Using Risk as a Basis for Tolerable Performance: An Approach for Building Regulation

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Background

“The risks to which society is, in fact, exposed are largely determined by regulations and how effectively they are implemented and enforced.”*

***Otway, H. (1985). H. Otway and M. Peltu, Eds., Regulating Industrial Risks: Science, Hazards and Public Protection, Butterworths, London.**

Risk & Building Codes

- **Building codes provide for the design and construction of buildings that provide an acceptable level of shelter and safety from natural and technological hazards**

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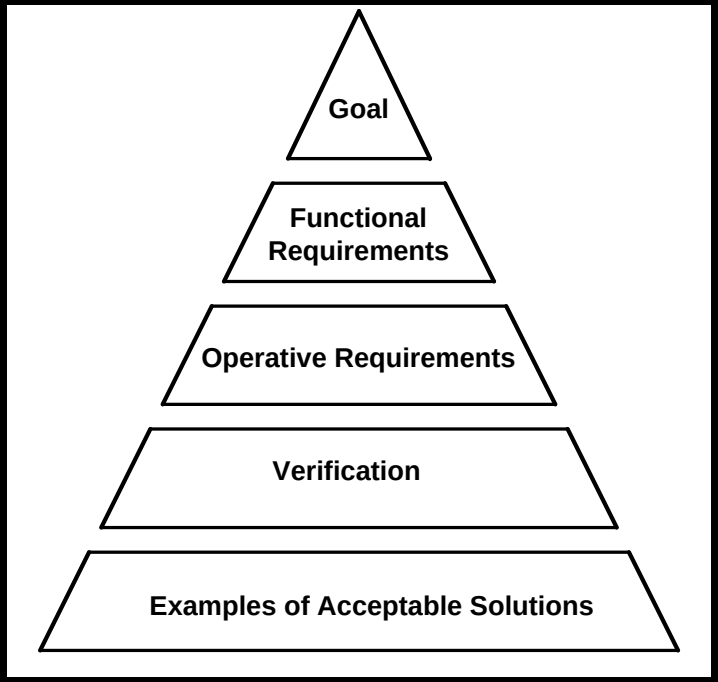
- **Building codes provide for the design and construction of buildings that provide an acceptable level of shelter and safety from natural and technological hazards**
- **Knowing what society finds acceptable in terms of minimum requirements for shelter and safety, one can establish performance requirements for the design and construction of buildings**

Risk & Building Codes

- **There are societal expectations for building performance during cyclones, earthquakes and fires**
  - Do not “fail” under “expected” events
  - Fail safe under “significant” events
  - There will be events for which design against failure is not practicable

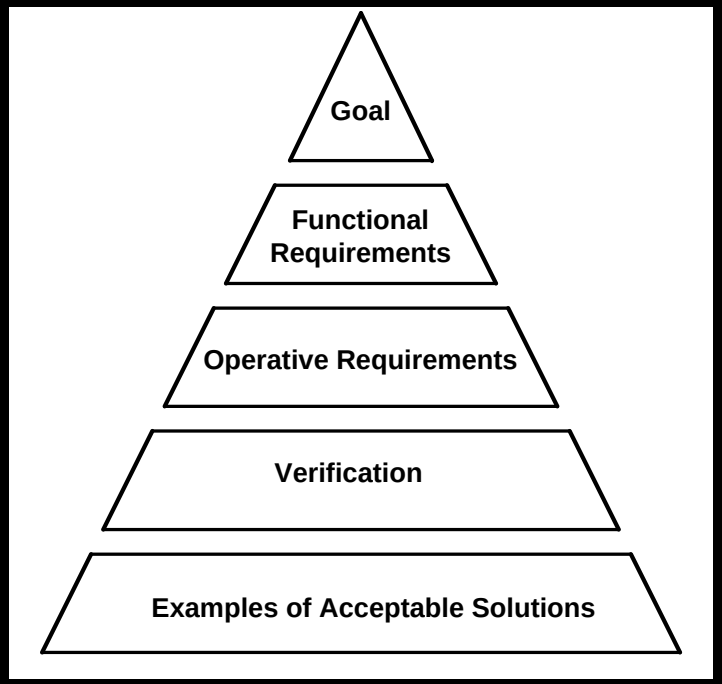
Performance Code Hierarchy

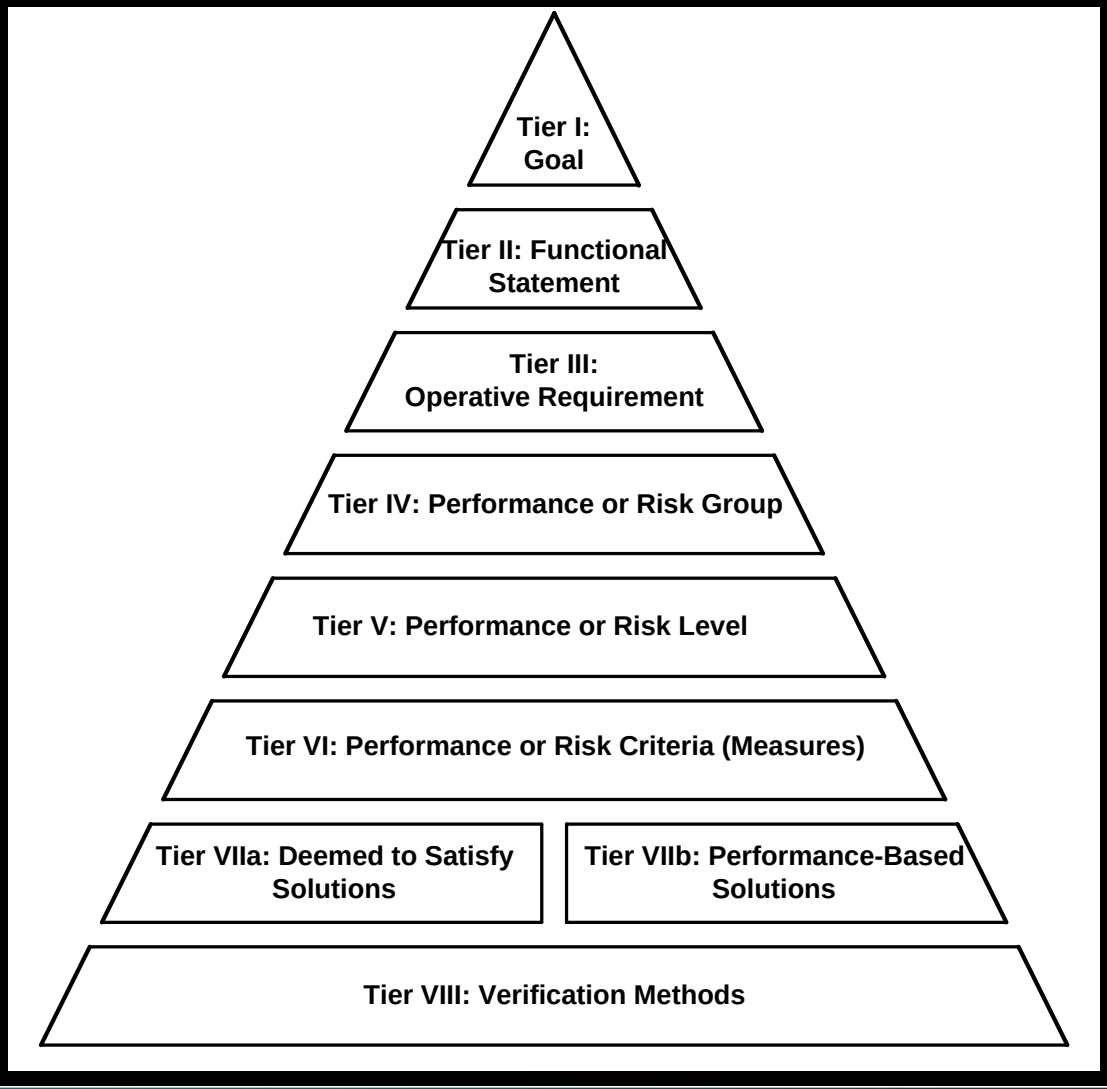


Nordic 5-tier Hierarchy (NKB, 1976)

- Level 1: Goals
- Level 2: Functional Requirements
- Level 3: Operative Requirements
- Level 4: Verification
- Level 5: Examples of Acceptable Solutions

IRCC Performance Code Hierarchy





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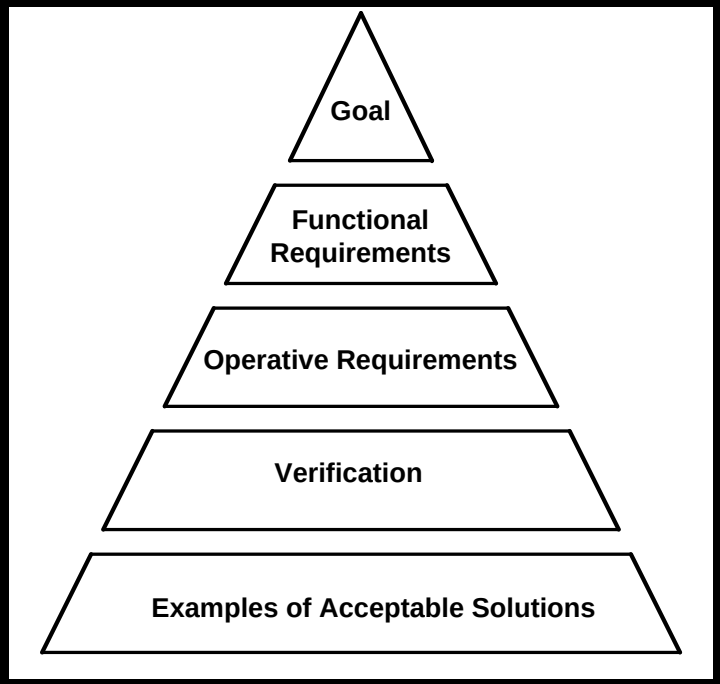
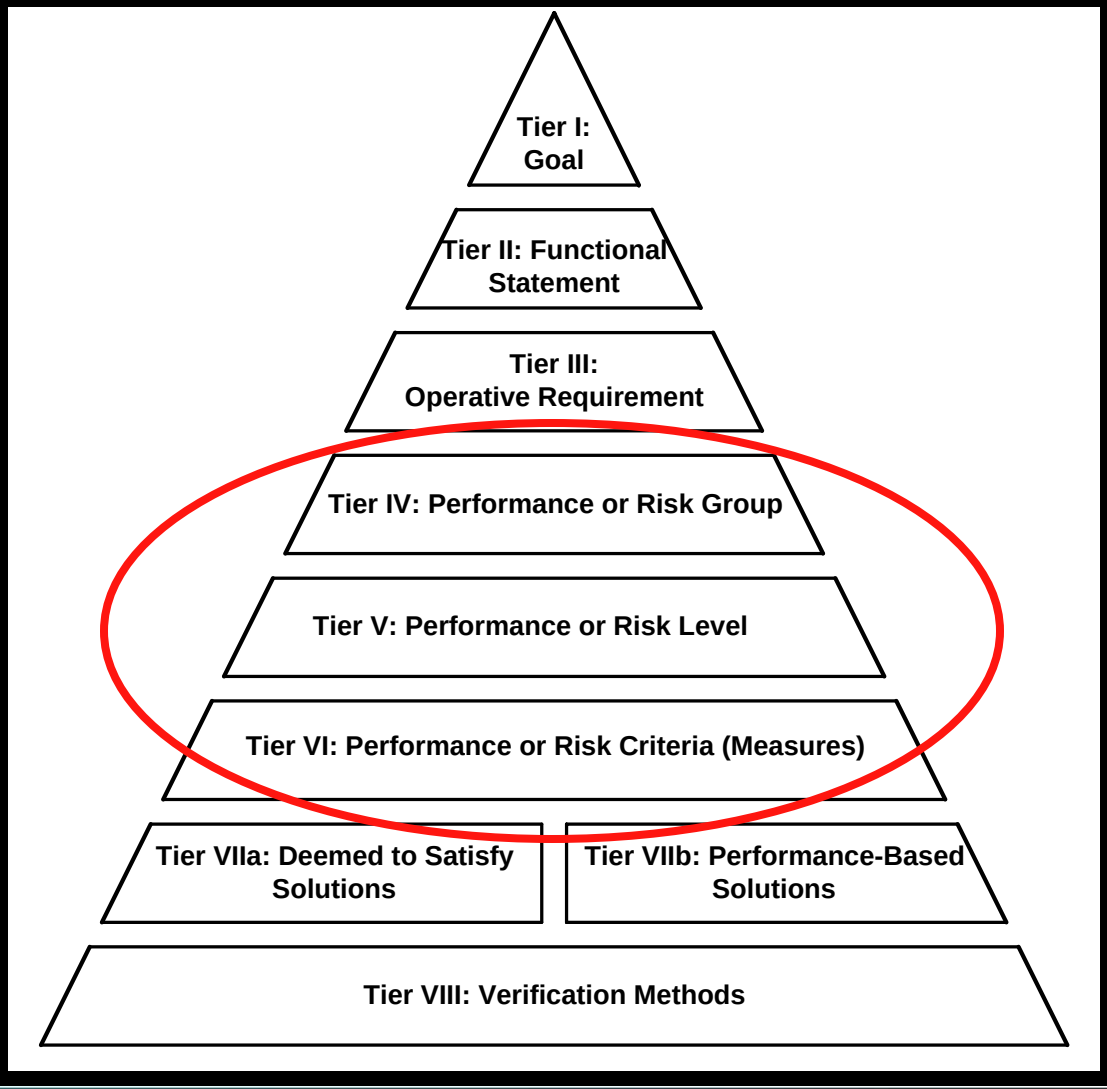
IRCC Performance Code Hierarchy





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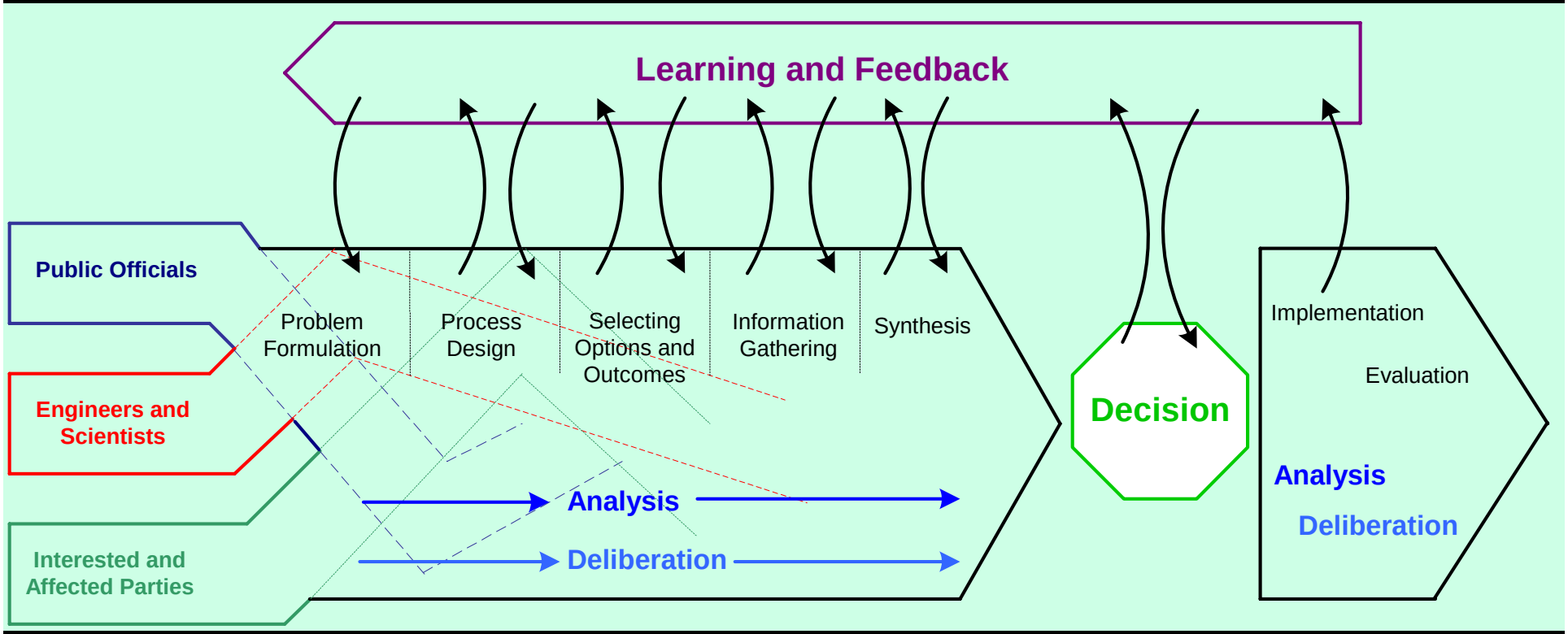
Risk-Informed Performance-Based Approach

- **Considers threat, risk and hazard data along with stakeholder and societal risk perceptions and performance expectations,**
- **Establishes agreed upon building performance targets for a broad set of hazard events, and**
- **Utilizes a mix of established and emerging technology and materials to design and construct buildings to agreed performance objectives**

Risk Characterization



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Risk Characterization

- **Who or what is exposed?**
- **If it is people, what groups are exposed?**
- **What is posing the risk?**
- **What is the nature of the harm?**
- **What qualities of the hazard might affect judgments about the risk?**
- **Where is the hazard experience?**
- **Where and how do hazards overlap?**
- **How much scientific consensus exists about how to analyze the risks?**
- **How much consensus is there among the affected parties about the nature of the risk?**

Risk Factors

- **The nature of the hazard, whether it is likely to originate internal or external to the structure, and how it may impact the occupants, the structure, and the contents.**
- **The number of persons normally occupying, visiting, employed in, or otherwise using the building, structure, or portion of the building or structure.**
- **The length of time and time of day the building is normally occupied by people.**

Risk Factors

- **Whether people normally sleep in the building.**
- **Whether the building occupants and other users are expected to be familiar with the building layout and means of egress.**
- **Whether a significant percentage of the building occupants are, or are expected to be, members of vulnerable population groups.**

Importance Factors

- **The service it provides (e.g., police, fire),**
- **The service it provides in an emergency (e.g., an emergency shelter, hospital, communications facility, or power),**
- **Its social importance (e.g., a historic structure, a church or meeting place), or**
- **The hazard it poses to the community, not just its occupants (e.g., chemical manufacturing facilities or nuclear power generating facilities).**

Performance Groups

- **Groups of building uses for which similar performance is expected during and after a design hazard event**
  - Group I - Low risk to life
  - Group II - All other than I, III, or IV
  - Group III - Increased risk to occupants or importance to the community
  - Group IV - Essential facilities or high hazard or risk occupancies

Events/Design Loads & Performance Indicators

- **Design loads that are representative of probable events that can be reasonably expected to impact the building -- deterministic or probabilistic (preferred)**
  - Small (Frequent)
  - Medium (Occasional)
  - Large (Rare)
  - Very Large (Very Rare)

Performance Indicators

- **Damage (performance) expectation:**
  - Structural
  - Nonstructural
  - Life safety
  - Contents
  - Hazardous materials release

Performance Levels

- **Four levels of “tolerable” damage, which are inverse of expected performance given design loads**
  - Mild
  - Moderate
  - High
  - Severe

Relational Matrix

MAGNITUDE OF DESIGN EVENT (INCREASING MAGNITUDE OF EVENT →)	INCREASING LEVEL OF BUILDING PERFORMANCE → **PERFORMANCE GROUPS**			
	Performance Group I	Performance Group II	Performance Group III	Performance Group IV
VERY LARGE (Very Rare)	SEVERE	SEVERE	HIGH	MODERATE
LARGE (Rare)	SEVERE	HIGH	MODERATE	MILD
MEDIUM (Less Frequent)	HIGH	MODERATE	MILD	MILD
SMALL (Frequent)	MODERATE	MILD	MILD	MILD

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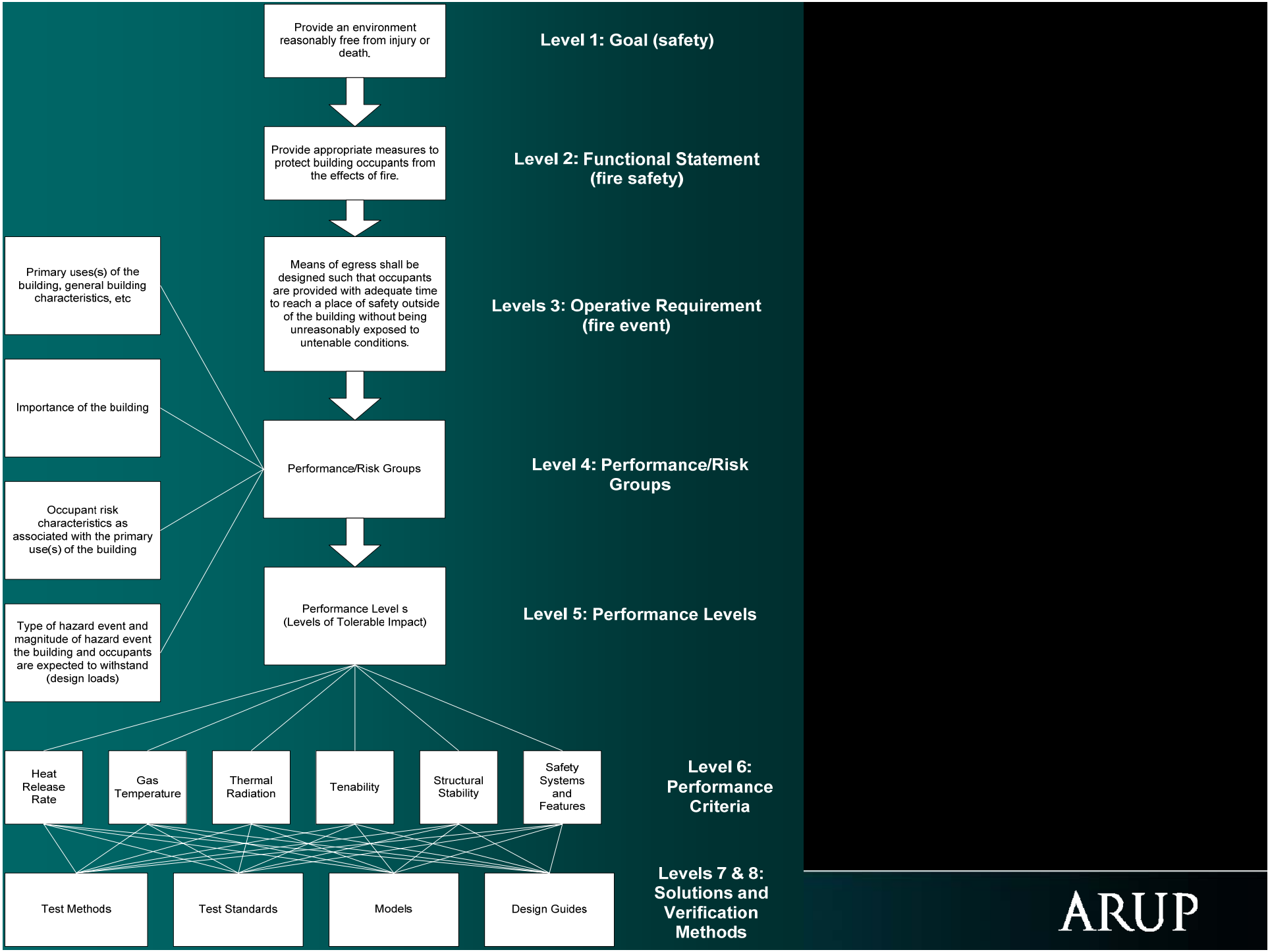
Performance Criteria

- **At the end of the day, quantified (measured, calculated, estimate) criteria are needed to assess performance, whether by testing, computational modeling, or other means**
- **There criteria do not have to be in the code, but must be in the system**


Provide an environment reasonably free from injury or death.
Level 1: Goal (safety)
Provide appropriate measures to protect building occupants from the effects of fire.
Level 2: Functional Statement (fire safety)
Primary uses(s) of the building, general building characteristics, etc
Means of egress shall be designed such that occupants are provided with adequate time to reach a place of safety outside of the building without being unreasonably exposed to untenable conditions.
Levels 3: Operative Requirement (fire event)
Importance of the building
Performance/Risk Groups
Level 4: Performance/Risk Groups
Occupant risk characteristics as associated with the primary use(s) of the building
Performance Level s (Levels of Tolerable Impact)
Level 5: Performance Levels
Type of hazard event and magnitude of hazard event the building and occupants are expected to withstand (design loads)
Heat Release Rate
Gas Temperature
Thermal Radiation
Tenability
Structural Stability
Safety Systems and Features
Level 6: Performance Criteria
Test Methods
Test Standards
Models
Design Guides
Levels 7 & 8: Solutions and Verification Methods
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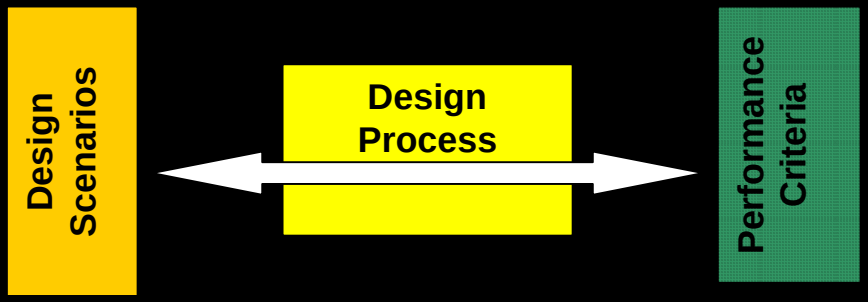
New Zealand Situation

- **One of the first performance codes (1992) – no performance criteria**
- **Moisture problem in the early 2000s – “leaky building syndrome”**
- **Abolished BIA and established new government department, Department of Building and Housing**
  - Redraft building act (done)
  - Incorporate better building controls (in process)
  - Review building code (in process)

Situation in New Zealand

	Performance Group I	Performance Group II	Performance Group III	Performance Group IV
Very Large (Very Rare)	Severe	Severe	High	Moderate
Large (Rare)	Severe	High	Moderate	Mild
Medium (Seldom)	High	Moderate	Mild	Mild
Small (Frequent)	Moderate	Mild	Mild	Mild



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Performance Matrix - Structural - Extended

Design Life (Years)			Design Life (Years)			Chances of Occurrence in Lifetime of Building					
25	50	100	25	50	100		**Key** ===>	Serviceability Design Point - Required	ULS Design Point - Required	SLS1 Design Point - Optional	Extrapolation outside range of 1170
							Performance Group				
Snow			EQ and Wind			Event	IL 1	IL 2	IL 3	IL 4	IL 5
1/500	1/1000	1/2500	1/2500	1/5000	1/10000	Extremely Rare	Collapse very likely	Collapse probable	Collapse possible	ULS likely	ULS possible
1/250	1/500	1/1000	1/1000	1/2500	1/5000	Very Rare	Collapse likely	Collapse possible	ULS likely	ULS possible	Moderate structural damage
1/100	1/250	1/500	1/500	1/1000	1/2500	Rare	Collapse probable	ULS likely	ULS possible	Moderate structural damage	SLS2 (Building function maintained. Structural and non-structural damage
1/50	1/150	1/250	1/250	1/500	1/1000	Probable	Collapse possible	ULS possible	Moderate structural damage	SLS2 (Building function maintained. Structural and non-structural damage	
			1/100	1/250	1/500	Moderately Probable	ULS likely	Moderate structural damage	Insignificant structural damage. Limited non-structural damage		SLS1 (no repairs needed to structure or other elements)
1/25	1/50	1/150	1/50	1/100	1/250	Highly Probable	ULS possible	Insignificant structural damage. Limited non-structural damage		SLS1 (no repairs needed to structure or other elements)	
1/25	1/25	1/100	1/25	1/50	1/100	Likely	Moderate structural damage		SLS1 (no repairs needed to structure or other elements)		
		1/50		1/25	1/50	Very likely	Insignificant structural damage. Limited non-structural damage	SLS1 (no repairs needed to structure or other elements)			

Performance Matrix - Structural

Chances of Event Occurring in Lifetime of Building	Performance Group 1	2	3	4
Extremely Low	Very Severe +	Tolerable Impact Level 5 (Very Severe)	Tolerable Impact Level 4 (Severe)	Tolerable Impact Level 3 (High)
Very Low	Tolerable Impact Level 5 (Very Severe)	Tolerable Impact Level 4 (Severe)	Tolerable Impact Level 3 (High)	Tolerable Impact Level 2 (Moderate)
Low	Tolerable Impact Level 4 (Severe)	Tolerable Impact Level 3 (High)	Tolerable Impact Level 2 (Moderate)	Tolerable Impact Level 1 (Mild)
Medium	Tolerable Impact Level 3 (High)	Tolerable Impact Level 2 (Moderate)	Tolerable Impact Level 1 (Mild)	Tolerable Impact Level 1 (Mild)
High	Tolerable Impact Level 0 (Insignificant)	Tolerable Impact Level 0 (Insignificant)	Tolerable Impact Level 0 (Insignificant)	Tolerable Impact Level 0 (Insignificant)

Key to Tolerable Impact Levels (TIL)	TIL 0 Insignificant	TIL 1 Mild	TIL 2 Moderate	TIL 3 High	TIL 4 Severe	TIL 5 Very Severe
	No significant effects on building elements, occupants or functions	Building function maintained. Little or no damage to structure. Minor damage to building fabric. Some contents affected. Building fully accessible and safe to occupy. (Compare SLS 2)	Building function affected for less than 24 hours. Minor damage to structure. Moderate damage to building fabric. Contents affected. Building accessible and safe to occupy.	Building function affected and building unsafe to occupy for up to 3 days. Moderate, but repairable damage to structure. Damage to building fabric requires replacement of some items. Most contents affected. Access inhibited. Most of building safe to occu	Building function affected and building unsafe to occupy for up to a month. Major damage to structure and building fabric, requiring repair for up to one year. Most contents seriously affected. Normal access denied for up to one year.	Building function seriously affected and building unsafe to occupy for up to a month. Major and extensive damage to structure and building fabric, requiring rebuilding. Contents not salvageable. Access denied for an indefinite period.

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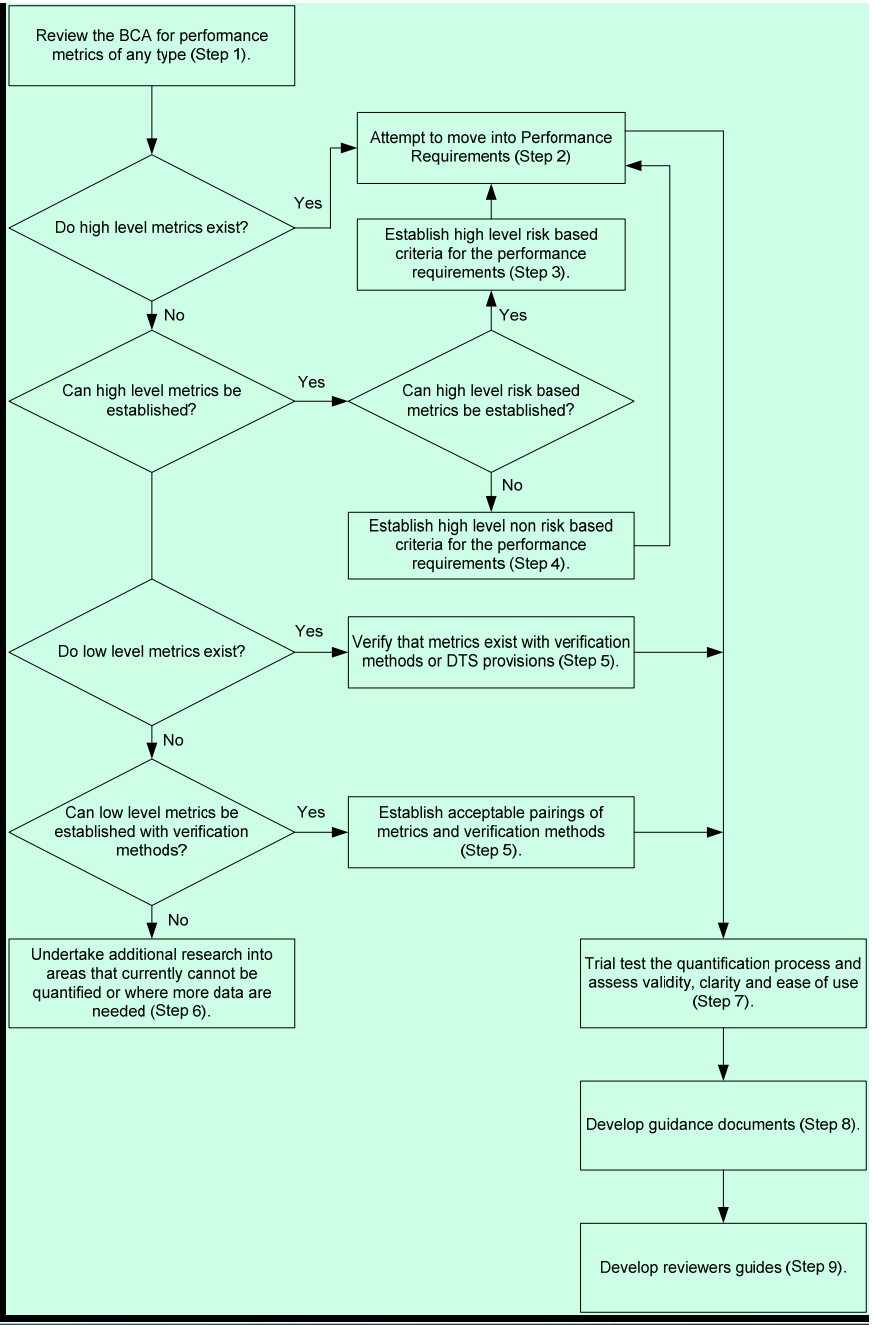
Australian Situation

- **Performance building code 1996 – no performance criteria**
- **Observed “leaky building syndrome” in New Zealand, found quality problems in NSW (Campbell Inquiry), and was subject to Productivity Commission review**
- **Result was to develop quantified performance metrics for the BCA. ABCB decided to look at risk as a basis of performance.**

Australian Situation

- **Wherever appropriate, risk should be a driver for establishing high level performance requirements. (A primary aim of building regulation is to provide adequate safety to building occupants: establishing building performance at levels of risk that are socially tolerable is a defensible approach.)**



Australian Situation

- **Risk means different things to different people, so a clear and common understanding should be sought.**
- **Events of concern should be clearly defined.**
- **Intolerable consequences (inverse of required performance) should be clearly articulated (can be qualitative).**
- **Values for likelihood (frequency, probability) must be quantifiable – this can be accomplished from existing objective data, new data, subjective estimates, or other accepted methods.**
- **Acknowledgement of uncertainty and variability should be made in the quantification process.**

Summary

- **There are societal expectations for building performance and for tolerable risk, and these can be linked.**
- **A useful measure of building performance is the maximum level of damage to be tolerated for design hazard events.**
- **Building performance groups (levels), maximum levels of damage to be tolerated, and magnitudes of design events can be based on analytical hazard and risk data, as well as public perceptions and expectations of the risk from hazards impacting buildings. These can then be linked to quantified criteria.**