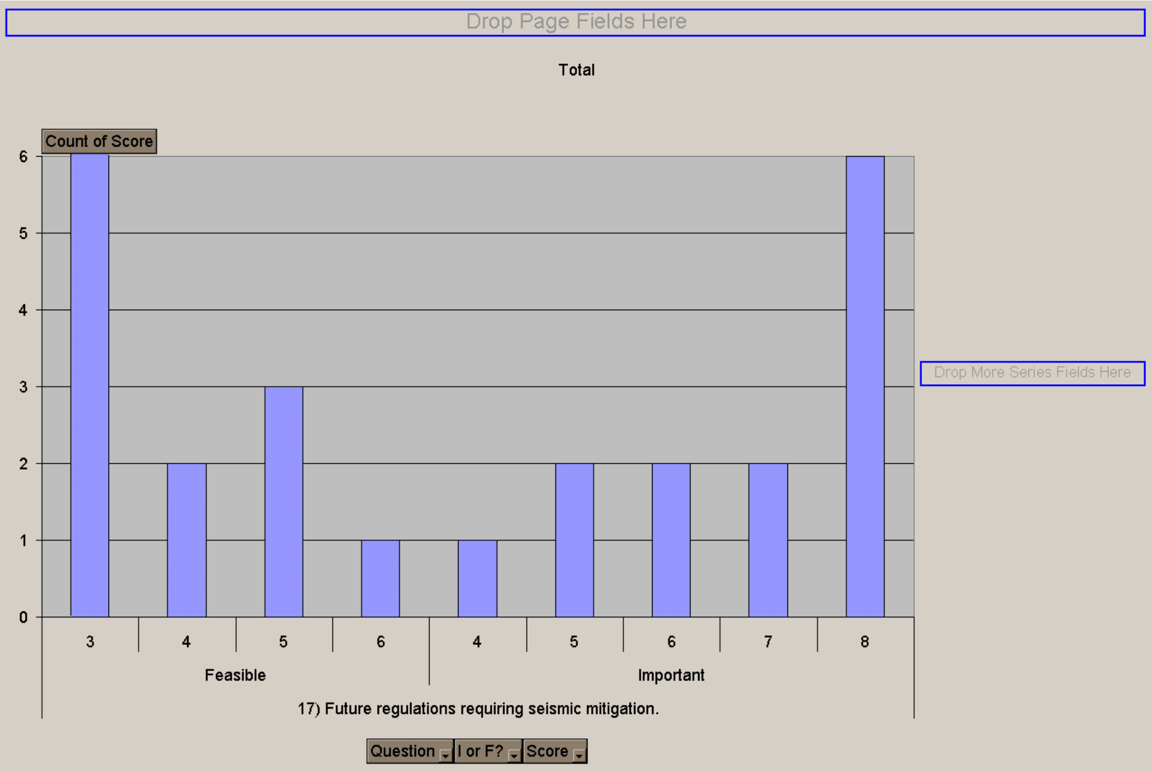
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17) Future regulations requiring seismic mitigation.
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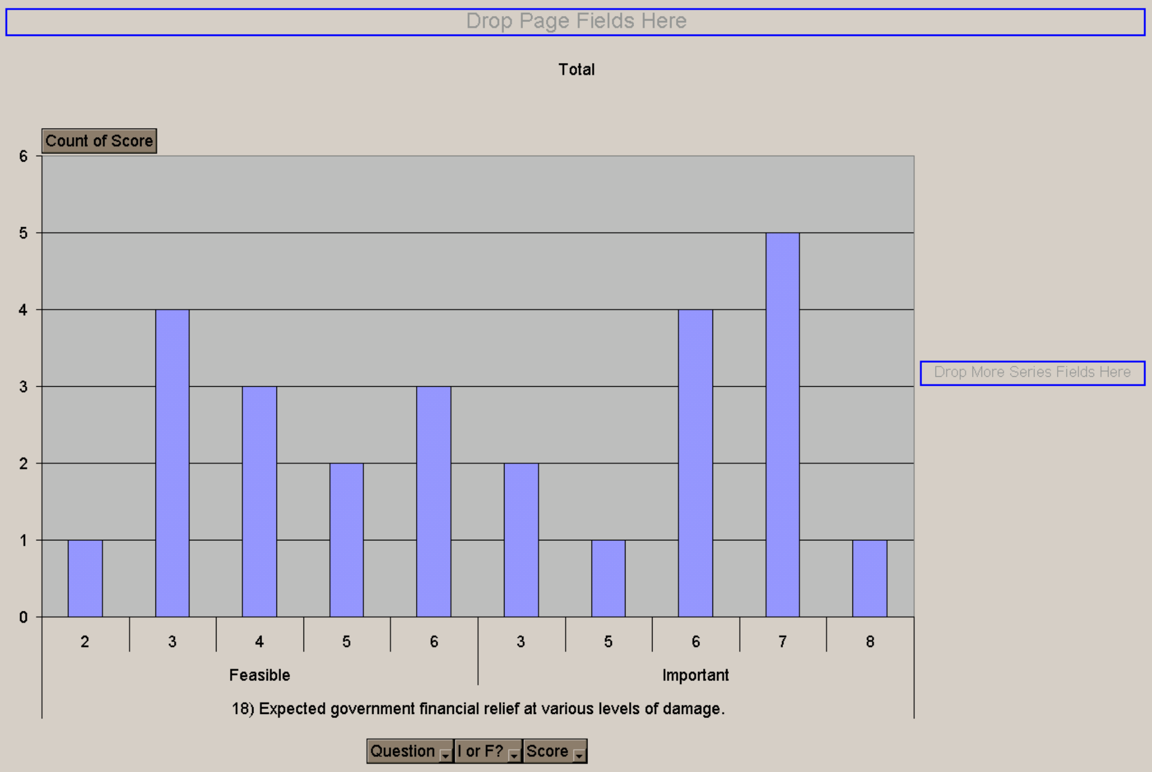
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18) Expected government financial relief at various levels of damage.
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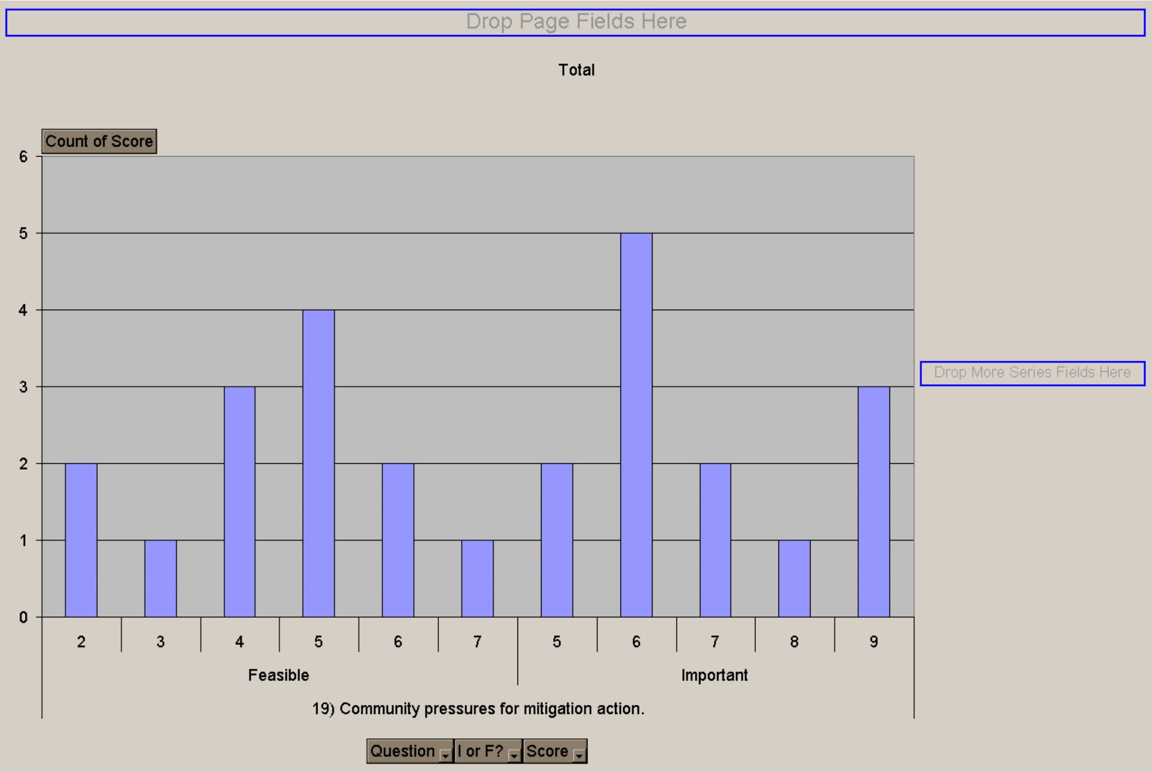
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19) Community pressures for mitigation action.
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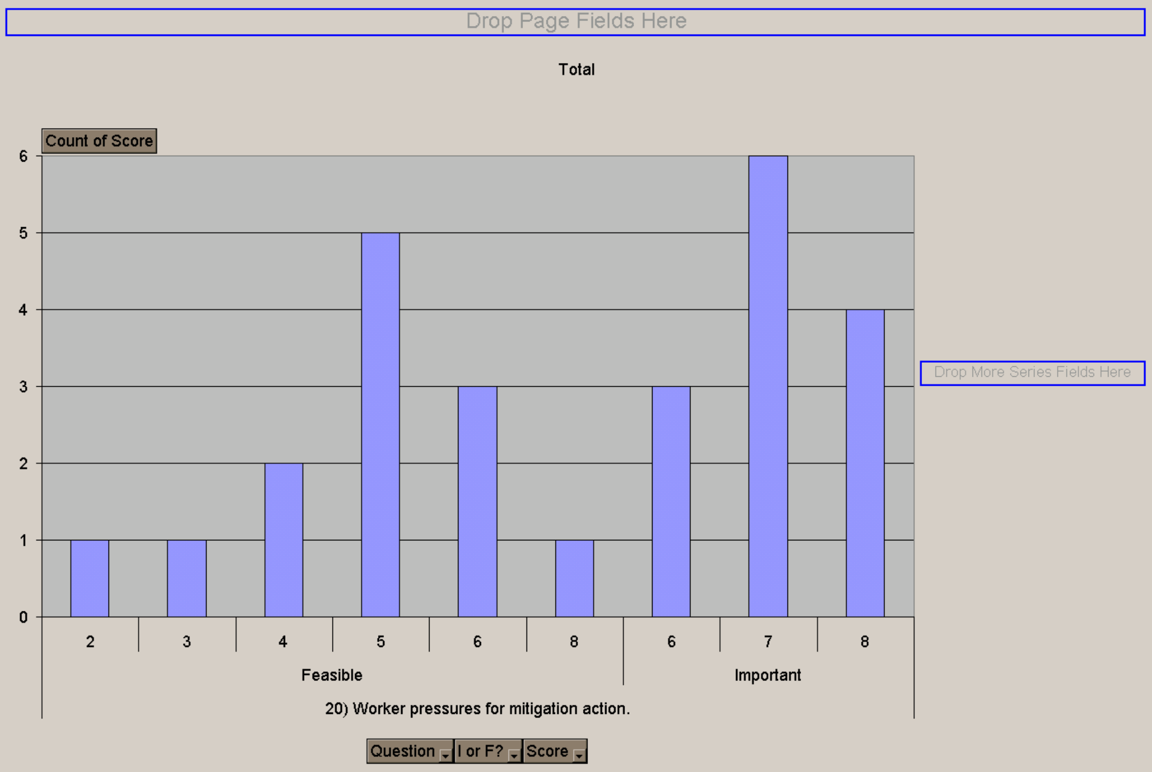
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20) Worker pressures for mitigation action.
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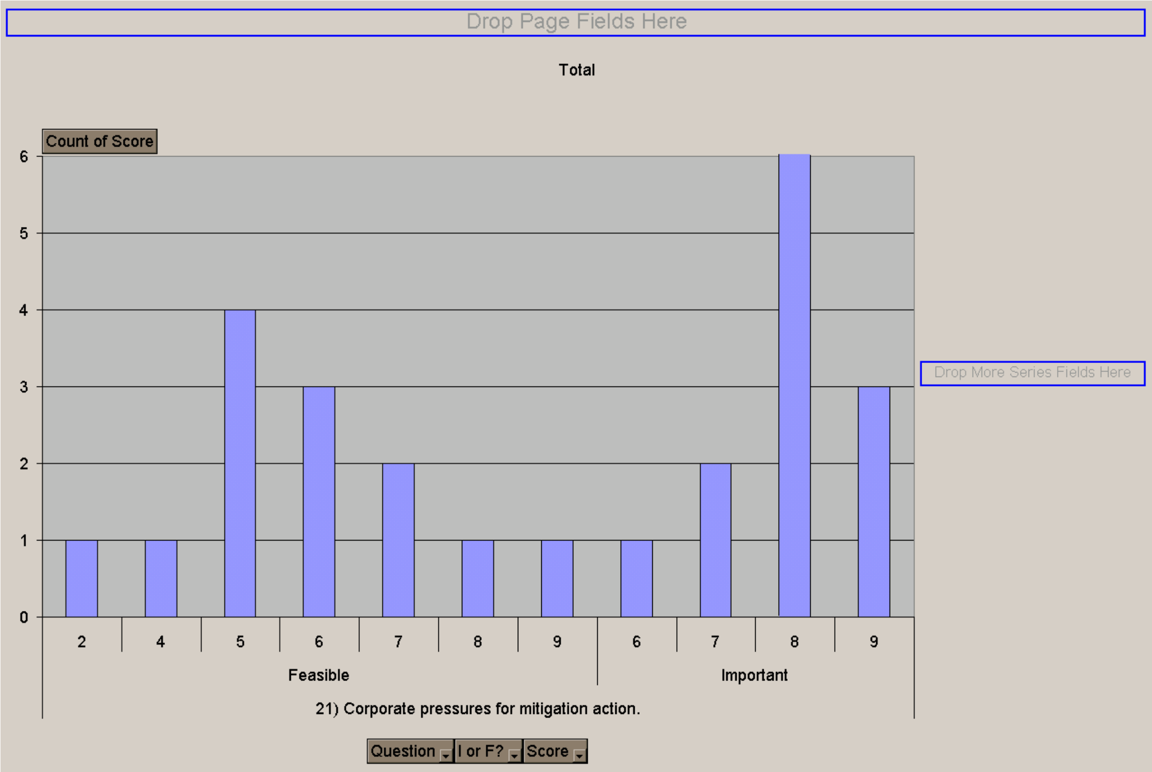
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Important
21) Corporate pressures for mitigation action.
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APPENDIX D: Mitigation Decision Modeling Example

MITIGATION DECISION MODELING EXAMPLE

Robert L. Nigbor
University of Southern California

Robert A. Olson
Robert Olson Associates

John Adams
RAND

INTRODUCTION

This Appendix presents a simple example of the usage of the qualitative and quantitative models for the earthquake mitigation decision process, the “quanta” of the Community Earthquake Risk Reduction Model (CERRM). This simple model is based upon the multiple and varied inputs to decision and action.

The example is intended to show the general potential of the methodology. It is fictitious and greatly simplified. It focuses on the seismic mitigation decision process within a medium-sized company faced with the need to reduce risk of all kinds, including seismic.

The proposed CERRM and this example are a seed for further work on more quantitative combination of engineering, social, economic, political, and other inputs to the decision process for earthquake mitigation and then to the aggregate effect of these decisions on the reduction of earthquake risk within a community or other groupings of people or assets.

MITIGATION DECISION MODEL

Qualitative Decision Tree

The qualitative “decision tree” model shown below has a specific focus: an earthquake risk mitigation decision within a private company having a single “champion” who is interested in the promotion of earthquake risk mitigation.

This model contains three “decision points.” The first is the decision to advocate, or encourage, the mitigation action. This may be done by one internal person (a “champion”) or an internal group. It may be prompted by external or internal political or social forces. Inputs to this decision are weighted engineering, social, political, and economic variables.

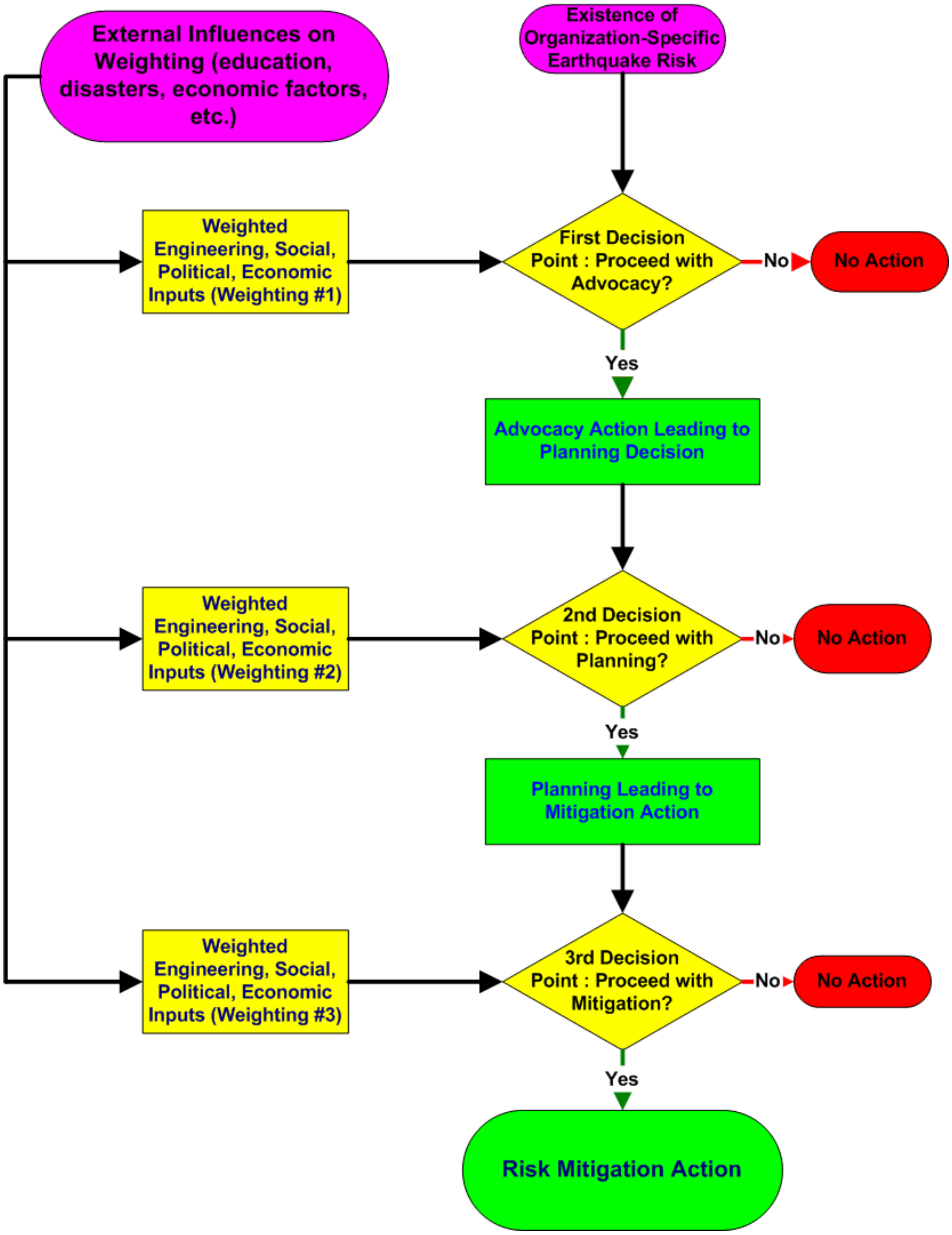
The second decision point is the decision to proceed with detailed planning, leading to recommendations to management or other controlling decision-making individuals or groups. This decision will be initiated by the actions following from the first decision, and will be influenced by weighted engineering, social, political, and economic inputs. The weighting will differ from that in the first decision.

The last decision is the decision for mitigation action by an internal decision-making individual or group, leading to the execution of the mitigation action. This decision will be initiated by actions following from the second decision, and will be influenced by weighted engineering, social, political, and economic inputs. The weighting will differ from that in the first two decisions.

In general, we must acknowledge that the weighting of the various engineering, social, political, and economic variables will vary from person-to-person, organization-to-organization, geographically, and temporally. Weighting can be affected by external stimuli from education, recent earthquakes or other disasters, economic conditions, and many other variables; these external effects may often be of interest.

This is indeed a very complex issue even in a qualitative sense. To be useful this model will need to be simplified greatly, with only a sparse number of inputs being considered.

Generalized Decision Model for Earthquake Risk Mitigation Action



Qualitative Decision Tree for an Organizational Mitigation Decision

Quantitative Framework Model for a Single Mitigation Action

Let the inputs be represented by a vector *X*. This vectors's elements are random variables representing the engineering, social, political, and economic quantities that are considered significant to a particular decision or group of decisions. Define a weighting vector *W*, of the same size as *X*, that contains the relative weights of the input variables in *X*. Further define W_1 as the weights for Decision Point 1, W_2 as the weights for Decision Point 2, and W_3 as the weights for Decision Point 3.

Define the following Bernouli random variables:

D_1 = Yes decision at Decision Point 1

D_2 = Yes decision at Decision Point 2

D_3 = Yes decision at Decision Point 3

D = Yes decision overall (same as D_3)

We can express the probability of a positive overall decision for mitigation as:

$$P(D \mid X, W) = P(D_3 \middle| D_2, X \times W_3^T) P(D_2 \middle| D_1, X \times W_2^T) P(D_1 \middle| X \times W_1^T)$$

This model has two important implied features. First, the probability that one passes a latter decision point can depend upon the margin by which earlier decision points were passed. For example, barely choosing Yes for D_1 can negatively affect the probability of Yes at D_2 or D_3. Secondly, the probability of choosing Yes at D_1 can be negatively affected by low probabilities at D_2 or D_3. Researchers, advocates, and policy makers may elect to allocate their efforts elsewhere if the chances of passing later stages in the decision process are small.

Now, define the random variable C as the quantitative reduction of earthquake risk R (defined by a specific metric such as life loss or dollars) by this specific action, as defined by engineering or other quantities; may be deterministic or random. We can then we can define in a probabilistic sense the expected reduction of risk E(R) (a random variable) by this action and its decision to be:

$$E(R) = C^* P(D)$$

This is admittedly a very general probabilistic model. It is intended to be a framework for future research in this hybrid engineering/social science arena. Application to a specific mitigation action will require the following steps:

- Definition of important inputs (components of X)
- Definition of the three weighting vectors
- Definition of the probability density functions (PDF) for each decision point
- Definition of the conditional relationships between the three PDF’s

EXAMPLE: ORGANIZATIONAL MITIGATION DECISION

This example demonstrates the methodology for modeling a single earthquake mitigation decision within a fictitious company. The details of this scenario are:

- Company A is a public computer manufacturing company with a single campus of buildings
- Company A is located in the east San Francisco Bay area where seismic hazard is high
- The 5 buildings in the campus were constructed in the 1970’s and designed to the Uniform Building Code’s seismic provisions. Current market value of the real estate and buildings is $80M. Building contents (inventory and equipment) are valued at $200M.
- No seismic mitigation has been done, either structural or nonstructural
- Minor earthquake damage in the 1989 Loma Prieta Earthquake was repaired
- The recommendation has been made to retrofit the campus both structurally and nonstructurally to allow the campus to remain functional after an earthquake at an estimated cost of $20M

- There are no government requirements for mitigation; this effort would be voluntary
- The Risk Manager is the primary champion and first decision-maker for seismic risk mitigation decisions
- The President is the next decision-maker in the decision tree
- The Board of Directors makes the final decision on this major investment/expense
- The main metric for decision-making will be dollars, done in a benefit-cost context

We will use the decision tree and the equation for the decision probability to demonstrate the use of this model for this fictitious scenario.

Qualitative Decision Model

The decision tree has been modified for this particular case and is shown in the following Figure.

There are three "Decision Points." The first represents the decision by the Risk Manager to proceed with internal advocacy of the seismic retrofit project. In this role, the Risk Manager is the "Champion" described in the general model description. Inputs to this decision are the existence of the earthquake risk and the external parameters modeled by the vector X crossed with the weighting vector W_1.

The second decision point is made by the Company A President. Upon recommendation by the Risk Manager, the President decides whether or not to pass the recommendation to the Board of Directors for a final decision. Inputs to this decision are the recommendation of the Risk Manager and the external parameters modeled by the vector X weighted by W_2.

The final decision point is the Board of Directors, who must approve a capital project of this size ($20M). Upon recommendation of the President, the Board decides whether or not to proceed with the seismic retrofit project. Inputs to this decision are the recommendation of the President and the external parameters weighted by W_3.

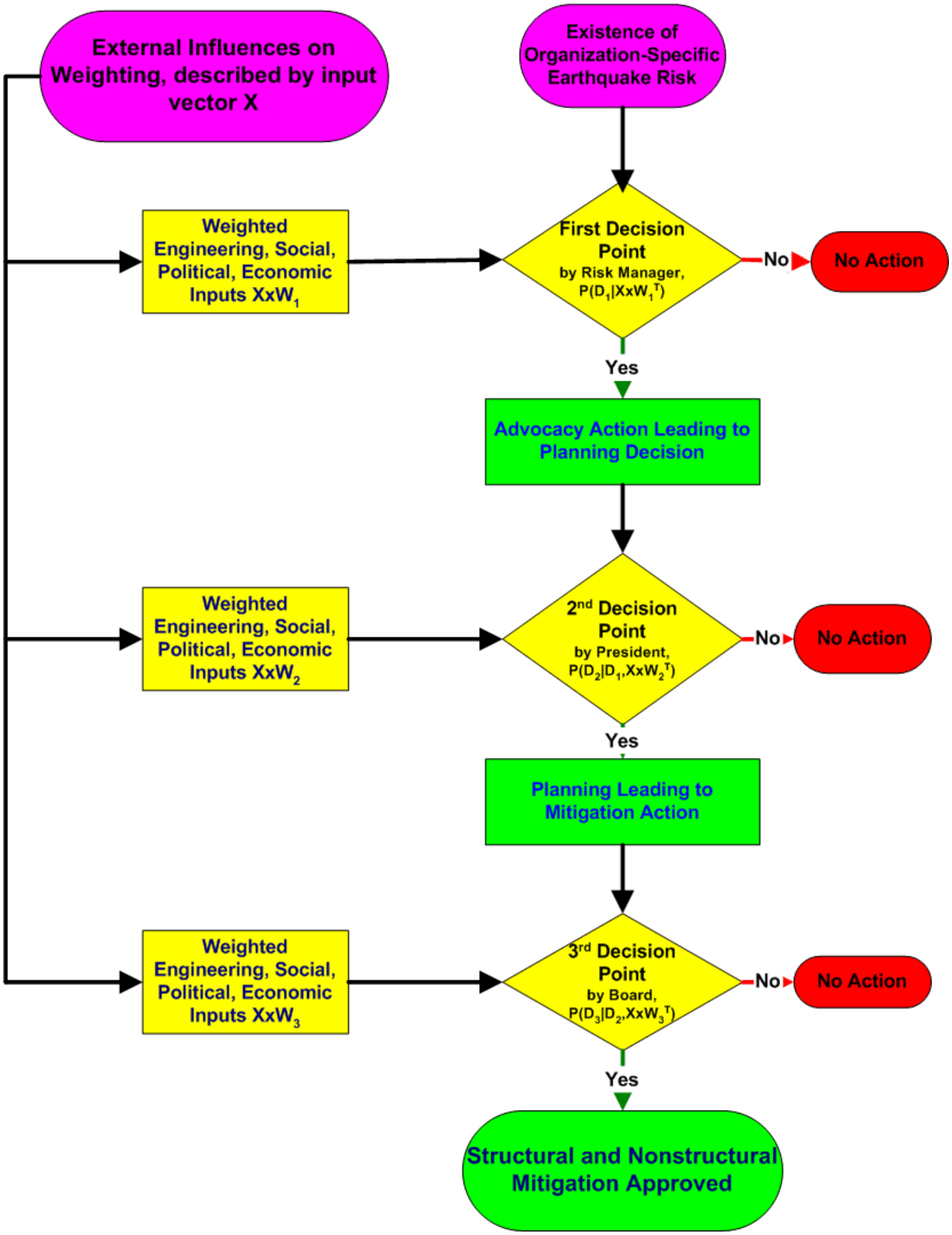
The next qualitative modeling step, beyond the decision tree, is to identify the elements of the external influence parameter vector X. This vector represents, in a simplified mathematical sense, the space in which the decisions are made. Going from the complex continuum of the real external influences to a relatively simple mathematical construct of a few dimensions is the heart of this modeling procedure and is its weakness.

Nevertheless, for this simple example we can qualitatively identify a few external influences that will likely dominate the decision process. These are:

- Direct seismic risk to the facility, as determined by engineering estimates and expressed as both estimated damage repair costs for scenario earthquakes and probable annualized loss
- Seismic risk to company operations, as determined by engineering estimates and expressed as both business interruption costs for a scenario earthquake(s) and probable annualized loss
- Cost of seismic mitigation, direct and indirect (business interruption)
- Cost of earthquake insurance
- Current financial condition of Company A
- Estimated future financial condition of Company A
- Government incentives (tax and other) for seismic mitigation
- Legal incentives (implied liability) for seismic mitigation
- Societal “pressure” to improve earthquake safety

While certainly not a complete list of influences, this partial list can then be passed to the next section for quantitative modeling.

“Company A” Decision Model for Earthquake Risk Mitigation



Modified Example-Specific Qualitative Decision Tree Model

Quantitative Model

In this section we attempt to develop a quantitative model of the form

$$P(D \mid X, W) = P(D_3 \middle| D_2, X \bullet W_3^T)P(D_2 \middle| D_1, X \bullet W_2^T)P(D_1 \middle| X \bullet W_1^T)$$

from the decision tree in Figure 2 and the list of significant influencing factors in the previous section.

This step is difficult, as it requires the statistical modeling of “soft” social science factors as well as the better (but not well) defined seismic risk factors. This will always be a difficult issue with such quantitative modeling, but there are methods and procedures for doing this within statistical practice. An example is “expert opinion” exercises using a modified Delphi method such as the RAND method.

So, for the purposes of this illustrative example, we will proceed with the following assumptions:

- We can assign a single random variable to each of the factors and define them as elements of the random vector X
- Probabilities are linear in the variables (this greatly simplifies the problem formulation but is possibly not correct in a real situation)
- A logistical model transformation ($\log(P/1-P)=XW^T$), as is often used in social science modeling, is appropriate (this simple functional form removes many constraints on X and W)
- Dim[X] = dim[W] (variables are independent)

Further, we have no reason to prefer a particular distribution for any of the elements of X. Therefore an element of X could be a continuous variable (anticipated cost, for example) or a discrete variable. Normalization or standardization may be needed for comparison of relative effects of elements of X.

The table below defines the elements of the influence vector X. This is the reduced space of this example model.

Elements of X and Dimensions of the Model Space

Variable	**Description**
X1	A PBEE-defined "decision variable" representing annualized facility loss normalized to a facility-based reference value (such as replacement cost/lifetime)
X2	A PBEE-defined "decision variable" representing annualized business interruption cost normalized to an operations-based reference value (such as annual profits)
X3	An engineering-defined mitigation cost estimate, normalized to a reference value (such as facility replacement cost)
X4	Annual cost of earthquake insurance, normalized to a reference value
X5	A variable representing current financial strength of the company
X6	A variable representing projected future financial strength
X7	A variable representing the effect of government incentives on the mitigation decision
X8	A variable representing the effect of legal/liability incentives on the mitigation decision
X9	A variable representing both internal and external societal pressures toward a decision to mitigate

For convenience in this example, we will adopt a simplifying logistical transformation of the probability functional as follows:

$$P(D_i \mid D_{i-1}, X \bullet W_i^T) = P(D_i \mid X \bullet W_i^T) = \frac{e^{XW'}}{1 - e^{XW'}}$$

or

$$\log(\frac{P}{1-P}) = X \bullet W^T$$

The table below provides some initial values for the input variables x_i and their weighting values w_i. These are semi-arbitrary values for demonstration only. Finally, both the conditional probabilities and the overall decision probability are calculated in the final table.

This formulation and these results can be further used to assess the effect of changes on one of the input variables on the outcome probability of positive mitigation decision. The figure is a plot of the effect of changes in the mean value of x_5, representing the current financial strength of the Company A, on the mean decision outcome with all other variable means constant. This shows an important feature of such a model: even with all of the assumptions and inaccuracies one can semi-quantitatively study the relative effects of individual factors on a decision.

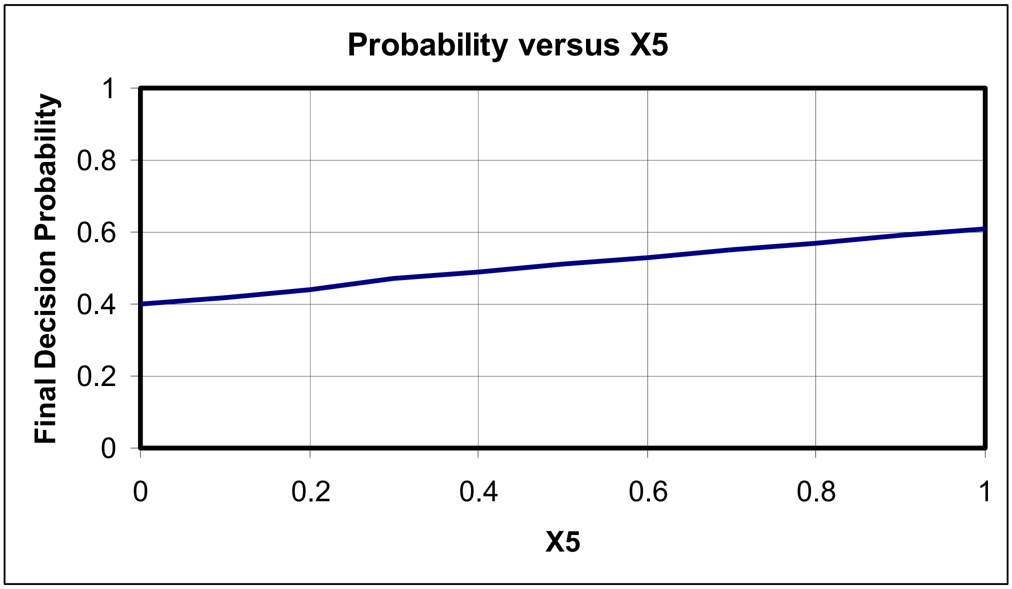
Example Values for X and W

i	Input Variable, xi	Step 1 Weight, W1i	Step 2 Weight, W2i	Step 3 Weight, W3i
0*	-1	0.5	0.5	0.5
1	0.4	1	0.3	0.4
2	0.4	1	0.5	0.4
3	0.3	0.5	0.6	1
4	0.7	0.5	0.6	1
5	1	0.5	0.7	1
6	0.9	0	0.4	0.3
7	0.2	0	0.4	0
8	0.1	0.2	0.3	0.1
9	0.3	0.5	0.4	0

* i=0 is a calibration/adjustment constant per standard practice in use of a logistic model transform

Calculated Decision Probabilities for the X and W in Table 2

Step	Probability of Yes Decision
1	0.81
2	0.85
3	0.89
Final	0.61



Effect of Variable x_5 (Current Financial Strength) on Decision to Mitigate

SUMMARY

This fictitious example is decidedly incomplete, and is not intended to imply either accuracy or precision. Further research is needed to refine this model and to define the needed variables, distributions, and functional relationships. However, the example does show the future promise of this Mitigation Decision Model as a tool to help understand the decision process and as part of a methodology for quantitative combination of engineering and social science aspects of the seismic mitigation process.