A Hypothetical Model for a Performance-based Codes System for the United States†

Richard W. Bukowski, P.E.
Senior Research Engineer
NIST Building and Fire Research Laboratory
Gaithersburg, MD 20899-0001 USA

The transition to performance-based codes is well underway in many countries of the world, and several have adopted such. Interest in performance-based codes in the U.S. is high, but the diffuse nature of the codes system here presents some special challenges which will need to be addressed. This paper attempts to highlight these challenges and suggest one possible approach to meeting them.

THE CURRENT U.S. SYSTEM

Building regulation in the U.S. is the responsibility of the States, some of which delegate this responsibility to local (county, city) jurisdictions. Most codes are based on model regulations developed by private sector organizations through a public hearing process in which code changes can be proposed and challenged by anyone but the right to vote to adopt, modify, or reject proposals is limited to code enforcing officials. Responsibility for final publication of the model regulations rests with a "Code Committee" which serves as the gatekeeper to the system and a point of appeal of the process. Further changes are made as these model regulations are adapted and adopted into law by local legislatures. Proponents of this process hold that while anyone can propose changes, keeping the responsibility for acceptance with enforcing officials assures that the model regulation best serves those charged with applying it to assure public safety.

Most standards are also developed by private sector organizations, but using a consensus process whereby committees of volunteers draft and maintain the standards. Proposals, which can be made by anyone are processed by the committee and can be challenged and appealed through a defined procedure. These committees must meet "balance" criteria under which participants are categorized (manufacturer, enforcer, user, special expert, insurance, etc.) and no category can hold more than a third of the votes. The standards process often also involves a committee to provide final review and appeal. Proponents of this system suggest that the resulting standards benefit from the diversity of involvement.

Model Codes

Public Proposal | Code Official Committee | Public Review | Public Hearing | Code official Vote | Publication

Standards

Public Proposal | Balanced Committee | Public Review | Comments | Public Review | Members Vote | Review/ Appeal

†International Conference on Performance-based Codes and Fire Safety Design Methods, Sept. 24-26, 1996, Ottawa, Ontario, Canada, SFPE, Boston, MA, 1996 (in press)

Responsibility for code enforcement also resides at the local level. Local officials review plans and issue building permits, inspect work in progress, and conduct final inspections before issuing a certificate of occupancy. Decisions as to what meets or does not meet the code, including equivalencies, are made by local officials. Assistance can be requested from higher authorities and interpretations can be obtained from codes and standards developers, but these are advisory only. Ultimate responsibility rests with the code enforcement official.

The codes prescribe requirements for health, safety, environmental, and conservation aspects of buildings as a function of general use categories. Restrictions on land use are the responsibility of a different organization called a zoning commission, and are not a part of the building code as is the case in some countries. Preservation of buildings of historical significance is yet another independent function, usually assigned to local commissions separate from the building regulatory process.

As the codes are written, there are standards cited within them which prescribe how to install and maintain systems which meet or exceed the minimum requirements of the voluntary regulations. These standards may be included or referenced.

Standards referenced in the codes prescribe how to install and maintain systems required or utilized voluntarily above minimum requirements set in the codes or describe test methods for regulated materials or products. All codes and standards in use in the U.S. incorporate an "equivalency clause" which provides for the approval of alternate methods of achieving the "intent of the code." These clauses are frequently cited as evidence that the current system is performance-based or at least allows performance evaluation. The problem is that the "intent of the code" is often unclear or at least subject to interpretation. Such interpretations may change over time, and the original, implicit assumptions may become lost. Thus, one major advantage of performance-based codes would be the clarification of the objectives (intent) of the code as well as agreement on acceptable methods of demonstrating that the objectives are met.

A MODEL FOR A PERFORMANCE-BASED SYSTEM

The defining characteristic of a performance-based system is the replacement of prescriptive requirements with performance objectives and the means to assess whether these objectives will likely be met. Thus, the transition to a performance-based code system will require that society agrees on its objectives for the built environment and on the methods by which performance is to be assessed. In the current system recommendations are made by the codes and standards community which are then adapted and adopted into law by state and local legislatures. It is reasonable to expect that these lines of responsibility will remain in any new system.

Setting Objectives

Prescriptive codes have implicit objectives which underlie the intent of the code's provisions. Thus the current codes and standards development process makes the public policy decisions as to what level of performance society expects of its built environment. Under this model, the existing codes and standards committees would develop quantitative objective statements for their documents through their existing open procedures.

Many countries going through this transition have taken the position that the level of performance desired by society is that embodied in the prescriptive code because, “Since there is no public outcry that they are too high, society is clearly willing to accept the current level of fire losses.” Brannigan[1] has argued that such statements cannot be made for a number of reasons.

Paraphrasing Brannigan’s points: First, such statements assume that the public is satisfied with an expected risk to life rather than a safety level. Fire, especially disastrous fires are rare events. When dealing with rare events the public may believe that the risk to life is actually zero.

Second, the claim that society is “satisfied with the level of safety achieved by our current regulations” assumes that the current regulations are the sole cause of this socially acceptable level of safety. Codes specify minimum requirements which are often exceeded in the recognition of liability or public image (e.g., significant improvements in fire safety were implemented by the lodging industry following the fires of the 1980's, well in advance of changes to the codes). If the performance level is set as equivalent to the minimum code, the result may be an increase in losses when compared to the code compliant building.

Third, it is assumed that the engineering methods accurately reflect the expected risk to life in different buildings. It may not be possible to predict accurately loss rates in the future due to the fact that stochastic elements are based on past materials and lifestyles which may change (e.g., Smoking materials are among the most commonly cited ignition sources in fatal fires. The rate of smoking is rapidly declining in many countries so the risk of cigarette ignition should be declining).

Fourth, by requiring that performance is measured against buildings built to the prescriptive code without specifying performance levels, it is assumed that both the buildings and society’s views of risk are static. Fire disasters often point out flaws in the code(s) which are subsequently corrected. If such a flaw were uncovered, the performance method would allow buildings to continue to be built with that aspect of risk uncorrected as long as that hazard goes unrecognized by the prescriptive code. Most societies would not accept such a practice.

Another approach has been to use selected engineering methods to evaluate buildings which just comply with the prescriptive code to quantify the implied level of performance. This approach is only a variation on the above, and suffers from the same problems.

A better approach is to ask the code committees and regulators to quantify their intent when they wrote the prescriptive code. Since they have been delegated the responsibility to set levels for society, this is appropriate and the result will be the levels they actually intended.

As an example, the Fire Marshal[2] in Boston established a set of objectives for fire hazard assessments for multi-family residential occupancies performed in support of requests for waivers of the prescriptive requirements of the code. They are:

- Limit fatalities or major injuries to only those occupants intimate with the fire ignition.
- Limit minor injuries to only those in the dwelling unit of origin.
- No occupant outside of the dwelling unit of origin should be exposed to the products of combustion in a manner that causes any injury.
- Limit flame damage to the dwelling unit of fire origin (this includes taking into account the

possibility of flame extension up the exterior of the building).

- C Limit reaching of hazardous levels of smoke and toxic gases to the dwelling unit of fire origin before safe egress time is allowed. At no time during the incident should the smoke conditions in any compartment, including the compartment of origin, endanger persons in those compartments or prevent egress through those compartments.
- C Limit the incident to one manageable by the Boston Fire Department without major commitment of resources or excessive danger to firefighters during all phases of Fire Department operation, i.e., search and rescue, evacuation, and extinguishment.

These would certainly be suitable as objectives of a performance-based code, and provide an additional level of detail necessary for engineering analysis. But this raises a question of whether the regulations should be based on overall fire risk or on fire hazards for a defined set of scenarios. This question will be addressed later in this paper.

Evaluating Performance

The evaluation of performance traditionally falls to the engineering professions so the responsibility for the evaluation methods logically rests with the engineering societies. The structural engineers went through this process over the past decade as they moved to a performance method. The Civil and Fire Protection Engineering societies are engaged in an effort to publish methods for assessing the structural fire resistance of steel, wood, concrete, and masonry assemblies. The Society of Fire Protection Engineers (SFPE) has pilot programs in fire model verification and to develop a "Code of Practice" for the profession similar to those developed for England and Wales[3], and in New Zealand[4].

A key aspect of performance evaluation is the framework of the engineering analysis to be employed. While the concept of overall risk management is growing in popularity in the business and insurance fields, the actual conduct of fire risk assessment may be technologically premature and may pose potential problems for regulators.

Deemed to Satisfy Provisions

All performance-based codes contain deemed to satisfy provisions. These recognize the fact that many aspects of fire safety design are well understood and do not need to be evaluated. Examples would include the physical dimensions of evacuation stairs (the so-called 7-11 stair) or that the provision of fire sprinklers would satisfy a performance objective of preventing flashover.
The inclusion of deemed to satisfy provisions are not intended to preclude the application of engineering analysis to justify alternate approaches -- only that experience has shown that certain approaches perform in a specific way. Such provisions will generally require compliance with specified standards to assure that the functions are performed reliably.

Approved Documents

Appended to the performance code are a series of Approved Documents, the first of which is generally the prescriptive code, recognizing that the complying with the prescriptive code is one way of meeting society's performance objectives. Other Approved Documents would include the collection of performance-based standards referenced in the code on the installation, operation, and maintenance of fire protection systems; safe operation of equipment or facilities; or methods of test or measurement of fire performance.

The Approved Documents might also include any Codes of Practice which are deemed appropriate for assessing the performance of designs against the objectives of the codes. Such referencing of methods within the code itself would give regulatory officials additional confidence that these methods provide acceptable results when properly used. In this context the term *sanctioned for use* within specific bounds would be preferable to being *approved* or *validated*.

RISK V.S. HAZARD ASSESSMENT

Risk assesses the *likliehood* of suffering a specific loss over all possible fire scenarios, thus requiring that many probabilities and statistical distributions be utilized in an analysis. Hazard analysis is a subset of risk which presumes certain scenarios (design fires) and assesses only the consequences of these fires. Adoption of either approach by local legislatures and enforcement by local officials requires that the basis for regulation be understandable by non-technical people. Further, legislators are hard pressed to accept the concept that risk can never be eliminated so risk goals involve an "acceptable level of life loss." The international community seems to agree that risk assessment is the preferred basis for establishing compliance with performance-based code objectives. However, a major problem with risk assessment remains the selection of an appropriate metric and the explanation of its meaning to non-technical people.

Risk of Life Loss

Expressing risk to life in a way which can be understood by the public is a problem which has been faced for years by the nuclear power and air transport industries with limited success. At the most basic level, risk to life is a small number generally expressed in scientific notation, which itself is not understood by most people. Risk is normally compared to events or activities such as the risk of being struck by lightning or the risk of death while skydiving. While the public impression is that these are rare events, they really have no good feel for how rare. This leads to the consideration of other metrics for risk.

Risk of Financial Loss

The measure of value in society is money, and the insurance industry has expressed risk in monetary terms for most of its history. Risk of financial loss is easy to understand and allows direct evaluation of offsetting benefits of investment in reducing risk or in the costs of insurance against the loss.

Financial loss is thus the perfect metric for risk but for one problem. The primary focus of fire codes is life safety, requiring that risk to life include a measure of the value of human life. Numerous (at least partially) objective measures of such value have been proposed -- earning potential over the remaining expected life, potential contributions to society, costs of insurance or legal settlements, and costs associated with regulation intended to reduce accidental fatalities to name just a few. In each case the concept that some people have less "value" to society than others is met with great objection, especially by those whose value is deemed lower.

Hazard Analysis

Such problems have led many to the conclusion that hazard analysis against a set of design fires derived for specific occupancies represents a more practical approach. Here, design fires established for specific occupancies will need to meet specific criteria including:

- They represent the range of challenges expected in the occupancy as identified by incident data and the expert judgement of code officials.
- They represent the range of occupant loadings and characteristics expected in the occupancy.

In order to be compatible with other provisions of an hazard analysis factors need to be addressed in a similar manner such as,

- Independent variables such as door positions, ventilation, transient fuels, weather, etc. can be distributed and accounted for.
- Reliability of fire protection features can be realistically accounted for in identifying the need for redundancy.

In a practical sense, basing regulation on hazard analysis for a specific set of design fires allows legislators to require that there be no losses expected under the design conditions; a much more palatable situation to explain to your constituents.

IMPLEMENTING THE MODEL SYSTEM

By overlaying the preceding considerations onto the existing U.S. building regulatory system a process for moving the U.S. toward a performance-based system emerges. This new system would still be implemented and enforced at the state and local level and be based on model codes and standards developed by the existing organizations under their current process. In these ways the change would be evolutionary rather than revolutionary. It further needs to be made clear that the prescriptive code is still available as an Approved Document and will continue to be used.

Setting Objectives

The process would start by developing a set of explicit objectives for codes, and function statements for standards. Standards, especially those for fire protection systems, should include reliability statements to quantify the likelihood that the specified function will be performed. These would be developed by the existing committees responsible for occupancy requirements in the current codes or for the standards they reference. Since performance evaluation would be hazard based, the objectives would be established for a specified set of fire scenarios which would also be established by these groups. These scenarios would thus represent design criteria in the same way that snow loads or wind loads are specified in current codes. The National Fire Protection Association's Life Safety Code Correlating Committee has recently assigned each of that Code's occupancy committees to develop an initial list of objectives within their area of responsibility.

Developing design scenarios will be more difficult as it needs to incorporate both data on the historical incidence of fire in a given occupancy and the judgement of experts as to what other conditions might prevail. All uncontrolled variables (weather, occupant loadings and characteristics, door positions, fuel load and distribution, etc.) should be specified as distributions so that the sensitivity to such variations can be determined. In these decisions in particular it is crucial to have the full involvement of the fire service both for the benefit of their experience and to assure that their needs will be met.

Evaluating Performance

In parallel with the establishment of performance objectives the engineering societies would continue the process of documenting appropriate engineering evaluation methods already begun. The results of these efforts would be incorporated into a Code of Practice and supporting standards of ASTM and NFPA. This Code of Practice would cover not only engineering methods sanctioned for use within specified bounds, but also should include a means to derive safety factors to account for the uncertainty of both methods and data used in them. Such a methodology is being developed under the umbrella of CIB W14[5].

This process presents an unique opportunity to harmonize international requirements and promote trade in the building design and construction field. Many countries are developing performance codes and there is general agreement on the form and content of the engineering evaluation methods. Efforts are underway under ISO TC92SC4, and CIB TG11 and W14 to develop common methods and this joint conference is seminal to the advancement of these activities.

Deemed to Satisfy Provisions

Coordination between the codes, standards, and engineering communities is crucial to the success of the entire process. One key area where consensus is needed is in the specification of design features which are deemed to satisfy objectives or functions identified in the code. Some proposals may be highly controversial and what may work in some countries may be unworkable in others. But agreement is not critical to harmonization since the performance approach is always available where countries are unwilling to concede that specific provisions meet related performance criteria.

SHIFTING PARADIGMS

This transition to performance-based codes and standards will result in many changes in the traditional roles of most organizations involved in the process as they change to provide the infrastructure needed for the new system to function. This is where most of the resistance to this change is rooted -- since many groups see nothing wrong with how they currently function. The point is not that they are now wrong, but that the advantages of a performance basis require a different approach to the process. The downside is that, if they fail to take up the new roles these will be addressed by others as the performance system comes into general use.

Model Codes

The existing model code bodies would continue to develop and promulgate the code, but now containing explicit objectives, “deemed to satisfy” provisions extracted from the prescriptive code, and Approved Documents, the first of which consist of the prescriptive code itself. The prescriptive code would then represent one acceptable solution, which would be expected to be used in most (about 90%) of cases. The performance objectives would represent public policy on the minimum acceptable level of performance permitted, by occupancy. Performance objectives may (and would be expected to) vary by occupancy or even within a single occupancy category. For example, within residential occupancies, hotels would continue to require higher performance than rooming houses which in turn require higher performance than for single-family.

The resulting model codes would continue to be adapted and adopted by local jurisdictions who may decide to modify objectives based on local conditions. Enforcement would continue at the local level, but increased technical assistance would need to be made available through the existing Evaluation Services system as needed by local officials. The fees for these services would be borne by the applicant as they are now. Alternatively, a system of peer review of engineering analyses by competing engineering firms might be established, modeled after the system used in New Zealand. Once again, the costs of the review are paid by the applicant.

Performance Standards

The role of standards would also not change significantly, but their format would evolve to support performance codes[6]. The central objectives enumerated in codes would identify functions (e.g., alerting occupants, extinguishing fires, providing reliable power to critical systems) which need to be performed for the objective to be met. Standards would identify functions that the systems covered would perform and how those systems need to be installed and maintained in order to be capable of providing those functions. Reliability estimates for systems in compliance with the standard would be included so that the need for redundancy could be assessed.

Professional Societies

Professional societies are the guardians of the profession. They develop codes of practice and provide the peer review upon which other professions depend for confidence in the applicability of the work submitted to them. In the same way that doctors provide second opinions, engineers may be called upon to review work of their peers in an unbiased and professional manner. The professional society facilitates this process and would act as an appeals board. As with the medical profession, it should become sufficiently commonplace that it would not be treated as adversarial. Professional societies further would serve a role in the continuing education of their members and in the education of those who interact directly with their members. This is particularly important as evolving calculational procedures play a more important role in the process.

Testing Agencies

Since the prescriptive codes will still be used, there will still be a need for lists of products which meet minimum performance criteria. However, performance analysis will result in a demand for certified data from an independent source for many products and materials. While examples of performance measurement methods exist, additional methods will be needed and these agencies could fill this role as well.

Code Enforcement

The enforcement community will become more familiar with fire safety engineering methods with experience. They would call upon their own consultants for technical review until such time as the workload demands an in-house expertise. As the fire service adds fire protection engineering expertise, this might be shared with the potential of improved cooperation between these agencies. Likewise, the fire service would become more involved in the development of performance objectives as a means to assure that their needs are met for safe operations in performance qualified buildings.

The application of performance techniques to a building's approval will mean that the supporting fire safety analysis will become, in effect, the "code" for that building. Variations from the design or assumptions in that analysis would represent code violations, so the analysis would need to be kept on file for the life of the building. This represents another opportunity for the fire service in their pre-planning activities or as a resource in fighting a fire or providing other emergency services in these buildings. The analysis should provide insight into what is likely to occur in a fire which would be of value in developing successful tactics.

CONCLUSION

Performance codes and standards represent a new way to design, qualify, build, and maintain buildings. The infrastructure is in place to allow an evolution to these new methods. The details of the functions of various organizations will change or expand to address the needs embodied in the performance-based methods. The common thread is that continuing education is crucial.

REFERENCES

1. Brannigan, V. and Meeks, C., Computerized Fire Risk Assessment Models: A Regulatory Effectiveness Analysis, *J Fire Sciences*, **13**, 177-196, 1995.

2. Fleming, Joseph F., Fire Marshal, Boston Fire Department, private communication

3. Barnfield, J., Cooke, G., Deakin, G., Hannah, M., Jones, T., Law, M., and Malhotra, B., Draft British Code of Practice for The Application of Fire Safety Engineering Principles to Fire Safety in Buildings, British Standards Institution, London, 1995.

4. Fire Engineering Design Guide, A.H. Buchanan, editor, Centre for Advanced Engineering, University of Canterbury, New Zealand, July, 1994.

5. Magnusson, S.E., Frantzich, H., and Harada, K., Fire Safety Design Based on Calculations, Lund University Department of Fire Safety Engineering, Sweden, in press.

6. Bukowski, R.W., Risk and Performance Standards, Proceedings of the 13th UJNR, March 13-20, 1996, Nat. Inst. Stand. Tech., Gaithersburg, MD 20899, USA, 1996.