Designing Buildings:

AN EXERCISE IN RISK MANAGEMENT

PART 2

By Armin Wolski

Introduction

In building design, architects and engineers perform risk assessments on an almost daily basis. Fire, tripping, fall protection, earthquake and glazing are subjects of risks to building users that are addressed in the design process. Engineers weigh risks and benefits when they make decisions about which loads to use, which safety factors are appropriate or which sensitivity checks are necessary to validate the quality of their design. Yet, with all the implicit use of such risk concepts, the explicit recognition of risk to address fundamental building safety issues is uncommon for the typical architect or engineer.

It behooves the community of architects, engineers, contractors and authorities to recognize that much of their task is one of risk management. When faced with "interpretive code applications" or even alternate methods of design and construction, an analysis, formal or informal, is the sensible approach. As a first step, this two-part article will describe to the building design community, by example, what is meant by the term "risk" in the built environment.

In Part 1 of this article, five key uncertainties were identified as characteristic of typical risk problems:[1]

1. **Uncertainty about the Problem;**
2. **Uncertainties in Ascertaining the Facts;**
3. **Uncertainties or Variations in Values;**
4. **Uncertainties about the Human Element; and**
5. **Uncertainties about Decision Quality.**

These key uncertainties are also evident in the building design, approval, construction and ongoing life span of buildings and facilities. Addressing or resolving these key uncertainties – whether explicitly or implicitly, whether qualitatively or quantitatively – together form the process of solving a risk problem; they are risk assessment and risk management, respectively.

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For the purposes of illustration, these uncertainties will be applied to a building fire risk problem – a typical risk problem that requires close collaboration between many disciplines: an atrium.

Uncertainties and Challenges

Uncertainty #1 is the question of problem clarification. In the building design industry, the challenge of properly identifying and framing the risk problems typically lie with the regulators and authors of the code, be it a prescriptive or performance-based code. For the most part, the designer tasked with the atrium design addresses this uncertainty only indirectly. In our case, the revealed or expressed preference of risk (or the "acceptable level or risk"), as published in international codes and standards, identifies multiple floor openings in buildings as a risk problem because of the undesired potential for smoke and heat transfer between levels. Either through experience or judgment, the collective wisdom as published in codes and standards tells us:

- There could be fire safety problems in atria buildings.
- There could be fire safety problems in buildings with interconnected floors that differ from problems in buildings without interconnected floors.
- The resolution of the problem, as codified in many codes and standards, is to provide safety to the occupants so that their egress is not compromised during a fire on another level.

With the problem best identified through codes and standards or through their own judgment, the designer is better able to assess and provide solutions that manage the risk appropriately.

It is notable that occasionally the code and/or standard may be "wrong" insofar that it addresses a risk problem incorrectly. For this reason, the codes keep changing. This constant evolution of the codes and standards is evidence that even problem definitions are rife with uncertainty at any one time.

Uncertainty #2 concerns the level of knowledge or facts associated with the risk problem or its proposed solutions. For example, the atrium analyst must be knowledgeable enough about the potential fire load in the atrium. The answer to the question may be based on a formal or informal survey of atria in university halls: What sorts of furnishings are commonly expected in a university building atrium? If a survey is not available, the analyst may look for knowledge that has been published as standards of practice, including referenced literature or guidelines. In some cases, an analyst might consider the worst-case fuel loading

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to be zero; however, according to a reputable reference, "even a 'sterile' atrium should consider a 1MW fire, a fire not of insignificant size." If likely fuel loading scenarios are identified, published fire testing can be consulted to quantify the hazard for inclusion in the analysis. Experience, testing and literature research are the predominant risk assessment methods used to address the risk (the uncertainties in knowledge) to inform the analysis (the fire modeling) and, in turn, to establish the appropriate management approach (the smoke control design).

Often, the design solutions for atria involve fans, dampers and power supplies that are assumed to be 100-percent effective. In this case, the level of knowledge associated with the solution is oversimplified. The engineer/analyst or designer rarely performs an analysis of system reliability. Suppose that there are 10 dampers that must open to provide make-up air for the atrium exhaust system. If each damper has a reliability of 95 percent, the reliability of all of the dampers operating correctly at the same time is around 40 percent. Having the appropriate knowledge in order to solve the problem is one issue; knowing what your solution offers is another issue.

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Uncertainty #3 concerns difference in values. A good designer is not someone who only understands his or her own fire safety problem, but one who also understands how the fire safety problem fits with competing design interests and goals and, in some cases, with competing risk problems. In the design process, the engineer is well-served to acknowledge how his or her interests, values and needs fit with those of others. For our atrium example, the architect might be interested in the aesthetic benefits of the atrium that make an architectural statement for the building. Or, perhaps, the architect is interested in the relationships between people in different parts of the building; the floor openings might provide the needed visual interconnection between occupants, which, in turn, provides a more cooperative and pedestrian-friendly environment. Similarly, mechanical engineers might see an open atrium as a means to optimize ventilation systems, and lighting designers might see an atrium as a means to optimize lighting systems. These optimizations save energy and make the building a more comfortable place. In contrast, however, building authorities might see the atrium as a great hazard to occupant and firefighter safety because it creates a pathway to spread smoke and heat throughout the structure.

These complementary and competing interests affect how the designer approaches the atrium problem. The risk problem can change if one or more of these values change.

Uncertainty #4 is about the human element: What do people know about the problem? Do the analyses, the assessment and risk management solutions accommodate human variability? This uncertainty is of great significance to successful design. Understanding how to address the human element in architecture might be the greatest uncertainty of all.

In our atrium example, the analyst might need to apply occupant movement models or egress models to determine the best design. In the use of egress models, the engineer needs to consider the human element: How will occupants react to a fire alarm? Will they start looking for an exit once they hear the alarm or will they start investigating the verity of the alarm? Will they start looking for loved ones, or will they call the fire department? If the design solution includes a voice evacuation speaker system, will such a system affect occupant behavior?

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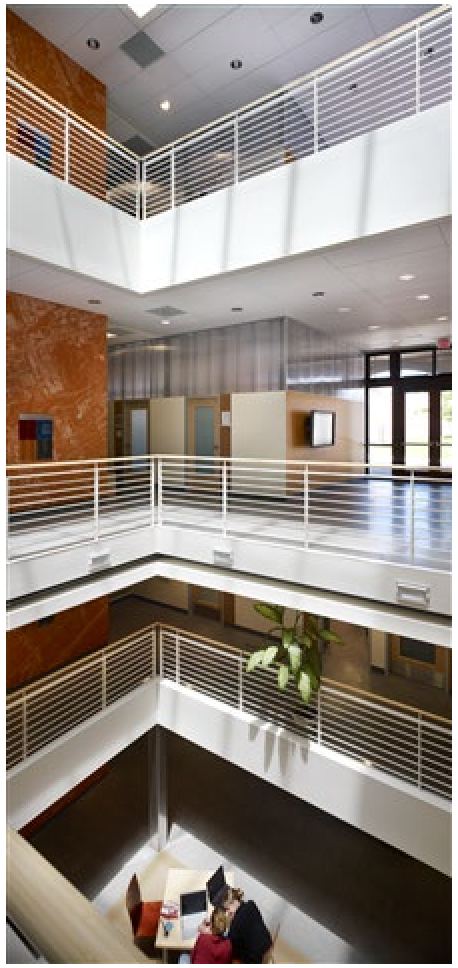
atrium smoke control system needs to be tested and maintained by people. A smoke control system analysis might account for people movement scenarios and human factors in evacuation and may not be a success if it does not account for human factors in maintenance. To minimize the uncertainty associated with human factors in maintenance, the analyst is well-served by collaborative efforts with all parties. With collaboration, the design minimizes complexity and increases practicality, and can result in a system that is easily and efficiently monitored and maintained by people plagued by human factors.

Uncertainty #5 concerns decision quality. The degree of uncertainty in decision quality is dependent on the tools or methods used, and on the qualification of the decision-maker (i.e., the analyst). Experienced, well-educated, well-qualified fire protection engineers acting as the primary analyst on such projects are well-versed in the limitations of their tools. Some tools are, however, better than others. A computational fluid dynamic model may provide the best decision quality for many atrium analyses, but such a model still retains a significant level of uncertainty, due to either an imperfect algorithm or imperfect user: Such software requires a high level of education and training for its proper application. Therefore, if a fire engineer uses an advanced modeling tool, such as Fire Dynamics Simulator (a common tool), the potential for error exists because of either imperfect user qualification or an imperfect algorithm. For example, after more than 10 years of use throughout the world, engineers have found that the FDS program consistently over-predicts soot concentration in a given space. This might result in an inaccurate prediction of the response time of a smoke detection system; the system might be predicted to respond more quickly than it would in reality, and results in error on the side of hazard. On the other hand, the same type of error creates a level of conservatism (safety) when applied to a tenability analysis that estimates the time to loss of visibility in the space. These decision quality uncertainties are key factors in concluding a risk management for an atrium.

The application of sensitivity analyses helps the design team review the decision quality. A sensitivity analysis might use a different tool; if computational fluid dynamics were used to reach a decision, perhaps a sensitivity analysis with other types of tools can provide a simple and efficient decision quality check. Additional checks may address such questions as: Does failure of the system jeopardize occupants more than if the system were not in place? Does the cost of a reliable system provide a reasonable cost benefit, or are there other measures that would provide better safety at reduced cost? Or, as we perform more and more analyses, discovering more about the tools, are we feeding back enough good information to the codes- and standards-making organizations to assist them in the development of regulations?



Now What?

Now that we know that a designer's task is one that needs to

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address uncertainties and balance issues and interests, we see that building design is one that is intimately entwined with risk assessment and risk management.

A risk analysis, be it qualitative or quantitative, can assist designers in a thought process that leads to better design. Furthermore, shifting the paradigm to risk management, appropriate risk analyses can assist designers in recognizing when prescriptive code implementation can lead to less safety, rather than more safety. If the codes recognize risk, then alternate methods of design, equivalencies or performance-based designs intended to increase design flexibility with no cost to safety can be made more transparent and easier for a building authority to accept. Without a conscientious thought process, without recognition of risk, such issues and opportunities might be lost. To be better designers, we must cultivate a habit of seeing building design challenges as risk problems. We must cultivate the habit of seeing the code as the framework that helps us manage risk problems.

As we move towards a risk-informed building regulatory process, a net increase in safety can be expected. Designers can use these concepts to reduce the uncertainties, reduce the likelihood of harm, increase accuracy, better inform owners and users and provide better buildings. Regulators can similarly benefit. For example, in recent years, with the growing evidence regarding fire risk in single-family homes, a risk-informed change to the *International Residential Code®* (IRC) has helped promulgate the fire sprinkler mandate in single-family homes throughout many areas of the country. This step will undoubtedly not only improve fire safety for occupants, but also increase safety for firefighters and reduce property losses. As the concepts of risk and risk management are embraced, regulators, designers, contractors and facilities engineers will be better equipped to optimize safety of the public. **bsj**

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[1]Fischhoff, B., Lichtenstein, S., Slovic, P., Derby, S. and Keeney, R., *Acceptable Risk*, (Cambridge Press, Cambridge Mass.: 1981) 9-46.

As always, your articles, ideas and submissions are welcome. Send them to foliver@iccsafe.org along with a daytime phone number at which to contact you with questions.