ABSTRACT
By addressing the safety of building users and the stability of structures under various natural and technological hazard conditions, building and fire codes address various risks to life and property. As performance-based building and fire codes are developed, they are increasingly being aimed at establishing clear and unambiguous levels of socially acceptable risk. What does this mean – to regulatory developers – to enforcers – to practitioners – to the public? This paper discusses the concepts of risk, acceptable risk, risk characterization with the aim of helping those in the building regulatory process better understand the complexities of resolving risk decisions.

KEY WORDS
Risk; Risk Acceptability; Risk Characterization; Performance-Based Building Regulation

INTRODUCTION
It has been stated that “the risks to which society is, in fact, exposed are largely determined by regulations and how effectively they are implemented and enforced” (Otway, 1982). There are numerous examples of this, from speed limits and drunk driving laws to environmental regulations. When speed limits are lowered, and enforced, and drunk drivers are removed from the roads, automobile-related deaths drop. When pollution controls are placed on smokestacks and automobiles, and the acceptable levels of effluent are enforced, the air is cleaner and the populace is less at risk from air borne pollutants. To be effective, however, such regulations must have clear risk-related goals and appropriate modes of enforcement. The same can be said for building fire safety regulations.

The intent of the current building and fire regulations used in the United States, and in many other countries, is to provide an acceptable level of safety, health, and welfare during the design, construction and use of buildings. Over time, however, factors such as catastrophic losses from fire and natural events, advances in technology, industry lobbying, fear of liability, and environmental health and safety concerns have caused prescriptive building regulations to expand from tens of pages in the late 1800s to thousands of pages today. With such an expansion adding more and more detail, and incorporating more and more code provisions to address specific concerns of various groups, it has become difficult to determine the overall level of safety being provided. In addition, it has been observed that the prescriptive building regulatory approach to assuring safety seems to work well for some hazards but fails to address others, and lacks mechanisms for balancing efforts to address the many sources of potential risk (McDowell and Lemer, 1991).

Given such a regulatory shortcoming, it would seem natural that risk concepts would be widely accepted in the building regulatory environment, especially as part of the transition to

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performance-based regulations. However, the concepts of risk and acceptable risk, and the use of risk analysis, are not clearly understood or widely accepted throughout the building community. This is true for many reasons. As reported in a U.S. National Research Council supported study (McDowell and Lemer, 1991):

“Lacking a common framework for discussion and analysis of safety, the public and government officials are often poorly prepared to deal effectively with issues that have small probabilities of occurrence and the potential for severe consequences. Development and broad application of risk analysis procedures will help facility professionals, policy makers responsible for assuring safety, and the people and property owners exposed to risk to understand more clearly the nature of those risks and to determine what levels of risk are socially and economically tolerable.”

Although some work has been recently undertaken on risk in performance-based building and fire regulation development (Meacham, 2000), and some countries plan to include risk concepts in their building regulations (ICC, 2000), the above issues remain essentially unresolved in most countries. In general, significant questions remain as to:

- the appropriate level of safety, or risk, at which to regulate,
- public expectation relative to “acceptable” risk, and
- the bases for assessing acceptable levels of building fire safety performance and risk.

To address these questions, developers and enforcers of performance-based building regulations need to more fully understand the concepts of risk, and ultimately, specific goals and objectives that reflect acceptable or tolerable levels of safety need to be incorporated into the regulations.

**WHAT IS RISK?**

It is often difficult for persons from different backgrounds to have a meaningful discussion of “risk” as there is no consensus definition. Covello and Merkhofer (1993) suggest the lack of a consensus definition is due to the fragmented way in which the field of risk analysis has developed. There are health risks, safety risks, economic risks, political risks and more, and what risk means and how it is measured is often a function of the context. Engineers often view risk as a numerical value that is a function of probability and consequences. Some social scientists view risk as a social construct, dependent upon the social situation and conditional knowledge (Wynne, 1992). Another view is held by some psychologists who believe that “risk” does not exist outside of our minds, but that it is simply a concept humans developed to deal with uncertainties of life (Slovic, 1992). Fischhoff et al. (1981) suggest that the selection of a definition of risk is a political one, chosen to express someone’s views regarding the importance of different adverse effects in a particular situation. They cite a number of dimensions to the definition issue, including objectivity (objective versus subjective probability and/or risk), dimensionality (there are usually benefits as well as consequences), data, statistics and units of measure, time impacts, values and perceptions. Add to the mix various cultural and economic viewpoints on risk, and one can easily develop at least seven types or approaches to risk, with the number of definitions being still higher (Renn, 1992).

To better understand how some of these differing views and perspectives come into play when trying to understand a risk problem, consider some of the issues related to just one approach to
risk: the engineering approach. Engineers often use what they consider to be a straightforward definition that combines the potential for an undesired consequence with the likelihood that such a consequence will occur (Rasmussen, 1990). This concept of risk is often represented mathematically as Risk (consequence/unit time) = Frequency (event/unit time) x Magnitude (consequence/event). Such a definition allows one to calculate a numerical value of risk. For example, one could calculate the annual risk of death from automobile accidents as Risk (deaths/year) = Frequency (accidents/year) x Magnitude (death/accident). Although this mathematical expression seems simple and straightforward, it has some problems, especially if used as a method to compare options.

For example, suppose one activity has a frequency of occurrence of $10^{-6}$ per year with an average consequence of $10^6$ deaths per accident, and another activity has a frequency of occurrence of $10^{-1}$ per year with an average consequence of 10 deaths per accident. Using only the mathematical expression above, the activities have the same risk, as $(10^{-6} \times 10^6) = 1$ and $(10^{-1} \times 10) = 1$. However, many individuals, and/or a society may prefer the latter to the former for a variety of reasons, including values, personal preferences, and/or cultural differences. On its own, this mathematical approach will not account for such differences, and thus a comparison between alternatives may not encompass all concerns. This approach is further complicated when there is disagreement on how the consequences are defined (e.g., in terms of health, safety, environmental impact, money, etc.).

The above mathematical expression is also used with “frequency” replaced by “probability.” This can result in additional concerns given that there are two significantly different views on probability: the frequentist viewpoint and the subjectivist viewpoint. In brief, the frequentist approach is held by classical statisticians who consider probability to be a property of a process that can be determined from an infinite population of data (Rasmussen, 1990). Consider the process of flipping a coin and trying to determine whether it will land head or tail side up. The probability of the coin landing head side up ($P_H$) is defined as the number of heads that are observed ($N_H$) divided by the number of coin flips ($N_F$) as the number of coin flips approaches infinity. This can be expressed mathematically as follows:

$$P_H = \frac{N_H}{N_F} \quad \text{as} \quad N_F \to \infty$$

To address the fact that an infinite population of data is impossible to obtain, frequentists have developed techniques for making estimates of the probability ($P_H$ in this case) and the associated uncertainty in the estimate using less than an infinite population of data. They believe that the resulting probability is a precise value and that information needed to estimate it can come only from observing the process. The subjectivist viewpoint, however, is that probability ($P_H$ in this case) has a value at any time that represents the total available knowledge about the process at that particular time. For the same case of flipping a coin, if the subjectivist examined the coin and found it to have a head and a tail and was well-balanced, and further observed the flipping process and found that to be fair, they would estimate $P_H$ as 0.5. However, if after ten flips, seven heads were observed, this information would be added to the previous knowledge in a
logical and consistent manner based on Bayes theorem (see Benjamin and Cornell, 1970; Apostolakis, 1978; or Von Winterfeldt and Edwards, 1986, regarding Bayesian approaches).

If a large enough number of coin flips was made, the frequentists and the subjectivists would each eventually obtain a value of $P_H$ that approaches 0.5. Nonetheless, many frequentists do not accept the subjectivist approach as being valid, and many subjectivists view the frequentist approach as being impractical, especially in the face of limited data. Thus, the acceptance of a risk estimate that is derived from a mathematical expression of the form $\text{Risk} = \text{Probability} \times \text{Consequence}$ will be dependent upon whether the probabilities are developed by frequentists or subjectivists and whether the receivers of the risk estimates are frequentists or subjectivists.

Looking only at the classical engineering (mathematical) definition of risk, two significant concerns are immediately obvious: societal and/or individual values, preferences, and/or cultural differences are not explicitly addressed, and the difference in opinion on probability makes broad agreement difficult. To address these concerns, and the others listed at the start of this section, a different definition is needed. Although an ideal definition may not be possible, a well-rounded definition or characterization of risk should include the concepts of (Kasperson, 1992; Stern and Fineberg, 1996):

- hazard,
- consequence, including all relevant consequences and valuing of the consequence (including off-setting benefits),
- perceptual differences,
- social and cultural experience,
- judgement(s) regarding the likelihood of the consequence occurring, and
- uncertainty and variability.

One definition of risk that includes all of the above issues is (Meacham, 2000): “the possibility of an unwanted outcome in an uncertain situation, where the possibility of the unwanted outcome is a function of three factors: loss or harm to something that is valued, the event or hazard that may occasion the loss or harm, and a judgement about the likelihood that the loss or harm will occur.” In this definition, the valuation of loss or harm is intended to consider physical, technical, social, cultural and psychological factors, and event or hazard is intended to consider any act or phenomenon that has the potential to produce loss or harm. Loss or harm to something that is valued includes such things as loss of life, injury, disease, reduced quality of life, inability to carry on economic activity, property damage, and damage to the environment.

ACCEPTABLE RISK?

As with the difficulties in gaining consensus on a definition of risk, there is no consensus on what makes a risk “acceptable” (or on whether that is even possible). The concept of acceptable risk has been a focus of research, discussion and debate for some thirty years. The debate was essentially opened when Starr proposed that societal risk acceptability could be determined by reviewing the level(s) of risk that society “accepted” in the past (Starr, 1969). Starr’s revealed preference concept suggested 1) that the public accepts voluntary risks on the order of 1000 times greater than involuntary risks, 2) that statistical risk of death from disease is a
psychological yardstick for establishing a level of risk acceptability, 3) that acceptability is proportional to the third power of the benefits, and 4) that social acceptance of risk is influenced by public awareness as determined by advertising, usefulness, and number of people participating. Although embraced by some, many viewed this concept as being an “engineering” interpretation and approach for addressing a complex social and psychological issue, and was met with skepticism and concern. These reactions served to initiate a period of considerable research regarding risk perceptions and risk acceptability in the social sciences and psychology (e.g., Kahneman and Tversky, 1974; Fischhoff et al., 1981; Slovic, 1987) as well as in engineering (e.g., Litai, 1980; Litai et al., 1983).

In response to Starr’s revealed preference concept, some psychologists argued that people’s actual perceptions of risk can only be determined through questioning and individual ranking/comparison of risks. This is known as expressed preference. Expressed preference itself is one component of what is known as the psychometric paradigm of risk acceptability. The psychometric paradigm is one in which well-defined heuristics and judgments about characteristics of hazards play important roles in determining individual perceptions, and therefore acceptability, of risk. The heuristics are availability; anchoring and adjustment; representativeness; belief in the law of small numbers and disqualification; and overconfidence. They primarily relate to one’s ability to accurately estimate the likelihood of some event or outcome occurring, and they impact both risk professionals and lay people (but often in different ways, thus causing many of the differences in perceptions).

The availability heuristic describes the observation that people tend to assign greater probabilities to events to which they are frequently exposed to through such avenues as family, friends, and the media (if the exposure is frequent, the event is readily available in one’s memory). This explains why lay people often overestimate such deaths from homicide, which is constantly in the news, and underestimate deaths from suicide, which typically has very little media exposure. Anchoring and adjustment reflect the observation that people’s estimates of uncertain values are influenced by some initial value (which may be unrelated), and make adjustments based on additional information. Representativeness describes the observation that people often judge an event based on reference to other events that resemble it, even if the resemblance carries little or no relevant information. Among risk professionals, this heuristic can help explain some common biases in statistical thinking, such as the failure to appreciate the difference in reliability between large and small samples. Closely related is the belief in the law of small numbers and disqualification. This heuristic can be characterized by those who believe small samples drawn from a population to be more representative of the population than is justified (based on standard statistical theory), yet also tend to “disqualify” information that contradicts strongly held convictions. These two characteristics are seen independent of each other as well. Finally, overconfidence can result when one is susceptible to the above heuristics (biases).

In addition to the above heuristics, it has been shown that individual risk perceptions are also influenced by the judgments people make about hazards (Slovic, 1987). To evaluate how judgments influence risk perceptions, a set of attributes was developed from various sources to describe the hazards, interviews were conducted, and the results of the interviews were mapped. The mapping is illustrated in Figure 1, where the attributes are shown in the boxes and the circles
indicate quadrants in which various hazards fall (e.g., quadrant 1 may include DNA technology and radioactive waste, and quadrant 3 may include bicycles and swimming pools).

By interviewing different groups of people and mapping the results, Slovic (1987) has shown that risk is often perceived differently by experts and non-experts. For lay people, the “dread” factor seems to be a driving concern in their perception of risk. However, for “experts,” the perceptions are more closely related to statistics, such as expected annual mortality. This is a strong argument against taking only a “statistical” risk approach for addressing public risk issues: the opinion of the large lay population may not be adequately represented.

Another issue to consider is that risks may not necessarily be accepted, but rather, are tolerated. Individual acceptance, for example, implies that one has all of the pertinent information on which to base a decision, that one understands the information and that one is free to choose whether they want to accept or reject the risk (Kasperson and Kasperson, 1982). By this definition of acceptance, an individual does not accept building-related risks, but rather, tolerates the levels of risk imposed upon them. For any individual, one can assess the level(s) of risk tolerability in a relatively straightforward manner. However, when one looks at societal acceptability, the variability between individuals makes the process of assessing tolerable risk levels more difficult, and the judgments of those who regulate the risks are necessarily subjective. The setting of acceptable or tolerable levels of risk not only requires judgments regarding the risk, but also about acceptable distribution of risks across various populations. This requires value judgments (Fischhoff, 1996; Kunreuther and Slovic, 1996; Keeney, 1981, 1992 and 1996), and various ethical issues enter into the decision-making process, including valuing consequences, paternalism versus autonomy, equity considerations, and a responsible decision process (Kasperson and Kasperson, 1982).

Figure 1. Risk Characteristics for Evaluating Risk Perceptions (adapted from Slovic, 1987).
In addition to the issue of differences in risk perception, other factors in the “acceptable risk” conundrum include the issues of assessing and expressing risk. Numerous methods exist for assessing (Covello and Merkhofer, 1993) and expressing risk (Stern and Fineberg, 1996), with the selection of a method or mode for assessing or expressing risk often made to support a particular position or to impact the receivers’ perceptions of risk. An example is the often referenced use of coal mining statistics (Crouch and Wilson, 1982), where the measure of risk one chooses to report reflects the position one is trying to make. In the referenced example, if one chooses risk of death from accidents per ton of coal as the measure, coal mining seems to have gotten safer. If one chooses deaths from accidents per employee, coal mining seems to have gotten riskier.

This issue is complex as the choice of a risk assessment method is often intimately tied to how the risk is expressed and what is known about the hazard and the consequences. For example, if one chooses a metric such as “increased chance of death by one in a million yearly,” one has to be able to demonstrate, to all involved, both the “nominal” yearly chance of death and how the chance of death would be increased by the hazard under evaluation. If one or more parties involved disagree with the risk metric or the assessment method, there will be problems from the outset. Consider the metric of death. Is it death per million people in the population? Is it individual risk of death? Is it death per unit concentration, ton of product released, ton of product produced, or other? Once the issue of what causes death is resolved, the next issues include the quantity or threshold value(s). If death per unit concentration is selected, for example, what evidence is there to support any given threshold limit exists at that concentration and for which people? Are all people affected or only some sensitive population? Questions such as this lead to still more issues, such as who should be protected and to what level, e.g., everyone to an absolute value, some sensitive population to the 99th percentile, or something else altogether? Finally, if death is used as a metric, the issues surrounding definition of the metric will be laden with value judgments, and considerable difference can be expected due to social, religious, philosophical and various other reasons.

One way to avoid the above issues is to avoid the use of death as a metric. One alternative is to use a surrogate, such as establishing a threshold for a known toxic material and focusing on how much of the material is in some product (organic or man-made) and how much can be expected to be released during an event. However, although some of the philosophical issues specific to discussions of “acceptable deaths” may be avoided, there will still be a number of issues related to estimating the levels in the product, how much is released, how is it released, and so forth. A large contributor to the above problem is that the data, tools, and methods for assessment and prediction may be lacking. These factors interject uncertainty, with which some people, such as regulators, politicians and lay people, have trouble dealing. Also, because of the difficulties in some analyses, simplifying assumptions made be made, which some parties may not understand or agree with. Issues regarding uncertainty will be discussed in more detail at a later point.

In an attempt to avoid some of the above issues associated with assessing and expressing risk, and in particular, with trying to define “actual” risk numbers, a variety of approaches have been proposed. These include:
• setting ranges of acceptability, such as the ALARP [As Low As Reasonably Practical] approach (Whipple, 1987; Kasperon et al., 1988a; HSE, 1988),
• establishing a lower or de minimus level of risk below which one is not concerned (from the Latin ‘the law does not concern itself with trifles’) or an upper or de manifestis risk level (Whipple, 1987),
• adding uncertainty factors (Morgan and Henrion, 1990),
• applying benefit-cost analyses (Kleindorfer et al., 1993), and
• applying comparative approaches (Wilson, 1984; USEPA, 1987; Finkel, 1996).

Although a number of regulations use one of these approaches, none of these approaches is without problems, and no one approach seems to be dominant or acceptable to all parties. A brief review of risk in regulation provided later will highlight some of the issues.

The benefit-cost approach is worth discussing in more detail here, as economic approaches are often associated with risk assessment and mitigation. The basic assumption is that if risk reduction techniques vary with cost and benefit, classical economic theory can be used to help describe an acceptable or optimal level of risk. In brief, fundamental economic theory dictates that the optimal level of risk is that at which the incremental or marginal cost of risk reduction equals the marginal reduction achieved in societal cost. This is illustrated in Figure 2 (Morgan, 1990).

![Figure 2. Economic Concept of Optimal Level of Risk (Morgan, 1990).](image)

However, in many regulations, the primary risk concern is the potential for loss of human life. This poses a significant problem, as society’s acceptance of risk varies with personal or social values, thus there is no universal agreement on how to value lives. This makes it difficult for regulatory developers to effectively and non-controversially apply economic models. Nonetheless, various approaches have been developed to address the issue of valuing human life. These range from assuming a value based on age and ability to earn income, to estimating the cost of a premature death averted by focusing on the costs of prevention or protection (Tengs et al., 1995) None of the methods are without problems, as there are always questions such as: what is the value to humanity for just being alive, for providing friendship and love? Also, people have difficulty assigning a value to their own lives. Howard demonstrated this by posing
the question: “How much money can I pay you to take this black pill that has a 0.001 probability of causing instant death?” and getting little agreement on an answer. Because of this, he has argued that it is not irrational to place an infinite value on one’s life when the chances of dying are high (Fischhoff et al., 1981).

The impact of personal and societal values on determining acceptability becomes more complex when multiple options are available. Consider an example where the costs and risks of various options A, B, and C are explicitly known (but significantly different) and each option provides equivalent benefit. (For example, A, B, and C might be three different surgical procedures, with the benefit being the return of one’s vision to 20/20.) Option A has the lowest cost and the highest risk of failure. Option C has the highest cost and lowest risk of failure. Option B is inbetween. The decision problem is illustrated in Figure 3 (Fischhoff et al., 1981).

Although option A is the cheapest, it may be that A would never be preferred, as the individual may be unwilling to accept the risk. The individual would then have to choose between B and C. As options B and C both provide significant risk reduction over A, it may well be that cost will be the deciding factor (especially where the risk difference between B and C is small compared to the difference between A and B), and the individual will select option B. If cost is not a factor, it may be that the individual will select option C. In short, the options must be reviewed based on the decision maker’s value system and available resources. In the end, an individual decision is required, based on available information, to determine which option provides an “acceptable” solution for the risk given the costs and benefits involved.

The above concept was promoted by Fischhoff et al. (1981), who suggested that an acceptable risk problem be viewed as a decision problem, where different solutions to a risk problem provide different benefits, and acceptability is a function of the options available and the option(s) selected. They argued that because values, perceptions, and available information may affect evaluation of the options, there are no universally accepted or acceptable risks. Rather, they argue that the acceptability of risk should be viewed as an attempt to solve or manage a
problem, and whether the risk is acceptable will be dependent on whether the approach to managing the risk problem is acceptable.

Since regulation is an approach to managing a risk problem, the acceptability of a risk is dependent on the acceptability of the regulation, and also, the manner in which the regulation is developed. Three major approaches to decision-making exist that can be used for acceptable risk problems: Bootstrapping, Expert Judgment, and Formal Analysis (Fischhoff et al., 1981). The bootstrapping approach essentially involves identifying and continuing policies that have evolved over time. If a regulation, for example, has been deemed “successful,” it is assumed that it has adequately balanced risks and benefits, and can provide a basis for establishing an acceptable level of safety or risk. This is how most prescriptive-based building regulations are developed, and is an approach used by some in the development of performance-based regulations to determine the “intent” of prescriptive code provisions. Problems exist, however, in that this approach reflects the bias that whatever was right in the past was correct, and is therefore appropriate for the future. Thus, new information and expectations may not be readily incorporated into the decision-making process.

The approach of expert, or professional judgment, is to rely on the judgment of technical experts, knowledgeable in the field, to make critical decisions. Such approaches are used in all aspects of building design, from structural engineering decisions to fire protection decisions. They are also used in the regulatory development process, particularly in the area of design and installation standards, which reflect the “best judgment” of the technical experts in particular fields. They may not be appropriate, however, as the primary method for the overriding building regulation development, in which social, economic, and value decisions are important.

Formal analysis encompasses a broad collection of formalized decision-making tools and methods, including decision analysis and cost-benefit analysis (see, for example, Merkhofer, 1983 and 1986). The assumption in this approach is that “intellectual technologies” can be used to help manage problems created by physical technologies (Fischhoff et al., 1981). Although well-structured and presumed to be comprehensive, such approaches are often questioned as to their ability to accommodate all relevant consequences and options, as to their approaches to valuation (such as the value of a human life), and as to the rigor which is actually used in practice.

Regardless of the decision-making approach taken, five crucial generic complexities exist for resolving acceptable risk problems: uncertainty about how to best define the decision problem, difficulties in assessing the facts of the matter, difficulties is assessing relevant values, uncertainties about the human element in the decision-making process, and difficulties in assessing the quality of the decisions that are produced (Fischhoff et al., 1981). How well a given approach or regulation contends with these uncertainties is an indication of its potential for success.

As a means to evaluate how well one of the three above approaches to regulation (Bootstrapping, Expert Judgment, Formal Analysis) addresses these concerns, Fischhoff et al. suggest application of the following seven criteria: Comprehensive, Logically Sound, Practical, Politically Acceptable, Compatible with Existing Institutions, Open to Evaluation, and Conducive to
Learning. These criteria are applicable to regulations independent of the industry, as Wolski et al. demonstrate in a comparison of such regulated areas as nuclear power plant design, seismic/structural design, environmental protection, food technology, and building fire safety (Wolski et al., 1998; Wolski et al., 2000).

In an attempt to integrate many of the factors that influence the acceptability of risk as discussed above, Kasperson and his colleagues developed the theory of social amplification of risk (Kasperson et al., 1988). The theory is based on the thesis that events pertaining to hazards interact with psychological, social, institutional, and cultural processes in ways that can amplify or attenuate perceptions of risk and shape risk behavior. Behavioral responses then generate secondary social or economic effects, which extend beyond direct impacts to health or the environment, to include a variety of significant indirect impacts. The extent to which a risk signal is amplified or attenuated by amplification stations is critical to how the receivers of the information will respond socially, technologically, and politically. Impacts of the amplification include enduring mental images, impacts on local economy, political and social pressure, social disorder, changes in regulation, increased insurance costs, and repercussions on other technologies. The amplification or attenuation may have direct implications for risk management and the tolerability of risk, as it is the consequences that are normally amplified or attenuated. This can result in the creation of controversies by focusing ‘too much’ on ‘small’ risks or by diverting attention from ‘significant’ risks to other areas (Kasperson, 1992). These implications are important to bear in mind during any effort to understand how certain risks may or may not become viewed as “acceptable.”

RISK CHARACTERIZATION

At one time, risk characterization was described as being the result of a risk assessment (NRC, 1983). However, more current thinking considers risk characterization as being the product of an analytic-deliberative decision-making process, wherein there is an appropriate mix of scientific information (from “traditional” risk assessment) and input from interested and affected parties throughout the process (Stern and Fineberg, 1996). In this paradigm, risk characterization is described as a decision-driven activity, directed toward informing choices and solving problems. It suggests that coping with a risk situation requires a broad understanding of the relevant losses, harms, or consequences to the interested or affected parties, and that risk characterization is the outcome of an analytic-deliberative process. These factors are important, for a number of reasons. For example, a singularly-focused view of risk may inadvertently miss important considerations, such as technical, social, economic, value, perceptual or ethical impacts. As a result, the problem may be formulated improperly, either technically, socially or in some other manner, and the resulting analysis may omit key parameters. In addition, if not all interested or affected parties are involved in the process, they may disagree with anything from the problem statement to the measure of risk selected. Sensitive populations may be left out, socio-economic factors may be ignored, or cultural sensitivities may be unknown.

The success of the risk characterization process depends critically on systematic analysis that is appropriate to the problem, responds to the needs of the interested and affected parties, and treats uncertainties of importance to the decision problem in a comprehensible way. Success also depends on deliberations that formulate the decision problem, guide analysis to improve decision participants’ understanding, seek the meaning of analytic findings and uncertainties, and improve
the ability of interested and affected parties to participate effectively in the risk decision process. In other words, good risk characterization requires a well-defined problem that those involved agree with, a sound scientific base, the proper use of analytical techniques with proper consideration of uncertainties and unknowns, and sufficient discussion and deliberation so that everyone understands all of the issues. The process will likely require several iterations, as new information and data become available, and as participants gain better understanding and raise more issues. It needs to be an interactive process, and not one where one group dominates the deliberations and/or analysis and forces a solution.

Finally, it is very important that the process have an appropriately diverse participation or representation of the spectrum of interested and affected parties, of decision-makers, and of specialists in appropriate areas of science, engineering and risk analysis at each step. As intimated above, if not all of the right people are involved, there may be problems in characterizing appropriately, valuing properly and gaining acceptance of the outcomes at the end of the process. The more widespread the participation, and the broader the scope of factors considered at the outset, the less likely it will be that major factors are overlooked. Once the risk situation (risk problem) and the interested and affected parties have been identified, the next step is to diagnose the risk decision situation. To accomplish this, eight interconnected steps are suggested (Stern and Fineberg, 1996), including: diagnose the kind of risk and the state of knowledge, describe the legal mandate, describe the purpose of the risk decision, describe the affected parties and the likely public reaction, and develop a preliminary process design. The diagnostic steps for risk decision making are illustrated in Figure 4.

Figure 4. Diagnostic Steps for Risk Decision-Making (Stern and Fineberg, 1996).

In addition to getting the right participation and adequately describing the risk situation, one of the most important factors in risk characterization is to ensure that adequate scientific and technical information is available to support the decision. This function occurs primarily in step one of the diagnosis stage: diagnose the kind of risk and state of knowledge. To help focus this effort, various diagnostic questions are should be asked about the hazards and the risks, including (Stern and Fineberg, 1996):

- Who is exposed?
- Which groups are exposed?
The risk characterization process outlined above has been applied to the performance-based building regulatory development process in the United States, and the outcomes are encouraging (Meacham, 2000; 2000a; ICC, 2000). As reported, the stakeholders better understand the issues, and the regulatory developers have more confidence in setting and enforcing tolerable risk levels.

CONCLUSION
Identifying and characterizing risk as a metric for use in building regulation and design is gaining momentum worldwide. At the present time, however, most building regulations do not explicitly address levels of tolerable or acceptable risk, which makes it difficult for designers and enforcers. There are many reasons for this, including the complexity of defining risk and its level of acceptability for the myriad stakeholders impacted by building regulation, obtaining adequate data for risk decisions, and developing broadly agreed frameworks for assessing and mitigating building-related risks. To help both the design and enforcement communities better understand and address these difficult risk issues, this paper has outlined key risk and risk acceptability concepts, with the aim of building a common vocabulary and approach to building risk assessment and mitigation.

ACKNOWLEDGEMENTS
Much of the above text is excerpted directly from, Meacham, B. J., A Process for Identifying, Characterizing, and Incorporating Risk Concepts into Performance-Based Building and Fire Regulation Development, Ph.D. Dissertation, Clark University, Worcester, MA, April 2000 (copyright Brian J. Meacham, all rights reserved), and is reprinted with permission.

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