Performance-Based Codes: History, Concepts & Trends

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Reimagining the ICCPC – Presentation and Roundtable Series

Overview

- Snapshot of current extent of PB building codes
- A bit of history on basis for code structure
- Examples of '1st generation' objectives, functional statements, operative (performance) requirements, approaches to methods of verification and examples of acceptable solutions
- Some issues / challenges with current approach
- Some trends and changes being considered internationally, and perhaps for any reimagined ICCPC of the future

PB Building Codes are Widespread

- Australia
- Austria
- Canada
- China
- England
- Germany
- Japan
- Netherlands

- New Zealand
- Norway
- Scotland
- Singapore
- Spain
- Sweden
- United States

These are just IRCC member countries (www.ircc.info) – there are others as well!

Many Share Common Structure

- Nordic 5-tier Hierarchy (NKB, 1976)
  - Level 1: Goals – essential interests of the community at large (society) with regard to the built environment.
  - Level 2: Functional Requirements – qualitative requirements of buildings or specific building elements
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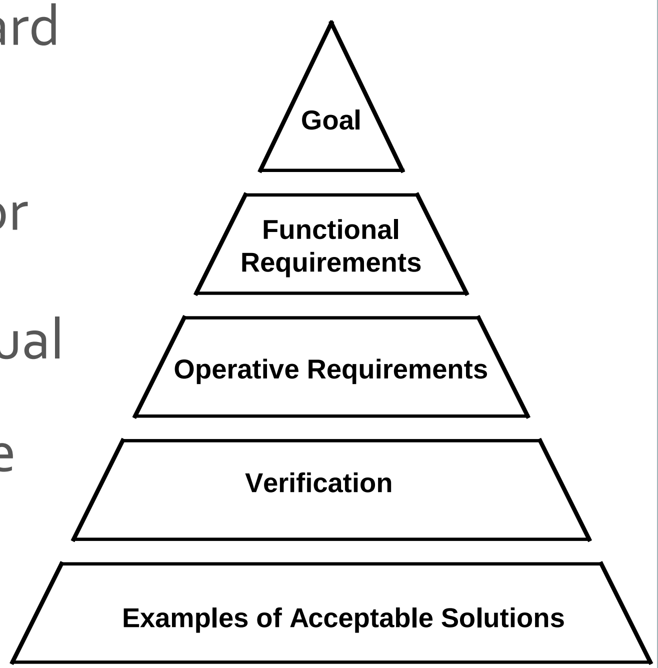
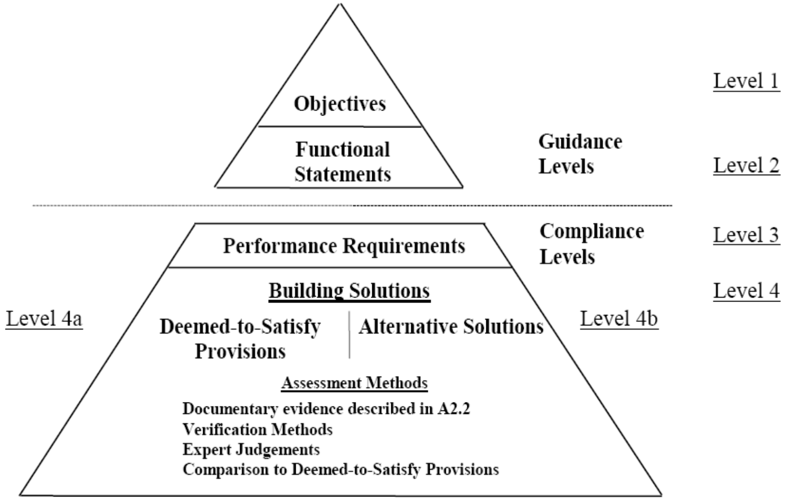
  - Level 4: Verification – instructions or guidelines for verification of compliance.
  - Level 5: Examples of Acceptable Solutions – supplements to the regulations with examples of solutions deemed to satisfy the requirements.

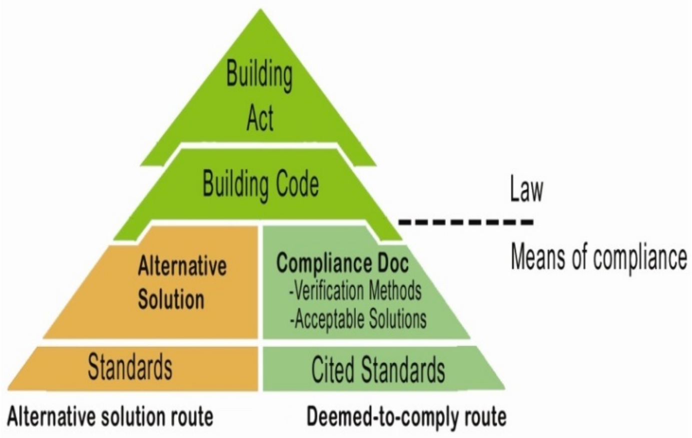


Many Share Common Structure

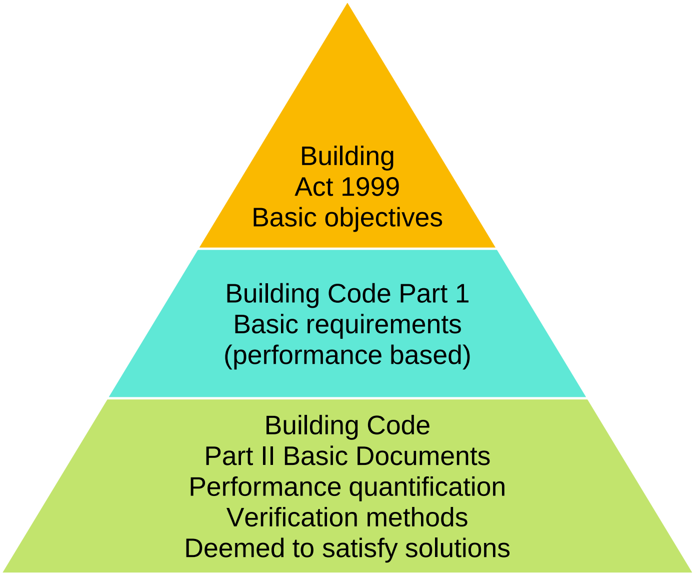
Australia (1996)



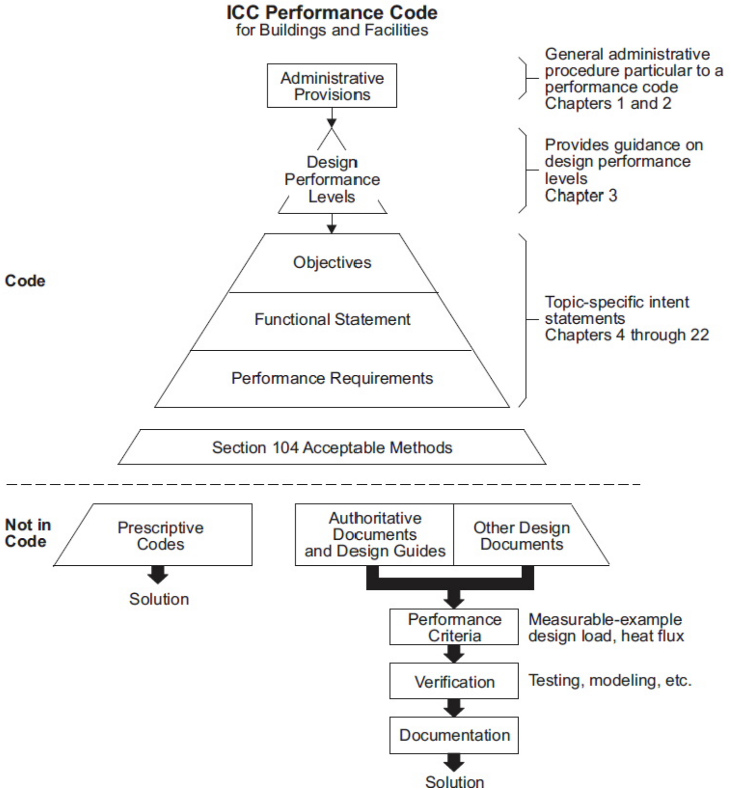
New Zealand (1992)



Spain (2006)



ICC (2000)



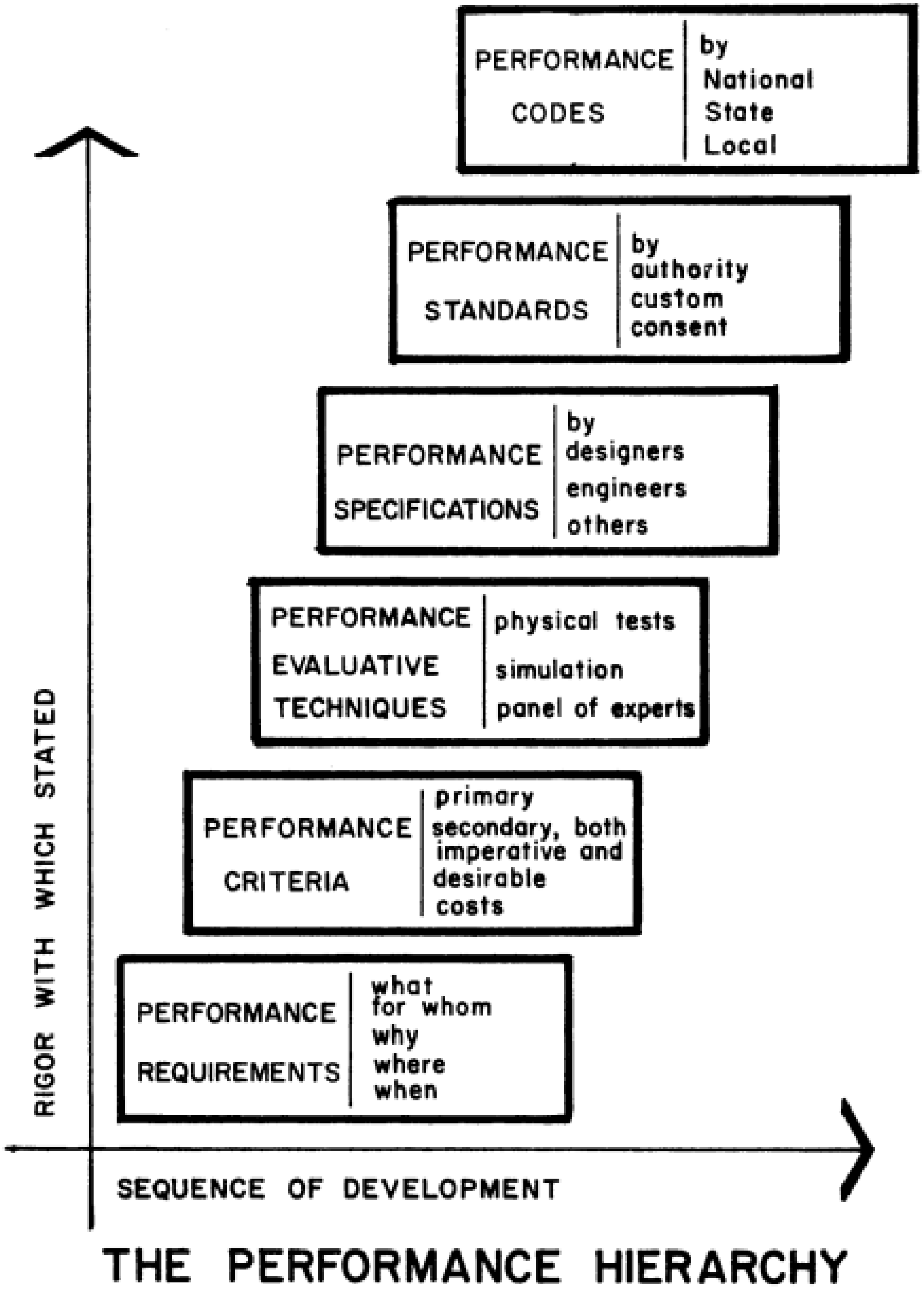
A Little History

A Little History

- Research organizations begad studying 'performance' approaches in 1960s and 1970s
  - US Department of Housing and Urban Development
    - The Performance Concept: A Study of Its Application to Housing https://www.huduser.gov/portal/sites/default/files/pdf/The-Performance-Concept.pdf
    - Operation Breakthrough
  - International Council for Building Research and Innovation (CIB)
    - W60 – performance concept in buildings (1970 - 2010)
    - CIB TG11 – PB building codes (1992-1997)
    - CIB TG37 – PB building regulatory systems (1999-2003)
  - SEAOC Vision 2000 (1995)
  - SFPE research on performance-based codes and fire safety design funded by NIST (1995-2000)

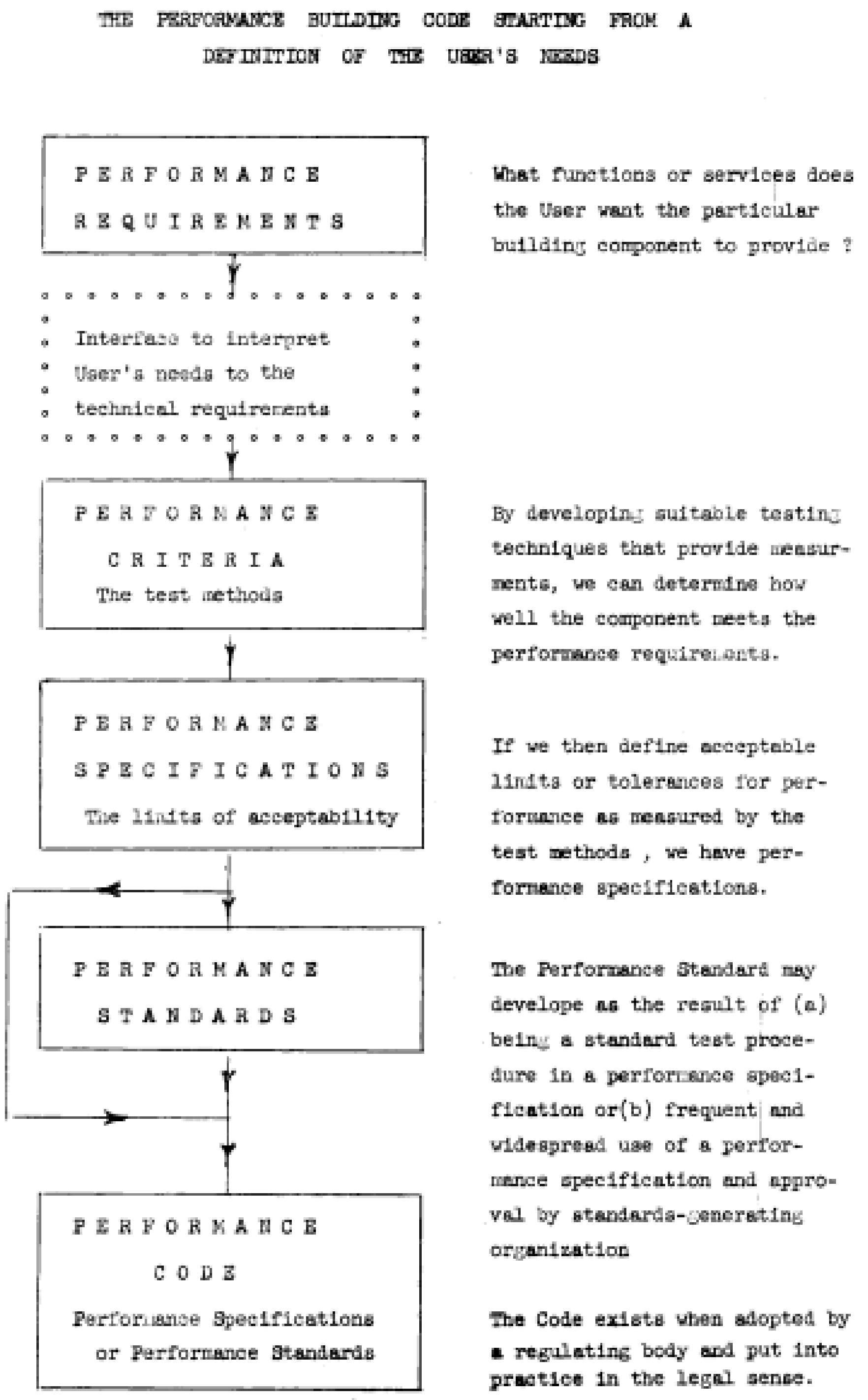
A Little History

- Performance Concept



A Little History

- Performance Concept



A Little History

- Operation Breakthrough

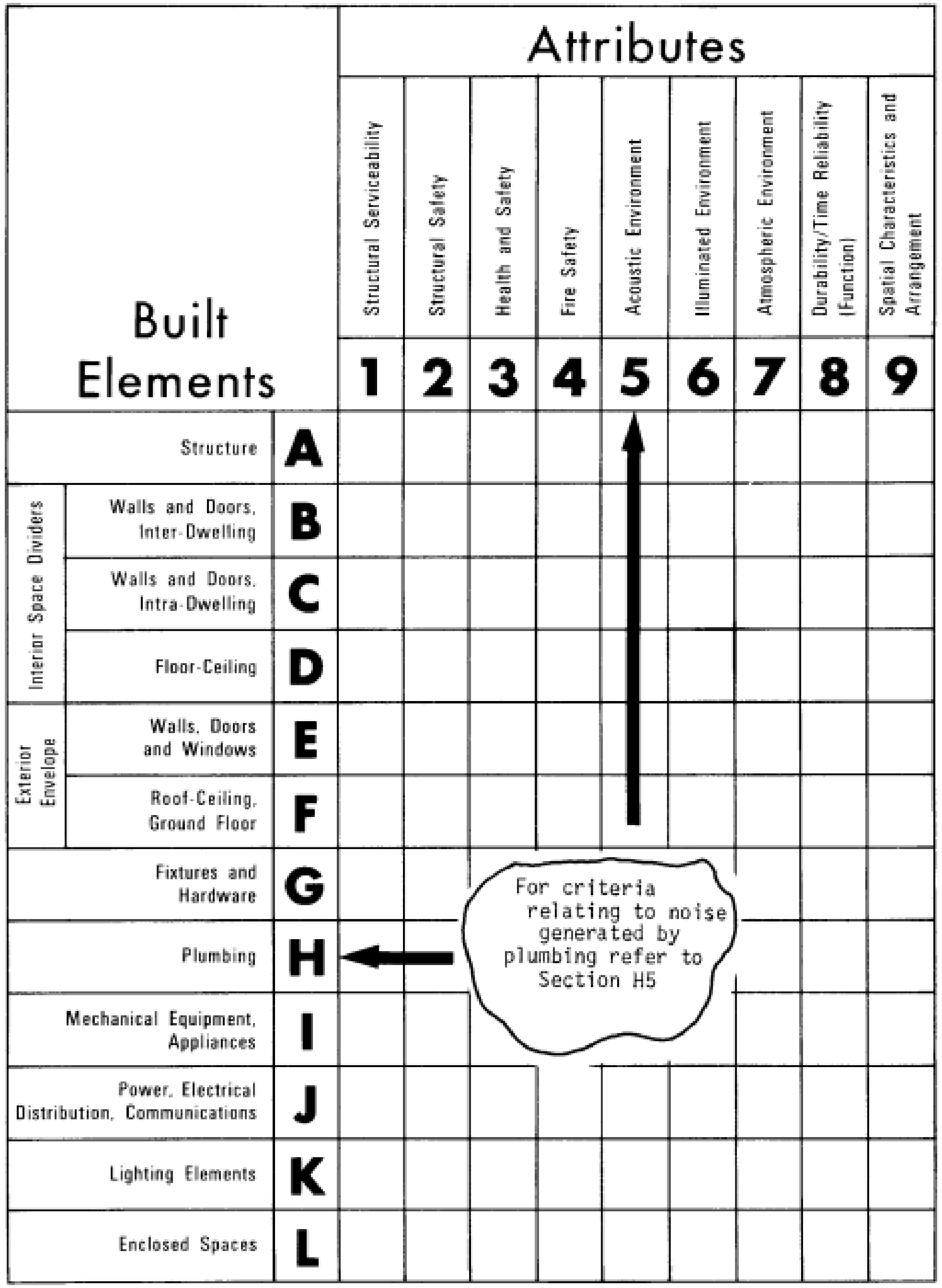


FIGURE 6 - Guide Criteria Matrix

A Little History

- Government pushes for deregulation (e.g. England) and microeconomic reform (e.g., Australia), along with desire to facilitate increased innovation and efficiencies in building design and operation in the 1980s led to performance-based building regulation
- Early functional- and performance-based building regulations / codes
  - England – 1985
  - Netherlands – 1987
  - New Zealand – 1992
  - Sweden – 1994
  - Australia – 1996

A Little History

- Nordic 5-tier Hierarchy (NKB, 1976)
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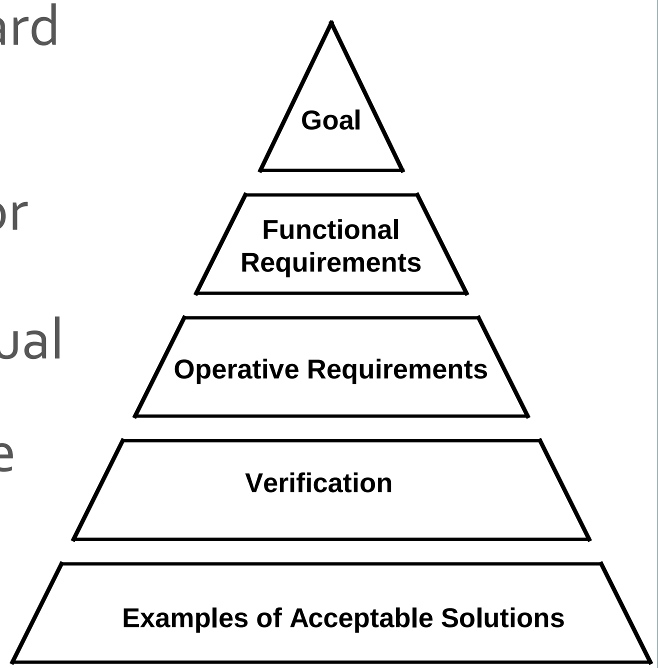
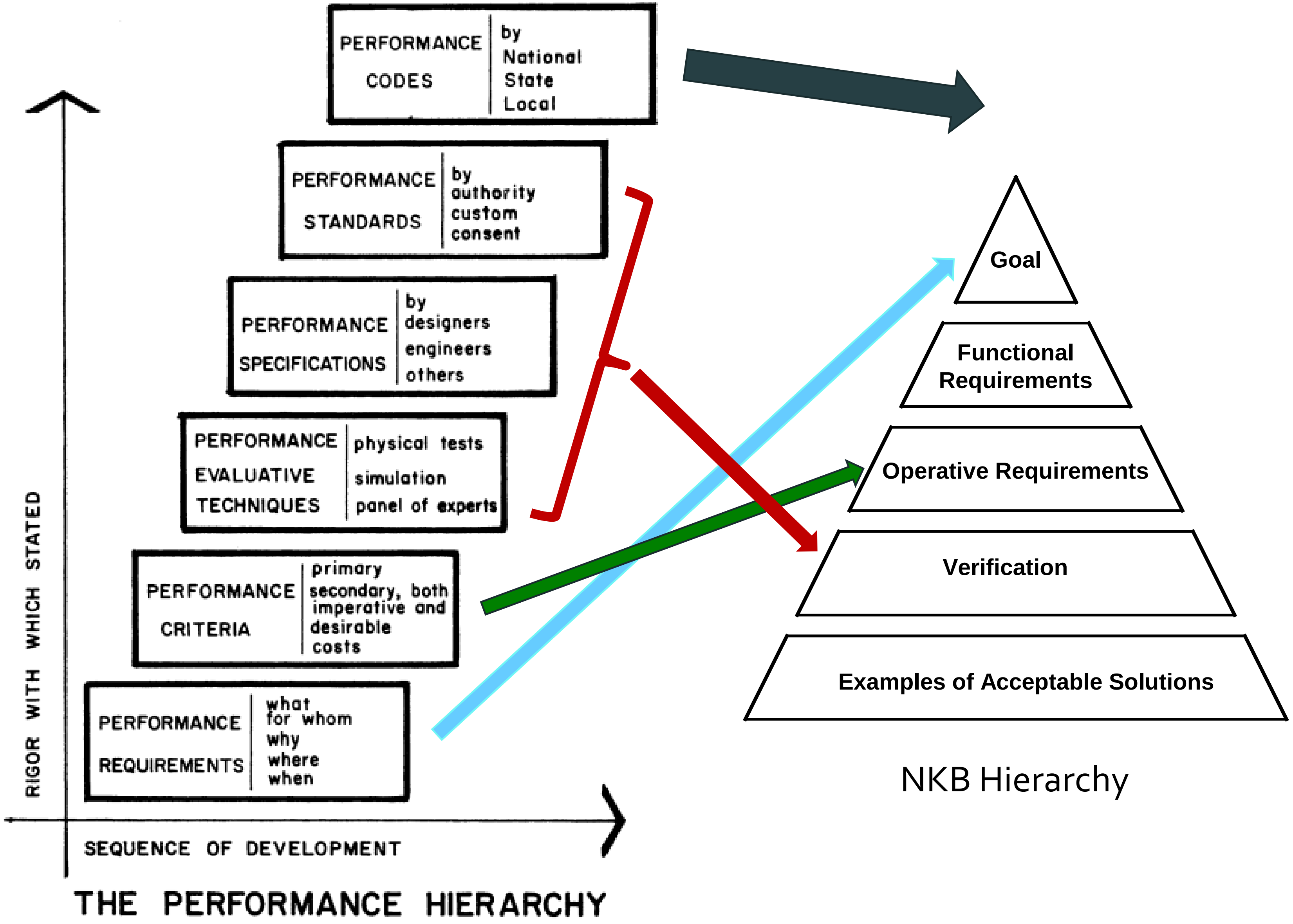


A Little History



1st Generation Functional Statements - Means of Egress

- England and Wales, 1991

  "B1 - The building shall be designed and constructed so that there are means of escape in case of fire from the building to a place of safety outside of the building capable of being safely and effectively used at all material times."

- New Zealand, 1992

  "C2.2 - Buildings shall be provided with escape routes which:

  (a) Give people adequate time to reach a safe place without being overcome by the effects of fire, and

  (b) Give fire service personnel adequate time to undertake rescue operations."

1st Generation Functional Statements – Structural

- England, 1991
  - A1 – Loading
    - (1) The building shall be constructed so that the combined dead, imposed and wind loads are sustained and transmitted by it to the ground—
      - (a)safely; and
      - (b)without causing such deflection or deformation of any part of the building, or such movement of the ground, as will impair the stability of any part of another building.
    - (2) In assessing whether a building complies with sub-paragraph (1) regard shall be had to the imposed and wind loads to which it is likely to be subjected in the ordinary course of its use for the purpose for which it is intended.
- New Zealand, 1992
  - B1.2 - Buildings, building elements and sitework shall withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives.

1st Generation Functional Statements – Noise

- England, 1991
  - E1. (Airborne sound, walls) A wall which—
    - (a)separates a dwelling from another building or from another dwelling, or
    - (b)separates a habitable room or kitchen within a dwelling from another part of the same building which is not used exclusively as part of the dwelling, shall resist the transmission of airborne sound.
- New Zealand, 1992
  - G6.2 - Building elements which are common between occupancies, shall be constructed to prevent undue noise transmission from other occupancies or common spaces, to the habitable spaces of household units.

1st Generation Functional Statements – Energy Efficiency

- England, 1991
  - None – not part of Building Regulations 1991
- New Zealand, 1992
  - None – not part of Building Code 1992

1st Generation Performance Requirements – Egress

- England and Wales, 1991
  - *None – Functional Statements only*
- New Zealand, 1992
  - "C3.3.1 - Interior surface finishes on walls, floors, ceilings and suspended building elements, shall resist the spread of fire and limit the generation of toxic gases, smoke and heat, to a degree appropriate to:
  - (a) the travel distance
  - (b) the number of occupants
  - (c) the fire hazard, and
  - (d) the active and passive fire safety systems installed in the building."

1st Generation Performance Requirements – Structural

- England, 1991
  - *None – only Functional Statements*
- New Zealand, 1992
  - B1.3.1 Buildings, building elements and sitework shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives.
  - B1.3.2 Buildings, building elements and sitework shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use.

1st Generation Performance Requirements – Structural

- New Zealand, 1992
  - B1.3.3 Account shall be taken of all physical conditions likely to affect the stability of buildings, building elements and sitework, including: (a) self-weight, (b) imposed gravity loads arising from use, (c) temperature, (d) earth pressure, (e) water and other liquids, (f) earthquake, (g) snow, (h) wind, (i) fire, (j) impact, (k) explosion, (l) reversing or fluctuating effects, (m) differential movement, (n) vegetation, (o) adverse effects due to insufficient separation from other buildings, (p) influence of equipment, services, non-structural elements and contents, (q) time dependent effects including creep and shrinkage, and (r) removal of support.

1st Generation Performance Requirements – Structural

- New Zealand, 1992
  - B1.3.4 Due allowance shall be made for: (a) the consequences of failure, (b) the intended use of the building, (c) effects of uncertainties resulting from construction activities, or the sequence in which construction activities occur, (d) variation in the properties of materials and the characteristics of the site, and (e) accuracy limitations inherent in the methods used to predict the stability of buildings.
  - B1.3.5 The demolition of buildings shall be carried out in a way that avoids the likelihood of premature collapse.
  - B1.3.6 Sitework, where necessary, shall be carried out to: (a) provide stability for construction on the site, and (b) avoid the likelihood of damage to other property.
  - B1.3.7 Any sitework and associated supports shall take account of the effects of: (a) changes in ground water level, (b) water, weather and vegetation, and (c) ground loss and slumping.

1st Generation Performance Requirements – Noise

- England, 1991
  - *None – Functional Statements only*
- New Zealand, 1992
  - G6.3.1 The Sound Transmission Class of walls, floors and ceilings, shall be no less than 55.
  - G6.3.2 The Impact Insulation Class of floors shall be no less than 55.
    - (Sound transmission class (STC) a single number rating derived from measured values of transmission loss in accordance with classification ASTM E413, *Determination of Sound Transmission Class*. It provides an estimate of the performance of a partition in certain common sound insulation situations)

1st Generation Verification Methods

- Verification methods include all methods necessary to demonstrate compliance with the code:
  - Test methods
  - Evaluation methods
  - Predictive methods
- Performance/evaluation/acceptance criteria are essential for verification methods
  - Strength of materials, illumination capacity, sound insulation, thermal insulation, lengths, widths, depths, heat release rates, critical temperatures, activation temperatures, ...
  - Challenge – criteria not typically presented in the code – up to the engineers to determine

1st Generation Acceptable Solutions

- Acceptable solutions are supplements to the Code that have been demonstrated to, or deemed to, satisfy the objectives and requirements of the Code
  - Prescriptive code-like solutions
    - Approved Documents (England)
    - Compliance Documents (New Zealand)
- Acceptable solutions are necessary for a variety of reasons
  - Economics: cost less to apply for most buildings because they are proven and readily accepted
  - Performance solutions are not always required

1^{st} Generation Acceptable Solutions

- Acceptable solutions, like Approved Documents in England, and Compliance Documents in New Zealand, provide largely prescriptive solutions, including reference standards (e.g., BSI and AS/NZ standards).
    - Much like removing structural (fire, noise, energy…) provisions from the IBC, making an individual compliance document for area (e.g., structural, fire…), and including reference standards in the compliance document

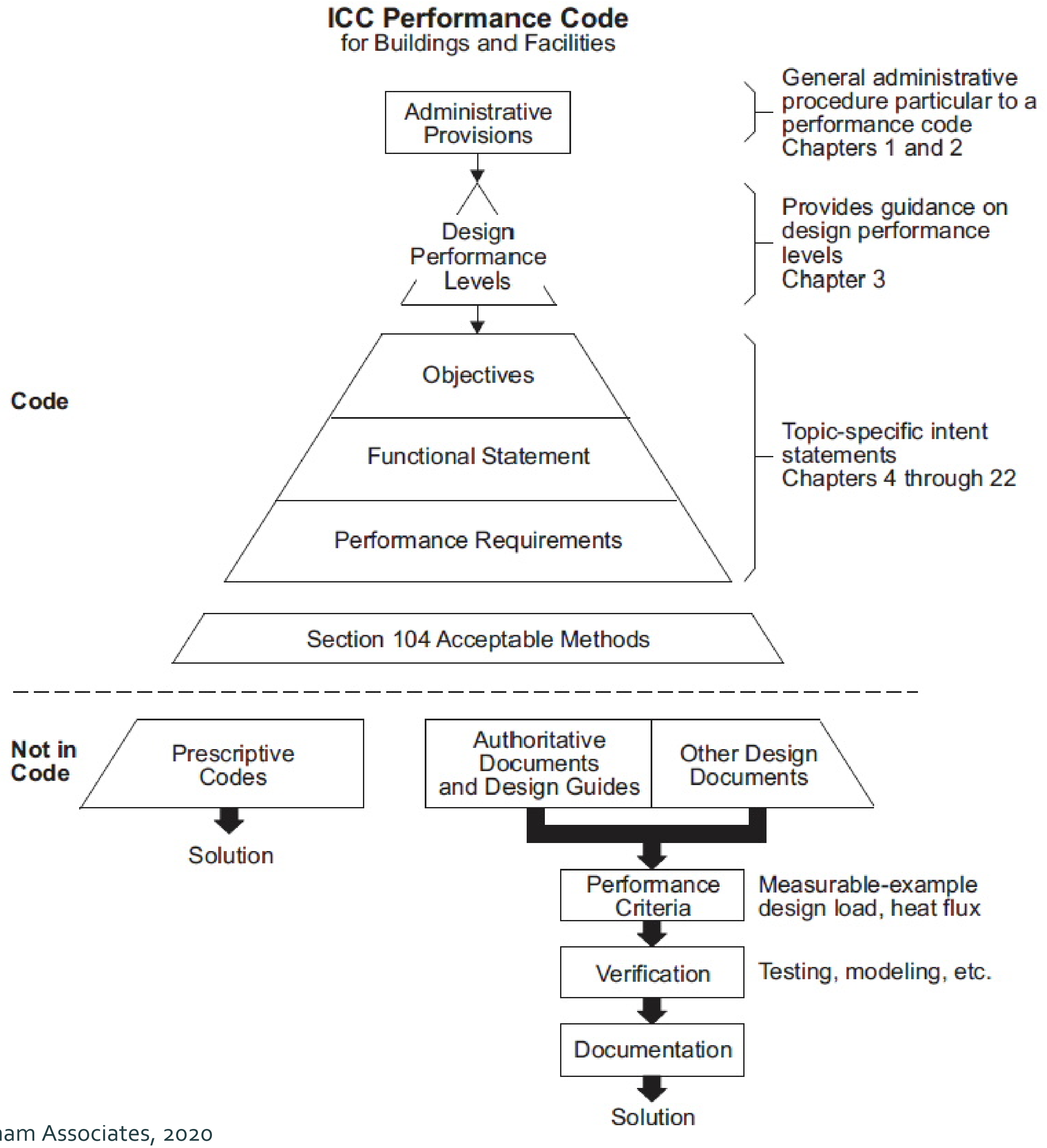
ICCPC Committee Approach – 1st Generation

- ICC formed committee of members with diverse background – code officials, engineers, etc.
- Chair was Robert (Bob) Weber, Clark County Building Department, based on experience with unique building designs on the Las Vegas Strip
- One of the staff liaisons was Beth Tubbs, who was participating in IRCC with Jon Traw, and who became convenor of the CIB TG37 group in 1999

ICCPC Committee Approach - 1st Generation

- For the first year or so, the committee collected examples of functional- and performance-based building codes from other countries, as well as performance-based design concepts from the engineering communities
- The main idea was to identify a model (or models) that seemed appropriate and modify as needed (i.e., don't reinvent the wheel)
- Ultimately, it was decided to 'borrow' the structure from New Zealand, but also incorporate the design load matrix concept from SEAOC

ICCPC Committee Approach - 1st Generation



ICCPC Committee Approach – 1st Generation

		PERFORMANCE GROUPS			
		PG I	PG II	PG III	PG IV
MAGNITUDE OF DESIGN EVENT	VERY LARGE	SEVERE	SEVERE	HIGH	MOD
	LARGE	SEVERE	HIGH	MOD	MILD
	MEDIUM	HIGH	MOD	MILD	MILD
	SMALL	MOD	MILD	MILD	MILD

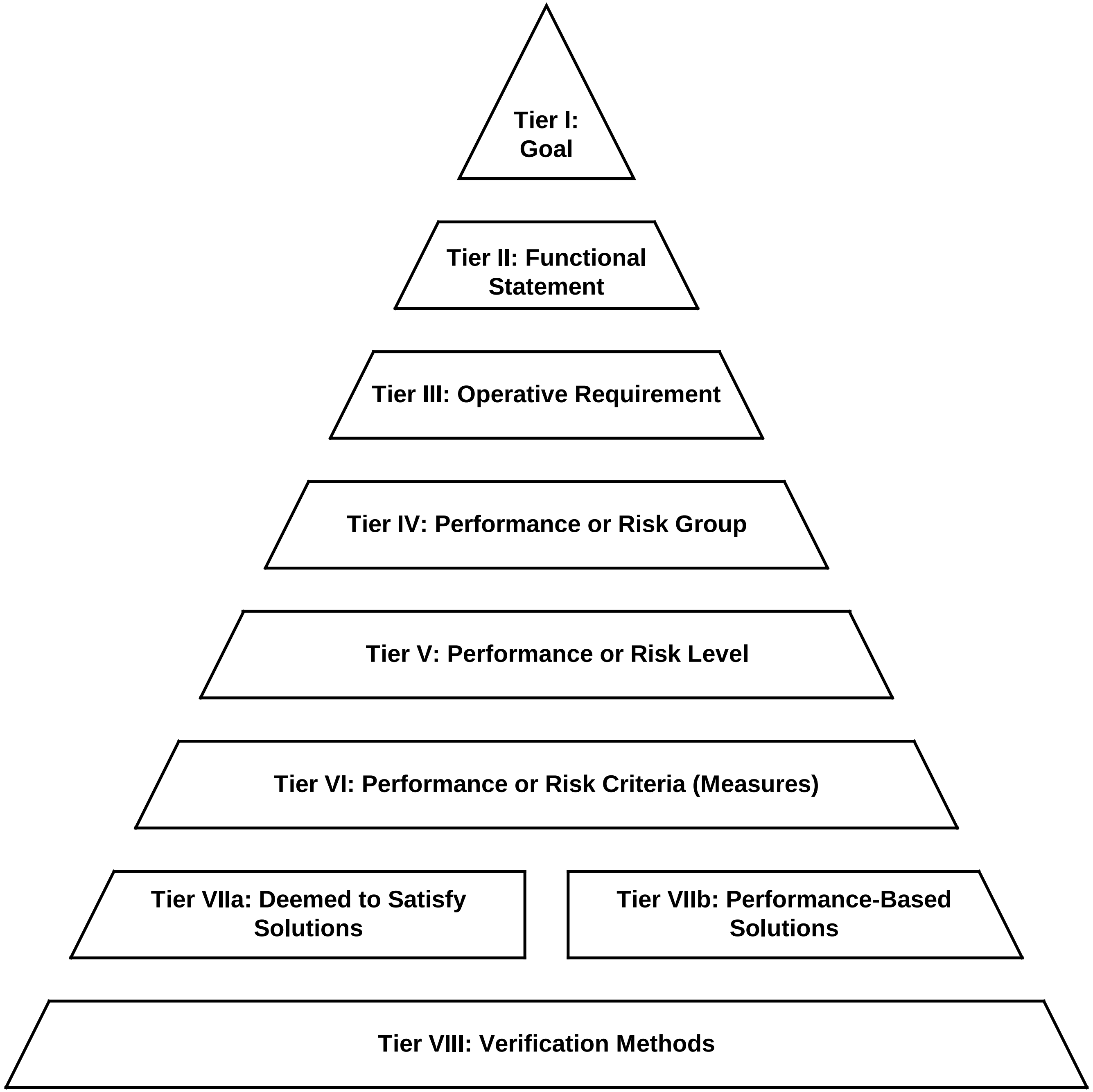
ICCPC Committee Approach – 1st Generation

- As the 'performance matrix' approach was developed, it iterated a bit based on feedback, but was ultimately included
  - Subsequently, the approach has been considered by performance codes in other countries
- Also, as the end of the development process approached, it was decided to merge the building and fire code components into one document to reduce duplication, and the building and fire code development committees merged

ICCPC Committee Approach – 1st Generation

- The end result is largely the ICCPC as published today, since very few revisions have been made
- The approach to fire loads was one area that changed based on comments, but the core concepts remained in place
- The idea of including risk and performance levels, and the matrix approach, are concepts that have been taken up by other countries since

ICCPC Committee Approach – 1st Generation



Challenges with 1st Generation PB Codes (and with Prescriptive Codes)

- In many cases, the level of performance being delivered is not entirely clear
  - What is 'adequate' time to evacuate a building safely?
  - What is the basis for a 200 ft travel distance to an exit?
  - What makes a 31 ft dead-end any safer than a 29ft dead-end (or 35 ft vs. 25 ft, or…)?
- Prescriptive codes, 'deemed-to-satisfy' solutions, 'approved documents' are all based on some perception of a tolerable level of safety/risk, but rarely quantified
  - This makes it difficult to demonstrate performance is achieved, or that solutions are 'equivalent'

Challenges with 1st Generation PB Codes (and with Prescriptive Codes)

- While functional statements provide flexibility, and performance requirements provide helpful additional detail, lack of quantitative measures creates challenges
- Criteria in standards can help – if demonstrably linked to code requirements
- If there is a lack of guidance in the market, large variation can result, and potential for failures exists
- Clear sets of verified and validated tools lacking
- Education / certification / licensure varies
- Professionalism and ethics in the market variable

Challenges with 1^{st} Generation PB Codes (and with Prescriptive Codes)

- The use of the term 'Verification Method" varies
  - Can be a completed example of how to comply with regulatory requirements
  - Can be prescriptive (well-defined) set of requirements that must be followed
  - Can be detailed engineering standards, with defined inputs and outputs
  - Can be 'flexible' application of 'approved' tools and methods of analysis

Challenges with 1st Generation PB Codes (and with Prescriptive Codes)

- The use of the term 'Verification Method" varies
  - For some areas of engineering analysis and design, verification methods rather robust and well-accepted
    - Structural engineering (Eurocodes)
    - Energy performance analysis
  - For other areas, in particular fire safety engineering, there is no well-defined, fully integrated analytical method (like reliability based structural design) or widely accepted and/or defined performance criteria (such as energy performance of buildings, in kW/m^2 or other metrics)
    - Many generic frameworks, not consensus on 'loads' and 'resistance'

Challenges with 1st Generation PB Codes (and with Prescriptive Codes)

- Government (building department / building control)
- Private certification
- Self Certification
- Mandatory peer review
- Optional peer review
- Combination
  - Many countries require peer review for performance-based designs, even if there are required governmental (or other) review and approval processes

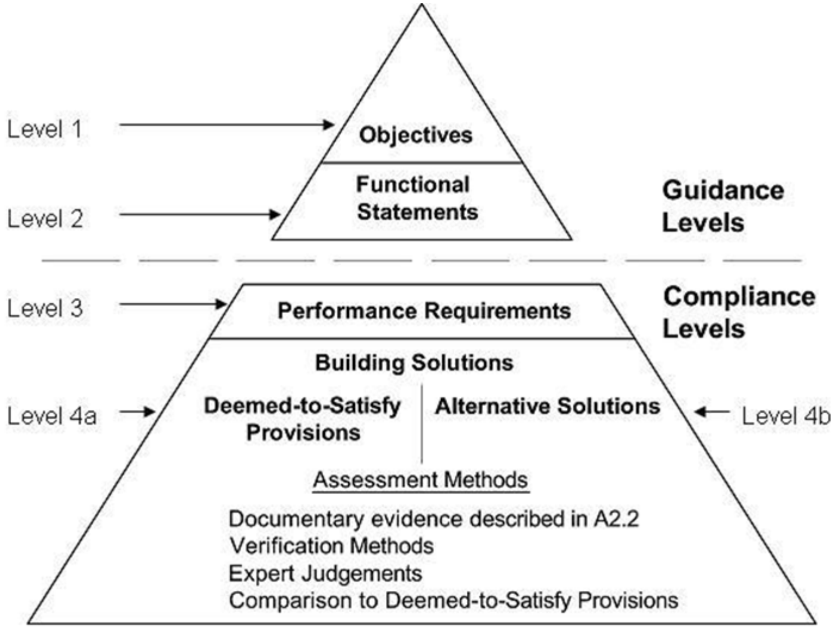
Challenges with 1st Generation PB Codes (and with Prescriptive Codes)

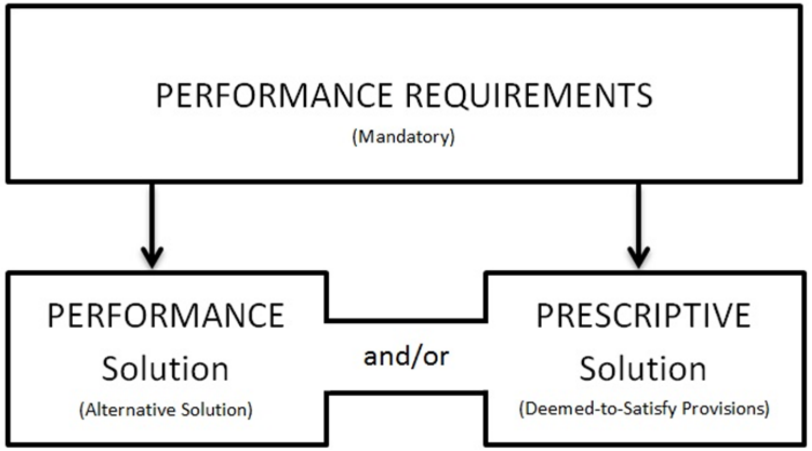
- Planning permit only
- Permit for planning and construction
  - Single or individual
- Design (plan) review and approval
  - Single or multiple reviews
  - All buildings or risk-based
- Site and construction inspections
  - Wide range - site preparation, foundations, construction, materials, services, systems, …
  - All buildings or risk-based
- Systems / building commissioning

Challenges with 1st Generation PB Codes (and with Prescriptive Codes)

- Range of “Restrictions” on “Qualified” Practitioners
- Limited by law / regulation
  - Licensing, such as Professional Engineer in USA, which sets minimum level
  - Restricted to approved organizations, such as in France
- No legal requirement, but largely ‘governed’ by professional bodies
  - Qualified by nominated engineering body and professional organization, such as Chartered Engineer in UK, where IFireE reviews qualifications for fire engineering, and chartering comes through the Engineering Council
- No legal requirement, no professional body membership requirements – completely up to the market
  - Nearly anyone can practice – quality depends on education and training – can be quite variable

Recent Issues / Changes / Trends





The current NCC Hierarchy on the left, emphasises the Deemed-to-Satisfy solutions, while the terminology of Alternative Solutions implies performance is outside the norm. The right shows a new hierarchy which more accurately emphasises the Performance Requirements as the only legal requirements. The two hierarchies currently both represent the legal structure of the NCC.

Source: ABCB, 2015

Recent Issues / Changes / Trends

- Climate change
  - Carbon emissions are leading to global climate change
  - Concerns include increasing temperatures, increasing storm intensities, increasing storm frequencies, sea level rise, and more
  - Responses include regulations for increased climate resilience and resource sustainability
- Resource sustainability can manifest in many ways, including reduction in materials (reduce embodied carbon), use of sustainable / renewable materials (e.g., timber), means to reduce energy costs (e.g., more natural lighting, natural ventilation, increased thermal insulation)
- Climate resilience focused on rain, wind and flood

Recent Issues / Changes / Trends

- Energy performance targets showing up in building regulations in many countries
  - Energy Performance of Buildings Directive (EU)
  - National Framework on Energy Efficiency (Australia),
  - Basic Environment Act. Article 4 (Japan)
  - Regulation of Civil Building Energy Saving by State Council (China)
  - International Green Construction Code (USA)
- Some concerns that ‘unintended consequences’ are being introduced due to ‘competing’ safety and sustainability objectives
  - Holistic approach being sought

Recent Issues / Changes / Trends

- In many countries, it has been recognized that insufficient guidance has been provided to assure consistent application, especially in fire safety
  - Some countries have developed more detailed fire safety engineering guidance, including New Zealand and Australia
- Several countries are looking at trying to establish tolerable / acceptable risk levels as basis for establishing performance criteria throughout the code
  - Including Australia and the Netherlands
- Several countries are considering moving toward risk-based or risk-informed design

Recent Issues / Changes / Trends

- NKB 5-tier Hierarchy
  - Level 1: Goals – essential interests of the community at large (society) with regard to the built environment.
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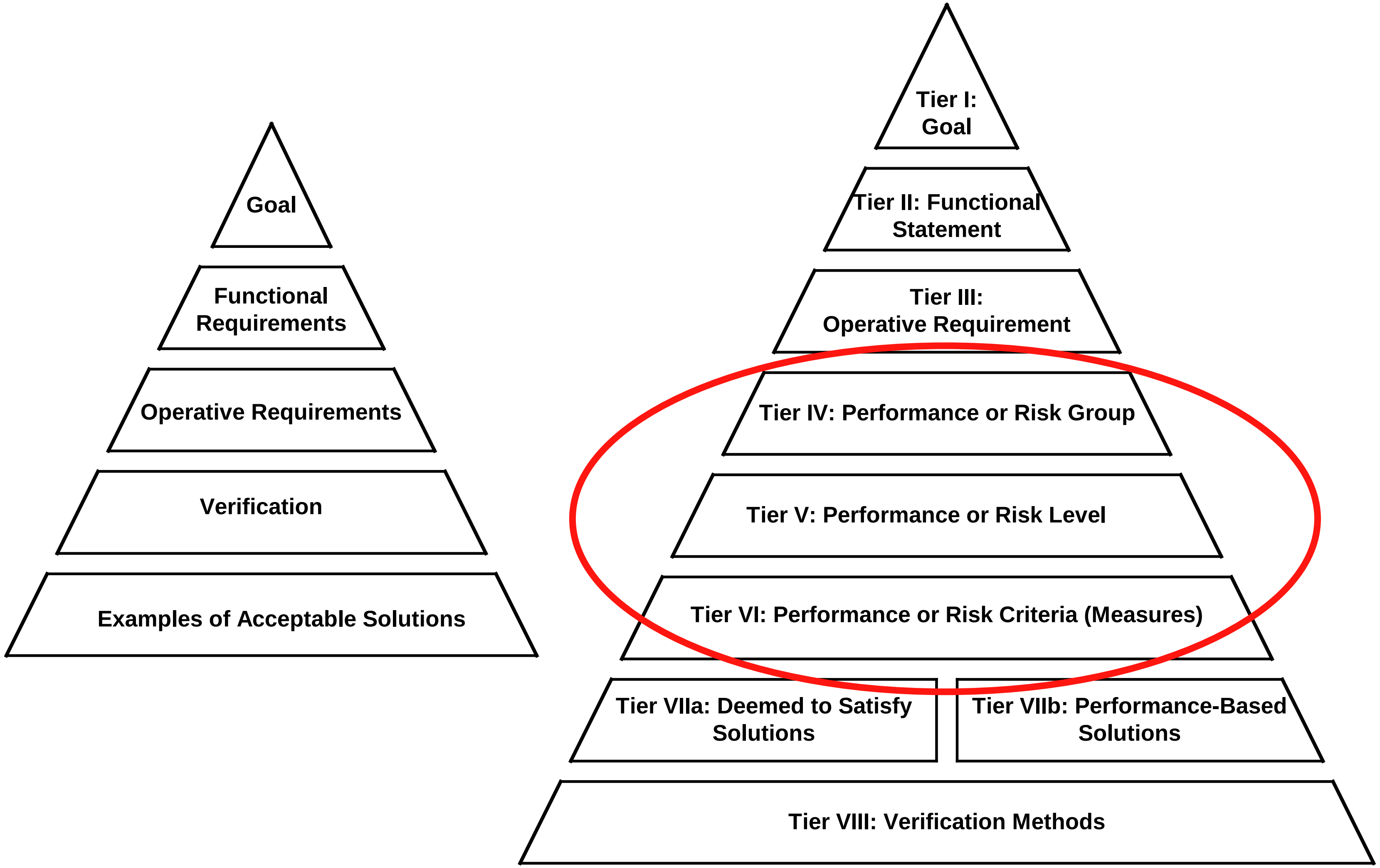

Recent Issues / Changes / Trends

- Pressure in a number of countries to reduce regulation / become more efficient
  - Australia – Productivity Commission Report
  - New Zealand – "Smart" Regulator
  - Scotland – Pressure to collect fees from industry to fund regulation
- Construction increases driving concerns about quality
- Existing buildings significant concern
  - Europe – energy retrofit (EPBD)
  - New Zealand – Earthquake-prone building, fire, …

Recent Issues / Changes / Trends

- In New Zealand, unexpected pressures due to separate development of fire compliance document and earthquake improvement to existing building
  - New compliance document C/VM2 for fire requires extensive analysis
  - Any building in earthquake prone area requiring seismic upgrade subject to meet current requirements
  - Triggering the need for costly FSE analysis, which may not be needed
- Similar pressure on other modification to building
- Triggering a review of requirements for existing buildings

Recent Issues / Changes / Trends

- In Europe, pressure to comply with EPBD – new and existing buildings – 2020 targets
  - Significant number of existing buildings need energy upgrades, but government incentives not strong enough for persons in the ‘energy poverty’ range
  - Exploring ways to evaluate energy upgrade prioritization for those most at risk (energy poverty category – those with not enough money to pay energy bills, but who also may be at risk due to age, infirmity, etc.)
- In addition, European New Green Deal has more focus on whole of life and recycled materials

Summary

- Use of performance-based codes (regulations) for buildings becoming more widespread – significant increase since 2000
- Most countries currently use 'NKB hierarchy', which shares common roots with US performance thinking from the 1960s and 1970s
- Critical aspects of the current approach are clear societal objectives, functional statements, operative (performance) requirements, verification methods, and examples of acceptable solutions.
- Long-standing concerns about capacity of professions (design and approval) still exist

Summary

- Increase desire to quantify performance
- Increase consideration of risk as a basis of performance
- Seeking systems / approaches to help balance new objectives (e.g., sustainability, resilience) with traditional objectives (e.g., health and safety)
- New pressures for 'smart' regulation (reduce regulation, cost, etc., while increasing quality)
- Push to address better the challenges with existing buildings – retrofit for energy, resilience (earthquake, climate change, …) – while maintaining health & safety objectives

Thank you!

- Questions or comments?
- Reimagining the ICC Performance Code - ICC (iccsafe.org)
- Performance@iccsafe.org