

# SFPE EUROPE



Q4 2021 ISSUE 24



AN OFFICIAL PUBLICATION OF SFPE

## Identifying Implicit Risk in the National Building Code of Canada

By: Keith Calder, Senez Consulting Ltd., Canada  
Elizabeth Weckman, University of Waterloo, Canada

### Abstract

This paper was presented at the SFPE20 International PBD Conference and Expo in Auckland, New Zealand in March 2020. The paper proposes a framework to facilitate the identification of the risk (performance) implicit to acceptable solution requirements in the National Building Code of Canada (NBCC) and facilitate the transition of the NBCC from an objective- to a performance-based format. The framework is intended to provide the quantitative means to bridge the gap between existing prescriptive requirements and performance objectives. A basic example is provided to illustrate the application of the framework. Although the paper deals specifically with the Canadian regulatory environment, the principles described in the paper are applicable in other jurisdictions.

### Introduction

This paper presents an approach to facilitate transitioning the National Building Code of Canada (NBCC) from objective- to performance-based. The NBCC was substantially updated in the 2005 edition to improve clarity of the fire and life safety requirements, reduce complexity and be more responsive to innovation. The updated 'objective-based' format was developed through a bottom-up analysis of the existing requirements to define high level, qualitative design objectives. Ten years following adoption of this objective-based format, the intended benefits have not been realized. Instead, industry has primarily continued to operate within the bounds of the previous, specification-based framework for design.

### Purpose for Building Regulations

In simple terms, building regulations are developed to limit undesirable events from occurring, and their implementation often follows incidents of significant scale or impact that draw attention to specific building design issues. Investigation and analysis follow such events to establish the conditions that led to the incident (exposure/risk), and solutions are developed to limit the occurrence or impact of such events in the future. These solutions are based on contemporaneous knowledge, capability (primarily related to the fire service), materials and methods, which are distilled to a concise written regulatory format. Following this practice, regulations have historically been driven by a political decision-making process, primarily founded on experience with little scientific basis [1]. This was recognized as far back as the early

1920's following an investigation into the high cost and inactivity in building industries in the United States when it was stated [2]:

*The building codes of the country have not been developed upon scientific data, but rather on compromises; they are not uniform in principle and in many instances involve an additional cost of construction without assuring more useful or more durable buildings.*

The same challenge was described by the Head of the Building Standards Section of the National Research Council of Canada in the 1960's relative to building codes in general [3]:

*In the broadest sense, building regulations develop from contingency to contingency. Each one represents an emergency measure taken with very little or no study. As the emergency recedes, the regulation tends to form part of traditional practice. It is added to the pile, which grows and grows.*

The cycle of code development therefore continues to follow response to the next incident or other impetus for change, so that the code incrementally advances. This presently happens with very little reconsideration of the cumulative risk factors embodied by the changes [1]. Over time, the changes become entrenched as accepted practice and recollection of the driving incidents and the specific risk context around the resulting modifications to the code diminish [4].

Accepted practice and requirements under the code are commonly expressed in a specification-based framework. Prescriptive specifications provide an explicit method by which to address and solve a problem, whereas performance-based specifications identify an end goal and allow any solution that achieves that goal. These two approaches are discussed in more detail below. It should be noted at this point though, that most building codes consist of primarily prescriptive, with only some performance-based, specifications.

### **Objective Based Format**

The Canadian Commission on Building and Fire Codes (CCBFC) began to study the feasibility of implementing performance-based codes in Canada in the early 1990's [5,6]. Research by Oleszkiewicz [7] provided a brief history of the development of performance concepts and experience regarding their implementation in the UK, Australia and New Zealand. Oleszkiewicz suggested that a high-level tree of objectives be extracted (bottom-up analysis of the existing acceptable solutions [8]) from the existing requirements and organized into a hierarchical framework considered to be an "objective-based" format.

The objective-based format would be focused on identifying high level objectives and linking those to the existing acceptable solutions. This format was envisaged as an intermediate step, "distinct" from a performance-based code [6], recognizing challenges other countries had faced transitioning from traditionally specification-based codes to a full performance-based framework [7]. While not completely performance-based, the objective-based framework was intended to:

- provide clarity of intent of the existing acceptable solutions, thereby reducing the complexity of the code [8];
- facilitate the development and acceptance of innovative designs [6];
- facilitate the development of performance requirements [6], including the introduction of performance criteria and eventually lead to a 'dual path' framework such as that in the Nordic Committee on Building Regulations (NKB) [6].

The CCBFC, Standing Committees and associated Task Groups worked from 1995 to the early 2000's to develop the proposed objective-based framework, which was eventually implemented in the 2005 edition of the NBCC [9]. It was structured into three main parts: objectives/functional statements, acceptable solutions, and administrative provisions.

The objectives are entirely qualitative and are formulated to state what the code is intending to limit. The primary objectives are [10] safety, health, accessibility for persons with disabilities, and fire and structural protection of buildings. The objectives are correlated with functional statements, intended to [10] “describe the conditions in the building that help satisfy the objectives”.

The acceptable solutions are the set of specification- and performance-based requirements from earlier (legacy) versions of the Code. These solutions were originally developed through a consensus process in Canada to address fire and life safety risks related to the design, construction and operation of buildings. The intent of application of the acceptable solutions is to limit those risks to a level considered acceptable to the general public. The NBCC uses the term ‘acceptable’, whereas others have used the term ‘tolerable’ [11] noting that society may not ‘accept’ the resulting level of risk, but instead ‘tolerates’ it.

Compliance with the fire and life safety provisions of the NBCC can be achieved by complying directly with the acceptable solution requirements (Division B), or through an alternative solution with appropriate justification. In preparing an alternative solution, the NBCC requires that the applicable acceptable solution requirements and attributed objectives and functional statements be identified and used to establish the expected minimum level of performance [10], which is considered implicit in the application of the acceptable solution requirements. It is this level of performance that is required to be met by an alternative solution design in achieving compliance. However, compliance with such a requirement is complicated by the lack of information and guidance by which to establish the implicit performance of either the acceptable or an alternative solution, as will be discussed below.

## **Challenge**

The current situation is largely an artifact of the expectation within the NBCC that an alternative solution must achieve the level of performance implicit in the existing acceptable solution requirements without explicitly stating any performance measurement methods or criteria. The text of the NBCC itself alludes to this lack of information by noting the following [1]:

*The objectives and functional statements are entirely qualitative...In many cases, [the quantitative performance targets] are not defined very precisely by the acceptable solutions - certainly far less precisely than would be the case with a true performance code, which would have quantitative performance targets and prescribed methods of performance measurement for all aspects of building performance.*

The importance of these performance targets has also been identified by others [7,12,13]. It is therefore incumbent upon the users of the NBCC to establish the fire and life safety performance targets, either directly or indirectly, to effectively demonstrate the acceptability of a performance-based approach (alternative solution). The lack of clarity associated with the necessary performance implied in the acceptable solution requirements can lead to misinterpretation and disagreement between stakeholders. Comparative methods have been developed to obviate the lack of clarity but have resulted in challenges associated with selection of representative metrics, methods of comparison and definitions of the levels of acceptable risk.

The implicit performance and risk associated with the set of ‘acceptable solution’ requirements defined in the current NBCC have not been defined in quantitative, scientific terms. This lack of quantitative performance and risk measures has limited the development and acceptance of alternative solutions to only those solutions considered directly analogous (comparative) to the acceptable solutions. Thus, alternative approaches have shifted to relative assessments that compare the fire and life safety performance of alternative design solutions directly against that of acceptable reference design solutions based on common evaluation metrics such as design fire size or occupant walking speed. The validity of this approach relies on there being an appropriate match between the design under consideration, the

reference design, and the evaluation metrics. In addition, development of acceptable solution requirements has been predicated upon certain factors, such as material type or configuration, which are then bounded due to the time period in which the acceptable solutions were developed. Innovative designs may employ new materials or configurations with characteristics that fall outside these bounds, resulting in either a real, or potentially perceived, unacceptable level of risk of injury and/or building damage in the event of fire.

To exacerbate the above issue, the fire and life safety requirements embodied within the acceptable solutions were developed over a period of the last 80 years. Some requirements were adopted from earlier US- and UK-based model building codes dating back as far as the 1800's. As such, the risk and performance implicit to these solutions have been time locked. They may not represent the likely magnitudes and consequences of present-day risks and also may not represent society's expectation of performance/risk today. This can result in designs that expose society to an unacceptable level of risk in terms of fire and life safety or alternately to undue cost of protective features without corresponding benefit.

With movement toward more sustainable practices and an increased pace of innovation, the need for greater flexibility in building design (i.e., type of construction, materials used, building size, etc.) has grown. However, departure from relatively standard principles of building construction is challenging within the current objective-based framework due to the breadth and complexity of the requirements associated with demonstrating that an innovative concept achieves the performance level implicit in the acceptable solution requirements. This complexity limits the ability to make directly comparative assessments between designs and often also precludes applying other means of demonstrating compliance, with the end result that it has significantly impacted sustainable practices and innovation in construction.

## **Approach**

The proposed approach to address these challenges is to develop a framework for the assessment of the basis of the existing requirements (Figure 1). This will set the stage for re-examination of those requirements in a current context to develop new and well justified quantitative performance/risk measures and allow for the implementation of those measures in a structured performance-based framework.

An understanding of the basis of the requirements provides a quantitative bridge between existing prescriptive requirements and performance objectives, which addresses some of the knowledge gaps that have limited the effective implementation of a performance-based framework for fire and life safety in building codes in Canada.

The proposed framework is structured to facilitate the identification of the performance/risk factors currently implicit to the acceptable solution requirements in the NBCC based on a historical analysis of the development (re-development) of the acceptable solution requirements. The proposed methodology to achieve this, summarized in Figure 1, includes the following:

- **Identification of the Originating Risk Basis ( $R^*$ ):** Analysis of the undesirable event(s) that initiated the development of the prescriptive requirements to provide a characterization of the risks/exposures from those undesirable event(s);
- **Identification of the Originating Risk Biases ( $M^*$ ):** Analysis of the knowledge, capability, materials and methods available at the time when the acceptable solution was developed in relation to the explicit or implied key parameters assumed to limit or control the risk. This analysis will incorporate the influence of assumptions/design features that impacted development of the solution(s);
- **Estimation of the Originating Acceptable Risk/Implicit Performance Thresholds ( $R_A^*$ ):** Analysis of the (acceptable) risk remaining upon application of the specifications and the corresponding performance expectations of the specifications; and
- **Identification of Simplifying Assumptions:** Identification of the assumptions used to simplify the solutions from the previous step into concise specifications that have been included in the NBCC. This information facilitates the estimation of the originating risk bases, biases, acceptable risk (implicit performance)
- **Identify the Extent of Building Characteristics Applicability ( $B^*$ ):** Identification of the characteristics that were key to the development of the acceptable solution requirements.

The result of the analysis is the identification of the qualitative (quantitative where possible) performance criteria (acceptable risk) implicit in the requirements listed for acceptable solutions to limit fire spread.

Identification of the qualitative performance criteria implicit in the requirements and factors key to the development of those criteria is the starting point for re-examination of the quantitative impact of the

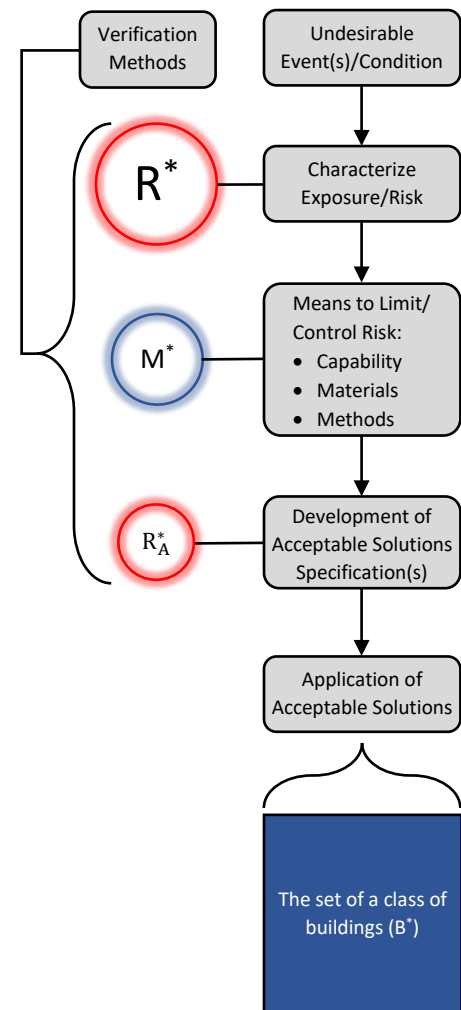


Figure 1: Proposed framework.

criteria in reducing the risk of fire spread. Since the NBCC is a societal instrument, quantification of the impact in reducing the risk will require normalization with risk levels considered acceptable by society today. Such re-examination, which is a recommended next step, will take account of currently available knowledge, capability, materials and methods to identify inconsistencies.

### **Illustrative Example**

The 2015 NBCC requires that the occupant load of an office occupancy floor area be determined on the basis of 9.30 m<sup>2</sup> per person [10]. The factor is a means to predict the occupant load by which appropriately designed egress facilities are provided, and the objective of its application is [10] “to limit the probability of overcrowding, which could lead to delayed egress during emergency evacuation, which could lead to harm to persons”.

The factor of 9.30 m<sup>2</sup> per person originates from the imperial unit version of 100 ft<sup>2</sup>/person (same factor in NFPA 101, “Life Safety Code”). This factor appeared in the first edition of the NBCC (1941 Edition [14]) and NFPA 101-T (1924 Tentative Edition [15]). Its origins are linked to health requirements from the late 1800’s associated with passive ventilation where a desirable limit of space was 1000 cubic feet per occupant [16]. This limit was applied to floor areas with a typical ceiling height of 10 feet, resulting in 100 ft<sup>2</sup> per occupant. This factor was confirmed through statistical analyses of office occupancies in the early 1900’s in many buildings which had been designed to the health requirements from the late 1800’s. The survey confirmed a maximum density of 100 ft<sup>2</sup> per occupant (stockbroker firms). Therefore, the expectation at the time was that office buildings would have an occupant load corresponding with the health limits associated with passive ventilation. The application of the factor became import following the Triangle Shirtwaist Fire in New York in 1911, where an appropriate means of sizing egress facilities based on the number of building occupants was desired.

The following can be established from the above abridged summary of the historical assessment of the origins of the occupant load factor for office occupancies:

- |                     |                                                                                                                                                                                     |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Undesirable Events: | life loss in numerous fires in the early 1900’s linked to inability to evacuate.                                                                                                    |
| R*:                 | Overcrowding relative to size of egress facilities.                                                                                                                                 |
| M*:                 | - Design egress facilities for office buildings based on a load corresponding to 100 ft <sup>2</sup> per person of floor area taken from health requirements in place at that time. |
| R <sub>A</sub> *:   | - A correlation between number of occupants and egress facility sizing to allow for egress from buildings in a certain time as a function of building height (performance measure). |

A more detailed analysis would provide the full context associated with considerations such as building construction and understanding of fire growth and development at the time, etc., but detail has been limited in this example for purposes of brevity.

The findings outlined above indicate that there is an opportunity to re-examine the occupant load factor for office occupancies based on more current methods for estimating loads consistent with factors corresponding with current building conditions since ventilation requirements and conditions have changed significantly in the last 100 years.

### **Conclusions**

This paper has outlined a framework that can be applied to establish the basis of the acceptable solution requirements in the NBCC, and thereby provide a quantitative bridge between existing prescriptive

requirements and performance objectives. Such an approach addresses some of the knowledge gaps that have limited the effective implementation of a performance-based framework for fire and life safety in building codes in Canada. The illustrative example demonstrates the application of the framework to identify the factors associated with current occupant load factor for office occupancies and provides basic information upon which the occupant load factor can be re-examined in a performance-based context. Although the framework has been applied to the NBCC, it can equally be applied to similar prescriptive solutions in other jurisdictions.

## References

1. Fischer, K., "Societal Decision-Making for Optimal Fire Safety", Doctor of Science Thesis, ETH Zurich, 2014.
2. United States. Dept. of Commerce. Building Code Committee, "Recommended Minimum Requirements for Small Dwelling Construction". Bureau of Standards, 1922: U.S. Government Printing Office.
3. R. S. Ferguson, Building Regulations: Problems of Tradition and Knowledge. 1974: Ottawa. p. 60.
4. Bennetts, I.D., Thomas, I.R. "Designing buildings for fire safety: a risk perspective", Progress in Structural Engineering and Materials, 2002, 4(2), pp. 224–240.
5. Canadian Commission on Building and Fire Codes, "Minutes of the First Meeting of the Canadian Commission on Building and Fire Codes", National Research Council of Canada, Ottawa, ON, January 1992.
6. Canadian Commission on Building and Fire Codes, "Minutes of the Third Meeting of the Canadian Commission on Building and Fire Codes", National Research Council of Canada, Ottawa, ON, November 1993.
7. Oleszkiewicz, I., "The Concept and Practice of Performance-Based Building Regulations", National Research Council of Canada, IRC-IR-697, November 1994.
8. Canadian Commission on Building and Fire Codes, "Minutes of the Fifth Meeting of the Canadian Commission on Building and Fire Codes", National Research Council of Canada, Ottawa, ON, March 1995.
9. Canadian Commission on Building and Fire Codes, "National Building Code of Canada", National Research Council of Canada, 2005.
10. Canadian Commission on Building and Fire Codes, "National Building Code of Canada", National Research Council of Canada, 2015.
11. Meacham, B.J., "Understanding Risk: Quantification, Perceptions, and Characterization", Journal of Fire Protection Engineering, Vol. 14, August 2004.
12. Bergeron, D., "Research in Support of Performance-Based Solutions in the National Construction Codes of Canada", 7<sup>th</sup> International Conference on Performance-Based Codes and Fire Safety Design Methods, Auckland, New Zealand, 2008, pp. 105-115.
13. Associate Committee on the National Building Code, "NBC News", National Research Council, 1(13), November 1959.
14. National Research Council of Canada, "National Building Code", N.R.C. No. 1068, November 1941.
15. National Fire Protection Association, "Building Exits Code", NFPA 101, 1924.
16. Calder, K., Locke, H., "The Historical Basis for Determining Occupant Loads", SFPE 12th International Conference on Performance Based Codes and Fire Safety Design Methods, April 2012.