Risk Management for Buildings—Has The Time Come?

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ABSTRACT

There are both incentives and challenges for applying formal risk management processes to buildings and other structures, including bridges, highways, dams, stadiums, shopping centers, and private dwellings. Based on an assessment of several issues, we conclude that for certain types of buildings and structures the time has come for the use of a formal risk-management approach, including probabilistic risk assessment methods, to help identify dominant risks to public health, safety, and security and to help manage these risks in a cost-effective manner.

Keywords: architectural surety, risk, buildings, structures, risk perception, risk analysis, risk management

INTRODUCTION

Although modern Americans are living longer and healthier lives than ever before in history, there is a perception throughout our society that our health, safety, and security are increasingly at risk. It is not unusual for our society to spend tens of millions of dollars on perceived risks while statistically significant risks go unaddressed.1 Much has been written about the significance of people’s perception of risk and how these perceptions can drive government policy and resource expenditures.2,3,4,5 Safety and security systems and special design features are incorporated into systems, equipment, and structures to address perceived risks. In an effort to achieve balance and temper perception with reality, some government agencies and industries are attempting to use formal risk management tools to analyze risks and to guide decision making.7,8 For years, the airline and nuclear industries have used formal risk assessment tools to improve designs and operational safety margins. Many aspects of environmental cleanup and nuclear waste management use risk assessment techniques for guiding technology selection and for selecting project goals.9 The Departments of Energy and Defense have applied risk management techniques to ensure both conventional and nuclear-weapon safety and reliability over a wide range of operational conditions. Risk management and assessment methodologies have been developed for fire protection, floods, earthquakes, and other threats to structures and systems. Manufacturing industries, including micro-electronics, petrochemicals, and pharmaceuticals, have applied formal risk and reliability assessment techniques to ensure product quality and public health and safety.10 In the light of these precedents, it seems appropriate to consider whether the time has come to use formal risk management techniques for buildings and other structures.

WHAT ARE THE CHALLENGES?

Why haven’t formal risk assessment and management methods been applied to such structures as domed stadiums, large high-rise buildings, major transportation systems, and so forth? There are several reasons. In the United States, construction practices have largely been governed by a complex and thorough experience-based set of rules and guidelines called the Uniform Building Codes.11 These prescriptive codes have evolved over the years to use the best demonstrated available technology for engineering and construction. They are supported by independent testing by, for example, the Underwriters Laboratories, Factory Mutual, and the Portland Cement Association and by many years of satisfactory performance.12 In general, buildings keep standing and bridges don’t collapse. Where there are uncertainties, safety margins and design and construction practices ensure that things work. Quality control processes guarantee that things are designed, built, and maintained in accordance with best engineering practice. Within the design envelope, there is high confidence that structures will perform safely and reliably. In
general, profit margins are tight in the construction industry, and there is little incentive to perform any analysis not required by "The Code." As a final risk-management tool, the owners of buildings and other structures can purchase insurance to reduce their liability for unforeseen or highly unlikely occurrences that could threaten human health, safety, and security.

This combination of excellent building codes, good engineering practice, and an insurance safety net leads to considerable inertia within the engineering and construction industry, which does not routinely use risk methods in current practice. Traditionally, risk assessments have been expensive to perform, they often have wide ranges of uncertainty, and there is little provision for recouping the cost of the assessments through reduced construction or insurance cost. These drawbacks also weigh against the use of risk assessment.

WHAT'S CHANGING?

The impediments to the use of formal risk management for buildings largely continue to outweigh the incentives. However, a number of factors are emerging that are likely to change this picture. One of these, mentioned above, involves society's perception of risk. People want to feel as safe and secure in public places as they do in their homes, but they are beginning to recognize that their work place or public gathering place may be subjected to conditions that go beyond the design basis for the structure. Terrorist attacks, whether through explosion, release of toxic chemicals, or fire, usually are not analyzed or accommodated for in design. Earthquakes can exceed, although with low probability, the design capabilities of structures, and certain design features, such as large glass panels or beams suspended with a single point of failure, can pose significant hazards to health and safety under some conditions. In light of this, it is increasingly recognized that the civil engineering aspects of buildings and structures must be viewed in light of the comfort, safety, and security systems of buildings. The interdependency and interrelationships between civil structural features and building systems becomes more important as the range and variety of hazards increases. For some time fire has been analyzed and addressed in holistic fashion by considering the protection of building structural integrity while coordinating fire protection system design and operation with that of heating, ventilating, and air conditioning systems and security systems. However, for other hazards, such as terrorism, earthquake, high wind, and external blasts, a holistic assessment of structures and systems is rarely performed, although the logical parallel to fire is obvious. An analysis of the risks arising from terrorism particularly calls for a detailed examination of potential single-point failures, although single-point failures can arise from a number of more common causes as well.

A final development that could enhance the likelihood that formal risk management approaches could be used for buildings and structures is that risk assessment tools (models, computer programs, data bases) are becoming more routinely available, more computationally powerful, and easier to use. With these tools, decision makers in government or industry could weigh the relative risks of various design options or lease options for existing buildings or structures. They could choose an optimum balance for dealing with a variety of hazards or threats and could trade off various retrofit options for addressing new threats as they emerge.

WHEN IS RISK MANAGEMENT APPROPRIATE?

It is likely that risk aversion and concern about perceived risks will increase within our society. The World Trade Center and Oklahoma City bombings, toxic gas releases in the subways of Tokyo, earthquakes in Kobe and other regions of the world, the collapse of aging bridges and buildings, and dam failures grab headlines and elicit a barrage of rhetoric, litigation, and government regulations. Often the actions taken in response to such events are expensive, piecemeal responses, addressing only the particular threat (e.g., fire or terrorist bombing) at hand. As a result, decisions are made and resources can be wasted on "hot-topic" problems, while other more likely and perhaps riskier threats and vulnerabilities are ignored.

Figure 1 illustrates some of the factors that might go into an informed decision about when formal risk management might be appropriate for structures. The left-hand side of the figure illustrates a typical building for which formal risk assessment would rarely be appropriate: a single-family house. Single-family houses generally share a number of characteristics that make them poor candidates for risk assessment. As structures go, houses
Formal risk assessment rarely appropriate
Formal risk assessment might or might not be appropriate
Formal risk assessment routine

- Monetary Value of Each Structure
- Construction Time and Materials
- Number of People Potentially Affected
- Actuarial Uncertainty
- Difficulty of Obtaining Insurance
- Perceived Risk to Safety or Security
- Formality of Risk Management

Figure 1. Initial factors affecting a decision to perform formal risk assessment for structures.

tend to be inexpensive, costing on the order of $100,000 per unit. Construction time typically varies from a few weeks to a few months. The number of people in a house at any one time, and therefore the number likely to be at risk, is small, on the order of three or four. Because of the very large number of houses, about 100 million units in the United States, actuarial data on typical hazards are plentiful. New construction is governed by the Uniform Building Code, for example, which is based on a wealth of data, practice, and engineering experience. Insurance that will cover not only the original purchase cost of any property loss, but even the replacement cost of such property, is readily available. Finally, most people perceive that they are "safe at home" and would likely be unreceptive to the idea that risk assessment is necessary.

The right-hand side of Figure 1 shows a structure for which formal risk assessment is not only appropriate, but routine: a nuclear power plant. In addition to the regulatory requirement that formal probabilistic risk assessment (PRA) be performed, other factors increase the usefulness of PRA in this case. Nuclear power plants are extremely expensive to build, costing on the order of $3 billion to $5 billion. Construction typically takes 4 to 10 years. Several hundred people are present at the site around the clock, and in the case of an accident that releases radioactivity, hundreds of thousands to millions of people could be affected. Worldwide, only about 400 commercial power reactors exist, and many of these are built to unique designs, particularly in the United States.
Actuarial data are thus essentially nonexistent. Stringent regulations are based primarily on engineering judgment rather than on experience. The owner's liability for hazards arising from nuclear accidents is limited by the Price-Anderson Act. Nuclear power plants tend to be perceived as dangerous neighbors for which all possible precautions, including risk assessment, should be taken.

The center of the spectrum in Figure 1 shows a high-rise office building as an example of the kinds of structures for which formal risk assessment might or might not be appropriate. Other structures in this category include stadiums, shopping centers, dams and reservoirs, and transportation assets like tunnels, bridges, or transportation terminals. These types of structures are intermediate between single-family dwellings and nuclear power plants for all the factors mentioned above: cost, construction time, number of people affected in the case of an accident, number of units in existence, the richness of actuarial data and engineering experience, and perception of risk. Within this group of structures, probably some are appropriate candidates for formal risk assessment and some are not. How should we make this decision?

In addition to a closer look at the factors shown in Figure 1, examination of a number of other factors is necessary to determine the appropriateness of formal risk assessment for this intermediate group of structures (Figure 2). For example, a structure may sometimes house a very large number of people, such as a large commercial building, shopping center, or athletic stadium. Only a fortunate turn of fate prevented hundreds or even thousands of people from being present, and possibly injured, in commercial buildings damaged by the Northridge Earthquake of January 1994, which occurred very early in the morning. If even if the structure itself does not house a large number of people, damage to the structure could affect a large number of people; for example, damage to a power plant or a transmission line can cause widespread collateral power outages. A structure may have symbolic value that would make a large monetary investment in risk assessment seem reasonable. Major damage to the Lincoln Memorial or the Statue of Liberty, through gradual failure of the foundations for example, would represent an incalculable loss to the people of the United States, even though their dollar value is not enormous. The perceived risk associated with the building may be very high, depending on recent headlines or some specialized use such as housing violent criminals. In these times, the possibility that a building may be an attractive target for terrorists because of some high-visibility government use or symbolic factor must also be considered. Finally, the vulnerability of the entire structure to the effects of failure at a single point should be assessed during the design phase.

As a result of this closer look at the structure, we may decide that an ordinary high-rise office building housing a few hundred people working for a number of low-profile businesses does not merit a full-blown risk analysis, because customary application of the Uniform Building Code and good engineering judgment are adequate. In contrast, a large federal building housing high-profile agencies (say, the Internal Revenue Service) and a foreign embassy in a major metropolitan center may well deserve formal risk assessment.

In performing the risk assessment (Figure 3), the analyst first identifies and prioritizes the hazards likely to affect the structure. Both the probability that a hazard will occur and the damage that the hazard will inflict if it does occur go into an assessment of the risk. The resulting analysis and ranking of the risks provides support for an assessment of possible alternative design, construction, or upgrading options. The results of the risk assessment could produce information leading to a variety of decisions. If construction has not begun, design modifications to mitigate projected risks could be implemented, often at minimal cost. For existing structures, risk-based decisions might drive remodeling, repair, demolition, or relocation of the occupants to another building. Risk analysis would also allow informed tradeoffs between security and ease of access or between comfort and safety.

ARE TOOLS AVAILABLE?

Once the decision is made to perform a formal risk assessment for a building, the analyst must select appropriate tools, usually a combination of expert scientific and engineering judgment and computer codes, to use in doing the work. At this time, few risk-assessment tools have been designed specifically for buildings, although many existing tools and methods for the analysis of fire, seismic loading, structural loading, blast, and so on would be more-or-less directly applicable to this specialized area. In addition, more generalized decision-support
Identify and Prioritize Hazards
- Aging
- Wind
- Flood
- Seismic
- Security
- Fire
- Blast

Apply Risk/Decision Methods
- Adapt and apply appropriate risk analysis tools
- Analyze and rank risks
- Assess alternative design and construction options
- Collect data needed to develop options
- Evaluate cost-benefit tradeoffs

Figure 2. Discriminating factors guiding risk assessment decisions.

Figure 3. Application of risk analysis to structures.
Finally, general techniques for risk management are widely known, and these could be applied to buildings by most risk analysts without modification.

**CONCLUSION**

In cases where there is a significant actuarial basis for decision making (e.g., the occurrence of fires in single-family dwellings) there is little incentive for formal risk management. Formal risk assessments are most useful in those cases where the value of the structure is high, many people may be affected, the societal perception of risk is high, consequences of a mishap would be severe, and the actuarial uncertainty is large. For these cases, there is little opportunity to obtain the necessary experiential data to make informed decisions, and the consequences in terms of money, lives, and societal confidence are severe enough to warrant a formal risk assessment. Other important factors include the symbolic value of the structure and vulnerability to single point failures.

It is unlikely that formal risk management and assessment practices will or should replace the proven institutions of building codes and engineering practices. Nevertheless, formal risk assessments techniques can provide valuable insights into the hazards threatening high-value and high-risk (perceived or actual) buildings and structures, which can in turn be translated into improved public health, safety, and security. The key is to choose and apply the right assessment tool to match the structure in question.

**REFERENCES**


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