QUANTITATIVE AND QUALITATIVE RISK ASSESSMENTS – A HIGHLY NEGLECTED METHODOLOGY

Derya Horasan,
Senior Fire Safety Engineer
Scientific Fire Services Pty Ltd
INTRODUCTION

Co-Authors:

Mahmut Horasan;
Scientific Fire Services Pty Ltd.

Khalid Moinuddin;
Centre for Environmental Safety and Risk Engineering (CESARE), Victoria University
INTRODUCTION

• Fire safety engineers rely on a wide range of deterministic methodologies which, almost by default, are adopted across the industry for certain issues.

• There is a wide spectrum of qualitative and quantitative risk based methodologies available to fire safety engineers.

• “Why are risk based methodologies less popular compared to other quantitative (and even qualitative) approaches?”
Types of Risk Assessments

- Fire risk assessment
  - Qualitative methods
    - Structured
    - Unstructured
  - Semi-quantitative methods
    - Points schemes
  - Quantitative methods
    - Matrix
    - Probabilistic
    - Full QRA
TYPES OF RISK ASSESSMENTS

Qualitative Assessments
• Checklists
• Narratives
• Failure Mode and Effect Analysis (or FMEA’s)

Quantitative Assessments
• Fault Trees
• Event Trees
• F-N Curves
VERIFICATION METHODS AND RISK ASSESSMENTS

• Verification methods, which are identified as an assessment method in the BCA, lend themselves to risk based approaches better than many other methods.

• With the introduction of further verification methods into the building codes there is a potential to adopt risk based approaches more readily.
VERIFICATION METHODS AND RISK ASSESSMENTS

Verification Methods:
‘A test, inspection, calculation or other method that determines whether a Performance Solution complies with the Performance Requirements’ (ABCB, 2016)

Typical Verification Methods include:
1. Calculation Methods: Utilising recognised Analytical/Mathematical Models
2. Laboratory Tests: Using tests on prototype components and systems
3. Tests-in-situ: examination of plans and verification by testing
New direction and approach to be undertaken in the coming years.

- Review of the Current Verification Methods;
- Review of an alternative Verification Method in the form of Quantitative Risk Assessments.
VERIFICATION METHODS – PROPOSED BCA METHODOLOGY

Intent is to uplift the new verification methods and approaches into the 2019 version of the BCA.

The outline of the fire safety verification document that is to be proposed.

Use NCC Fire Safety Verification Method

Prepare a Performance Based Design Brief

- Scope of the project
- Identify relevant NCC Performance Requirements
- Determine appropriate design fire scenarios
- Determine the rules and parameters for the design fire scenario
- Determine the occupant profile
- Document all decision and assumption in the PBDB

Carry Out Analysis, Modelling or Testing

- Carry out analysis, modelling or testing in accordance with the determined design fire scenario.

Colate and Evaluate Results

- Colate findings from the analysis, modelling or testing undertaken for each design fire scenario and evaluate if the findings to determine if they adequately address the PBDB acceptance criteria.

Prepare a Final Report

The final report should clearly demonstrate that compliance with the NCC Performance Requirements agreed in the PBDB has been achieved. The content of a typical final report might include:
- the PBDB
- analysis, modelling or testing undertaken
- analysis, modeling or testing results
Example of the Proposed Verification Method:

Performance Requirement: **CP1**

Applicable Design Scenarios: BE, UT, CS, FI, UF, CF, RC, SS

- **BE**: Fire Blocks Exit;
- **UT**: Fire in normally occupied room threatens occupants of other rooms;
- **CS**: Fire starts in concealed space;
- **FI**: Fire Brigade intervention
- **UF**: Unexpected Catastrophic Failure
- **CF**: Challenging Fire;
- **RC**: Robustness Check;
- **SS**: Structural Stability
CP1 for the uninitiated

A building must have elements which will, to the degree necessary, maintain structural stability during a fire appropriate to—

(a) the function or use of the building; and
(b) the fire load; and
(c) the potential fire intensity; and
(d) the fire hazard; and
(e) the height of the building; and
(f) its proximity to other property; and
(g) any active fire safety systems installed in the building; and
(h) the size of any fire compartment; and
(i) fire brigade intervention; and
(j) other elements they support; and
(k) the evacuation time.
The above detailed process may be applied to a method that is specific to an alternative Probabilistic Verification Methodology.
## VERIFICATION METHODS – ALTERNATIVE METHODOLOGY

The design scenarios in the context of a probabilistic methodology:

<table>
<thead>
<tr>
<th>Design Scenario</th>
<th>Intended Outcome</th>
<th>Probabilistic Method Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Blocks Exit (BE)</td>
<td>Viable Exit Route has been provided for building occupants.</td>
<td>Design issue dependent but can be readily applied.</td>
</tr>
<tr>
<td>Fire in normally occupied room threatening occupants of other rooms (UT)</td>
<td>Demonstrate ASET&gt;RSET.</td>
<td>Readily applied and is a suitable method/approach that can be adopted in lieu of ASET/RSET (F-N curve, Monte Carlo Simulation, ERL etc.)</td>
</tr>
<tr>
<td>Fire Stars in a concealed Space (CS)</td>
<td>Demonstrate that fire spread via the concealed space will not endanger occupants.</td>
<td>Review of statistics pertaining to the type of fire with consideration of the classification can be adopted. This in turn will demonstrate compliance.</td>
</tr>
</tbody>
</table>
## Verification Methods – Alternative Methodology

<table>
<thead>
<tr>
<th>Design Scenario</th>
<th>Intended Outcome</th>
<th>Probabilistic Method Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Brigade Intervention (FI)</td>
<td>Demonstrate that fire brigade can undertake fire brigade intervention until completion of search and rescue activities.</td>
<td>This scenario is no different between the various methods and would be readily applied.</td>
</tr>
<tr>
<td>Unexpected Catastrophic Failure (UF)</td>
<td>Demonstrate the disproportionate failure is not likely to occur for the duration of the fire event.</td>
<td>Statistics in combination with a risk assessment approach could be readily applied to demonstrate the occurrence unexpected catastrophic failure of a structure.</td>
</tr>
<tr>
<td>Design Scenario</td>
<td>Intended Outcome</td>
<td>Probabilistic Method Options</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Challenging Fire (CF)</td>
<td>Demonstrate ASET&gt;RSET for design fires in various locations within the building.</td>
<td>Readily applied and is a suitable method/approach that can be adopted in lieu of ASET/RSET (F-N curve, Monte Carlo Simulation, ERL etc.).</td>
</tr>
<tr>
<td>Robustness Check (RC)</td>
<td>Demonstrate that if a single fire safety system fails, the design is robust that disproportionate spread of fire does not occur. (i.e. sensitivity study)</td>
<td>Utilising an ascertained benchmark, the reliability of a fire safety measures can be assessed to influence the impact of a potential failure scenario.</td>
</tr>
<tr>
<td>Structural Stability (SS)</td>
<td>Demonstrate that the building does not present risk to other property in a full burn our scenario.</td>
<td>Review of statistics pertaining to the type of fire with consideration of the classification can be adopted. This in turn will demonstrate compliance.</td>
</tr>
</tbody>
</table>
VERIFICATION METHODS – ALTERNATIVE METHODOLOGY: WORKED EXAMPLE

Performance Requirement CP1 has been assessed with consideration of the following design issue:

“The proposed adoption of combustible materials that will form part of the external bounding wall construction within a residential building that is typically required to be of Type A construction (i.e. non-combustible)”
The methodology/approach adopted is an F-N Curve Evaluation. The equation of the F-N Curve risk ranking parameters is defined by:

\[ F = mN + C \]

Where,
- \( F \) = the cumulative or non-cumulative frequency of the event
- \( m \) = the slope
- \( N \) = the predicted number of persons impacted upon
- \( C \) = Anchor point
VERIFICATION METHODS – ALTERNATIVE METHODOLOGY: WORKED EXAMPLE

• The ‘F’ value as part of an F-N curve is the key outcome or set of outcomes that determine the impact that a certain event has on society.

• This ‘F’ value can either be a single point (non-cumulative) on the graph or alternatively can provide an overall graphical output/diagram from a set of data (cumulative) outlining the frequency of an event and the associated societal risk.
VERIFICATION METHODS – ALTERNATIVE METHODOLOGY: WORKED EXAMPLE

• For example, the ‘F’ value can be the data specific to the number of fatalities that occur on the roads.
• ‘F’ can be ascertained by calculating the total number of fatalities that have occurred. (i.e. 100,000 events where 1 person was killed, 10,000 events where 2 people were killed and so on).
• The objective is to calculate the cumulative frequency of events per year.
• The ‘M’ value or slope of the F-N curve is typically represented as a negative scale.

• This is predicated on the fact that where the lower probability of an event is likely to have a higher impact/magnitude resulting in an increased number of fatalities.
• A simple example can be the comparison of a plane crash compared to car accidents.
• The probability of a plane crashing can be considered to be a lot less however the number of persons impacted upon is significant.
• In the scenario of a car accident, the occurrence of an accident is much greater however the number of person impacted upon each time is limited and less significant.
• The steepness of the slope of an F-N curve is generally a user specific parameter.

• It assists in presenting data with respect to risk aversion. The steeper the slope provided the more risk averse is the overall profile.

• Typically a default slope that can be adopted is a steepness of m= -1.

• This is identified to be a risk neutral slope as the order of magnitude is equal as it both increases and decreases.
### Examples of Slope Steepness:

<table>
<thead>
<tr>
<th>Country</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (NSW only)</td>
<td>-1.5</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>-2</td>
</tr>
<tr>
<td>Denmark</td>
<td>-2</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>-1</td>
</tr>
</tbody>
</table>
• **N**: The Number of Persons Impacted Upon
• The ‘N’ value represents the number of persons that have been impacted by an event.
• This information is either based on historical data or project specific using assumptions and a degree of engineering judgement.
**C: The Anchor Point**

Sum of the frequency of ALL events for an entire population where a fatality has resulted.

<table>
<thead>
<tr>
<th>Country</th>
<th>Individual Risk (Probability / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Between $3 \times 10^{-6}$ and $4.6 \times 10^{-6}$</td>
</tr>
<tr>
<td>Australia (NSW Only)</td>
<td>Between $3 \times 10^{-6}$ and $7.4 \times 10^{-6}$</td>
</tr>
<tr>
<td>Canada</td>
<td>Between $6 \times 10^{-6}$ and $1.3 \times 10^{-5}$</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Between $4 \times 10^{-6}$ and $6 \times 10^{-6}$</td>
</tr>
<tr>
<td>United Kingdom (Wales and England Only)</td>
<td>Between $4 \times 10^{-6}$ and $7.3 \times 10^{-6}$</td>
</tr>
</tbody>
</table>
Acceptance Criteria/Benchmark:
F-N Curve range in which data is presented:
• Acceptable;
• ALARP or As Low as Reasonably Practicable
• Intolerable.
### Number of Fires within Residential Buildings

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Number of Fires in Buildings NSW</th>
<th>Residential Fires in NSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>6504</td>
<td>4631</td>
</tr>
<tr>
<td>2003</td>
<td>6388</td>
<td>4527</td>
</tr>
<tr>
<td>2004</td>
<td>6165</td>
<td>4321</td>
</tr>
<tr>
<td>2005</td>
<td>6566</td>
<td>4600</td>
</tr>
<tr>
<td>2006</td>
<td>6257</td>
<td>4397</td>
</tr>
</tbody>
</table>
Number of Fatalities within Residential Buildings

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Number of Fatalities</th>
<th>Residential Fire Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>33</td>
<td>27</td>
</tr>
<tr>
<td>2003</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>2004</td>
<td>50</td>
<td>47</td>
</tr>
<tr>
<td>2005</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>2006</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Total:</td>
<td>147</td>
<td>134</td>
</tr>
</tbody>
</table>
### Number of Fatalities within Residential Buildings (Per Incident)

<table>
<thead>
<tr>
<th>Year</th>
<th>1 Fatality</th>
<th>2 Fatalities</th>
<th>3 Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>14</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>9</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>2004</td>
<td>25</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>2005</td>
<td>11</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>2006</td>
<td>9</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Total:</td>
<td>68</td>
<td>40</td>
<td>26</td>
</tr>
</tbody>
</table>
## VERIFICATION METHODS – ALTERNATIVE METHODOLOGY: WORKED EXAMPLE

### Form of Material Ignition (Apartments, Units and Other)

<table>
<thead>
<tr>
<th>Year</th>
<th>Structural Member, Framing</th>
<th>Thermal, Acoustical insulation within the wall, partition or floor ceiling space</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>86</td>
<td>22</td>
</tr>
<tr>
<td>2003</td>
<td>75</td>
<td>29</td>
</tr>
<tr>
<td>2004</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>2005</td>
<td>83</td>
<td>25</td>
</tr>
<tr>
<td>2006</td>
<td>74</td>
<td>20</td>
</tr>
</tbody>
</table>
VERIFICATION METHODS – ALTERNATIVE METHODOLOGY: WORKED EXAMPLE

The Assessment (The F-N Curve Graph)
The Assessment (Deaths/DtS Benchmark)
The Assessment (Deaths/Inclusive of the Fires within Wall Structures)

- Two Fatalities
- Single Fatality
- Three Fatalities

Increase representative of the 2%-2.5% of cases where fires occurred in wall cavities/structures in residential classification.
VERIFICATION METHODS – ALTERNATIVE METHODOLOGY: WORKED EXAMPLE

Both Sets of Data Together (DtS/Proposed)

- Two Fatalities
- Single Fatality
- Three Fatalities

- Two Fatalities
- Single Fatality
- Three Fatalities
CONCLUSION

• F-N Curves and other Probabilistic Assessments (Monte Carlo/Expected Risk to Life) are readily able to be adopted to assess and achieve compliance with the Performance Requirements.

• Transparency and detailed documentation is required when conducting an assessment – Complexity of the Assessment.

• Data collection and collation needs to be improved – Multiple Bodies in Australia.

• Further Education will be needed by the industry as a whole for Verification Methods and Probabilistic Risk Assessments.
CONCLUSION

• Verification Methods may improve the level of fire engineering, however it may also result in the loss of innovation.

• The overall direction is to achieve a level/quality of fire engineering that is accepted and recognised by the community to their expectations.

• A suitable period to review and consider the suitability of any method once applied is critical to understand the benefit or detriment of its application.
• Thank You and Any Questions?