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Comparative Insight on Building Code Paradigm Shift Practice and Updates: International Perspectives

Amarachukwu Nwadike, Suzanne Wilkinson, Charles Clifton
Department of Civil Engineering, the University of Auckland
Private Bag 92019, Auckland 1142, New Zealand
anwa156@aucklanduni.ac.nz; s.wilkinson@auckland.ac.nz; c.clifton@auckland.ac

Abstract **–** This paper shows an overview understanding of building codes practice in different countries across the globe. Approach to building code practice and updates differs from country to country, but its primary aim is to provide the minimum requirements to protect life and properties in the built environment. The building code philosophy is to avoid collapse during and after an earthquake and other related extreme loading conditions. The data approach for this study was from the secondary source. This review aims to examine the paradigm shift in building code practice across different nations to determine which countries are embracing performance-based regulation through efficient building code improvement. The paper lays out performance base approach status, mode of compliance, amendment interval, issues that necessitates updates, implementation, code enforcement and highlight some challenges that need to be overcome to harness the full potentials of the innovative building code practice. The study provided a better understanding of comparative insights into the various building code in the selected countries and the factors that encouraged the paradigm shift in building code to accommodate technological innovation in the construction industry. The paper showed that many developed and developing countries are gradually shifting from prescriptive-based code to performance-based building code due to innovation, economic boom on infrastructure and persistent disaster occurrence in the built environment.

Keywords**:** Building code, Updates, Performance-based regulation, Prescriptive-based building code, Innovation.

1. Introduction

Following the consistent occurrence of a disaster and its destructive nature, building code has been seen as a measure of having a safe built environment. Building code provides the minimum structural safety requirements to protect lives and properties during or after an earthquake and other related extreme loading conditions. Many countries have introduced, enacted, updated and enforced their building code over the years to conform to the current demand to have a sate built environment. The impact of a disaster or the likelihood of its occurrence has threatened the peace of human, especially earthquake, which has the highest number of the death toll. Most of the deaths come as a result of total or partial collapse [1] of the building during the extreme loading.

The most deadly disaster that necessities the introduction of building regulations in many countries is the earthquake. Some of the selected countries established their codes following a catastrophic disaster [2], while others as a result of an increase in infrastructural development in anticipation to protect her citizens from any form of a disaster like an earthquake or through creative research. However, building standards help to ensure and maintain the integrity of the construction industry in line with structural behaviour during abnormal conditions. Even though building code cannot eliminate risk, but it can reduce risk to a satisfactory level. [3] Firmly agrees that building code is the vehicle for achieving disaster risk reduction in the built environment.

This paper presents the conceptual framework addressing the decision of countries moving from prescriptive based building code to performance-based method, method of compliance, amendment intervals, issues necessitating building code updates and enforcement and ways of updating building code. The list of chosen countries and year of first building code establishment respectively are shown in Table 1. Reasons for building code or regulation establishment vary from country to country. These reasons range from providing safety to humanity and properties due to experienced disaster or unforeseen disaster in, booming in infrastructural developments, innovation in research and otherwise.

Table 1: List of building code establishment and updates of various countries.

	Country	Year of first code introduction	Update Interval	Reason for building code.	Enforcement	Regulatory bodies
1	New Zealand	1842	No specific period but regularly	Earthquake and research innovation	Ministry of Business, Innovation, and Employment [MBIE]	Ministry of Business, Innovation, and Employment [MBIE]
2	Australia	1965	3	Earthquake and research innovation	States and territories	Australian Building Codes Board [ABCB]
3	Canada	1941	5	Earthquake and research innovation	Province and territorial governments	Canadian Commission on Building and Fire Codes and the Canadian Code Centre
4	Japan	1919	Between 3 to 5	Earthquake	Japan municipal government	Japan central government
5	Vietnam	1961	No specific period but regularly	Research innovation and boom in infrastructural development	Ministry of Construction and Provincial People's Committees	Ministry of Construction
6	UK	1666	No specific period but regularly	Innovative research	UK government, Welsh government, the Scottish government and the Northern Ireland Executive	Ministry of Housing, Communities & Local Government and Building Regulations Advisory Committee
7	USA	1645	3	Earthquake and research innovation	Federal States, Counties, and Cities	No specific body but includes ICC, IAPMO NFPA, ASHRAE

2. History of Building code in the selected countries

The first known building code dated back in 1772 BC by King Hammurabi of Babylon. The building code has progressively developed over time, but its aim remains to protect lives and properties in the built environment. Among the countries under consideration, USA was the first country to introduce building regulation in 1645 before their constitution took effect in 1789 [4], followed by the UK in 1666 after the great fire of London. The USA has no unified building code, but the International Building Code (IBC) is the most widely used code, administered by the International Code Council (ICC) [5] and [4]. Japan began research into earthquake resistance structures following the 8.0 magnitude earthquake of

Mino-Owari in 1891. Japan lies in an active seismic region in the Asian continent and has experienced several earthquakes of higher magnitude compared to any country around it. First Japan recognised uniform building code was established in the year 1919, known as the urban building law [1]. In 1961, the first Vietnam construction standard was introduced; however, it served till 1990. Vietnamese construction standard was coined from the former Union of Soviet Socialist Republics (USSR) building standards [6]. New Zealand building regulation started in 1842 known as the Raupo House Ordinance and was later replaced with the Municipal Corporations Act in 1867. The 1931 earthquake pushed for the establishment of building standards in New Zealand in 1935. The 1991 Building Act in New Zealand became the enacted national building standard in the country. The official building code of Australia was enacted in 1988 through the establishment of a committee called

Interstate Standing Committee on Uniform Building Regulation (ISCUBR) that drafted the building code from the existing building regulation called the Australian Model Uniform Building Code (AMUBC) in 1965 [7]. In 1914, the first Canadian National Building code was published, although there were existing building regulations guiding the building construction. The Canadian constitution included that building regulation is the full responsibility of each province.

3. Issues necessitating Building code updates and enforcement

Building code updates have been a consistent long practice, although some of the amendments are as a result of the after-effect of disasters [8], like earthquake rather than an act of fore-thought [2], to reduce the disaster risk. Review and improvement of building code should be a critical and integral part of pre-disaster planning to avoid the loss of lives and properties rather than a post-disaster scheme. The result of building code updates majorly depends on the type of code, location, and approach towards modification, the method of application and enforcement and the readiness of the involved stakeholders in handling the updates post challenges. The dedication and commitment of the stakeholders towards achieving a successful building code update is a crucial issue for consideration.

Building code modification aims to reduce disaster risk in line with building back better principles, which includes integrating disaster risk reduction activities into the existing standards to have buildings that are resilient to earthquakes and other related extreme loading conditions. Reducing the impact of a disaster is one of the primary reason to have a frequent building code amendment, hence, the non-amended building code is a disaster on its own over a period. Updating building code gives the opportunity to make corrections, include omissions, introduce new concepts or methods for smooth implementation, respond to changes from research findings, gained experience, and meet up with the expectation of the society [9].

It is a good practice to modify existing building code but when the amendment should take place, what should be amended and how to improve the code becomes a challenging issue that poses a question to answer. Hence, holistic impact analysis is critical because it gives answers to the raised question above. [10] Suggested that codes should be reviewed every three years since it is the average duration for a business cycle. In this study, the selected building codes have undergone a series of revisions at different time intervals. Recently, the USA and Australia building code are updated every three years respectively, to welcome new creative innovations and add market value. The first Australian building code in 1988 was later modified in 1990 and from 1st of May 2004, the code was set to be updated yearly before its extension to three years cycle interval in 2016 [11]. New Zealand, the UK, and Vietnam have no specific time interval for building code updates; however, the amendments are carried out whenever the need arises. In 1924, earthquake resistant construction regulations were reviewed and updated, due to the Great Kanto earthquake in 1923 that caused significant havoc in Japan. Subsequently, Japan building standard Act undergoes several revisions following almost every earthquake incidence [1] and [12], although [13] stated that it is updated between 3 to 5 years but not mandatory. The Vietnamese construction standard has passed through numerous amendments, some of which are based on other standards like the American Standards System and British Standard[6].

Furthermore, the Ministry of construction Vietnam allows the use of other building codes to practice in the country, but designs made with such codes must seek approval from the construction authorities, and this accounts for the economic growth in the construction industry in Vietnam, through the influx of foreign investors. The Canadian building code has been on a regular revision scale every five years from 1960 to date to welcome innovations into the Canadian construction industry. In the UK, the Building Regulations Advisory Committee [14] raised a concern that before a baseline of 5 years will be

accepted for updating the UK building code, there should be a clause for flexibility for the necessary amendment [14]. Notwithstanding, there is no specific interval for updating the UK building code, but it is regularly updated.

Despite that building regulations should be subject to change over time, it is evident that when it is frequently changed without outlined guiding principles that include the periodic intervals and required training in a coordinated manner, it can become complicated for its users regarding implementation, this can result to disaster on its own.

4. Paradigm Shift in building code

The quest to have a building code that is flexible in implementation and appreciates creative innovations has caused a tremendous paradigm shift from the conventional prescriptive based building code to a performance-based approach. These have been viewed as a one step further techniques [4] because it clearly defines the expected performance criteria end-result of how a structure should behave during an earthquake and other related extreme conditions over its lifetime service. Prescriptive based method outlines the step by step procedure on how to build a structure, and when strictly followed, it is deemed fit to demonstrate compliance. One of the main advantages of Performance-based approach is that it encourages technological innovations from all users, but professional skills are mostly required, while the later gives the detailed procedures which are accomplished without more professional skills. The prescriptive method is straightforward when all the laydown procedures are clearly stated and strictly followed. [15] Opined that the cost of construction and failure of new construction material to gain space in the construction market necessitated the improvement in the building code. According to [Scott Williams, 2016], the performance-based method delivers structures that are more aesthetical with a lower cost. [16] Noted that performance-based building code outlines the mandatory goals expected of a building rather than enforcing prescriptive based regulations. The Centre for International Economics, Benefits of Building Regulation Reform, Canberra affirmed in 2012 that the use of performance-based regulation had increased the productivity gain of the Australian building and plumbing industry.

Almost all the first published building code of countries started with a prescriptive method, but the gradual popularity of performance-based method shows that it is an excellent measure to achieve a better safe environment. Especially as [17] noted that seismic code does not only protect people, but it also tries to protect the buildings themselves. To encourage building code implementation and compliance to achieve a safe built environment, performance-based approach gained increased popularity. The Organization for Economic Cooperation and Development (OECD) have attracted the member countries to adopt the performance standard to improve their respective economic efficiency through increased building regulation incentives [18]. [19] Strongly advocates for building code amendments as a priority measure to achieve disaster risk reduction environment.

However, it presents some unique challenges in satisfying this approach regarding incurred cost and complex calculations and laboratory test to achieve compliance. Although the performance-based method has been introduced in many countries, in some cases, the method of cross-checking designs still follows the usual conventional method. The prescriptive method is cost-effective [18]; nevertheless, it does not allow for flexibility in design, although [16] argued that performance-based regulation reduces regulatory cost. Although the performance-based way may be more beneficial in both flexibility and products design, it is problematic to test or validate the performance of complex structures up front. Hence, adequate care must be taken to use performance-based criteria in regulations, guidance, and standards, and it is advisable to implement additional prescriptive methods in conditions of complex structures [20].

The United Kingdom championed and pioneered the first published performance-based building code as early as 1985, followed by New Zealand in 1992 building code based on performance, Japan in 1998 but was enforced in 2000 with stricter laws and Australia in 1998.

It was a difficult task for USA building code to be converted to performance-based regulation because of non-unified code and most importantly, the United States codes are not promulgated by the federal government [21]. However, the performance-based code was adopted in 2002 as specified by the International Code Council [22]. The USA performance regulation was formulated based on the key features of the United Kingdom, Australia, and New Zealand performance-based codes [21]. New Zealand building code has undergone several modifications that introduced performance-based approach building code in the 1991 Act but was enforced in 1992. The performance-based building regulation in New Zealand was

designed in accordance with the Nordic model [23], which can be compiled through Verification Method, Acceptable Solution, or Alternative Solution. An update 2012 to the New Zealand performance regulation enhances more creative opportunities in design and specification by the use of numerical modelling to display compliance through the provision of Verification Method for fire protection (C/VM2) [23]. The Japanese performance-based building standard only states the objectives and functional requirements of the performance approach, however [22] suggested that it is a quantitative performance code. The ministry of construction of Vietnam established Vietnamese building code embedded on the performance-based concept in 1996, this concept outlines the minimum technical guidelines appropriate to accomplish compliance, and it also makes provision to attain compliance through deem-to-satisfy provisions [6]. However, the Vietnamese performance-based approach seems to be shallow in providing required criteria's in some areas, thereby, leading to difficulties in implementation [6]. The innovation in the Canadian construction industry in 2005 paved way to the publication of the first objective-based building code [24], which allows the use of more performance and less prescriptive based approaches to attain compliance. The code gave a detailed measure to gain compliance without confusion [4]. The Australian building code was fully converted into the performance-based method in 1996 through the establishment of the Australian Building Codes Board (ABCB) in 1994. The building code of Australia consists of objectives, functional statements, performance requirements and building solutions [25], that is contemporary, progressive and working well [26].

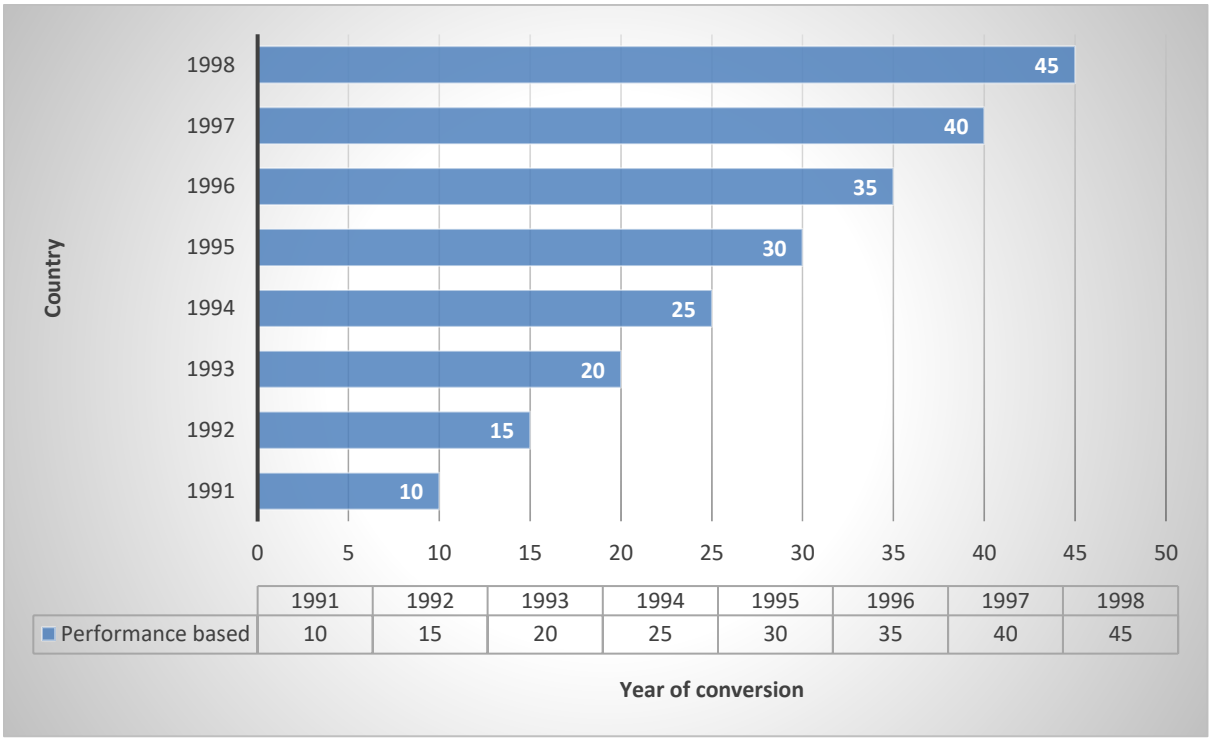

Fig. 1: Year of adoption of the performance-based building code in various countries.

The international council for research and innovation in building and construction (CIB) and the inter-jurisdictional regulatory collaboration committee (IRCC) provides an international platform where different countries discuss and share ideas on how to improve their performance-based regulation [27]. Figure 2 shows the list of various countries and when the adopted and enacted performance-based building code into law.

5. Method of compliance with performance-based building code

The introduction of performance-based building code has gained a full spread acceptance, and many countries have adopted the technique to grow their respective construction sector. Majority of the countries that changed their codes to performance-based followed the hierarchy defined by the Nordic committee on building regulation [21, 28] as shown in figure 2, to achieve compliance. However, the application differs from country to country [29]. It was later discovered that more explanatory criteria's and measures are needed to evaluate compliance through performance-based method [30, 31]. In response to the compliance deficiency in the performance base method, Meacham J. Brain developed and modified the [28] hierarchy into an eight-tiered performance-based hierarchy in collaboration with the members of the Inter-jurisdictional Regulatory Collaboration Committee [32] and [4] as shown in figure 2.

Basically, there are three major ways used to demonstrate compliance to building regulations in line with the performance-based approach followed by many countries like New Zealand, Australia, Japan, the UK, USA etc. Firstly, the verification method allows the use of a testing method (laboratory test), engineering analysis like calculation and experimental measurements (tests-in-situ), which when adhered are deemed fit to compliance. Secondly, the acceptable solution prescribes specific construction methods like the prescriptive based approach by giving step-by-step processes of how a structure should be built to show compliance, which is normally used in a simple residential building. The final method is the alternative solutions where the leading innovation and uniqueness are embedded in performance-based regulation because it empowers the designers to introduce a new solution [33]. This method uses qualitative or quantitative measures to demonstrate compliance to the building code like a comparison with the verification method or the acceptable solution, expert evidence, trading literature, etc. to show compliance [33]. The quantitative measure here means defining the required performance level and can be seen as prescriptive if it contains performance requirements, while qualitative measures are the objectives, functional statements and occasionally performance requirements [29]. Concerning compliance, building projects in Australia are manually checked against the building code for certification purpose which is prone to error and time-consuming [34]. This problem is complicated by regular amendments of the building codes [35, 36]. [37] Recommended the use of BIM-enabled code checking system to Australian building compliance process.

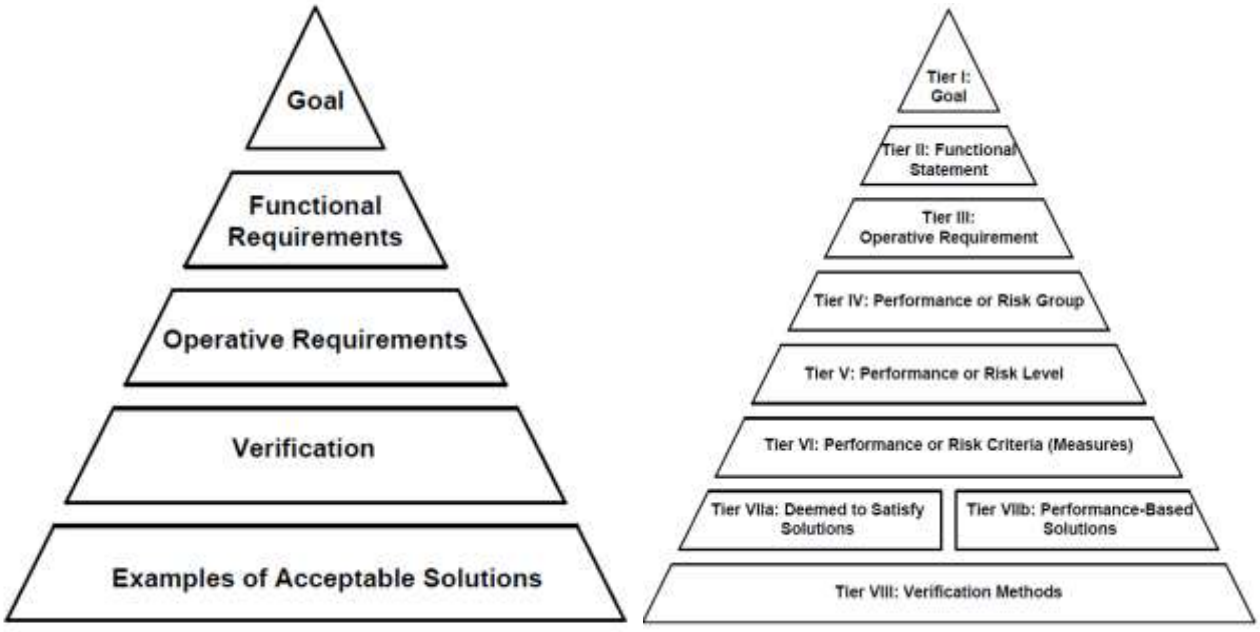

Fig. 2: NKB hierarchy model [28] (left) and the eight-tier hierarchy model; [4] (right).

However, in 2016 Australia's National Construction Code [NCC] simplified the compliance structure and changing terminologies by making more clarifications between the compliance level and guidance [38], as shown in figure 3. NCC also changed terminology that leads to the building code pathway to compliance by renaming alternative solution to performance solution [38].

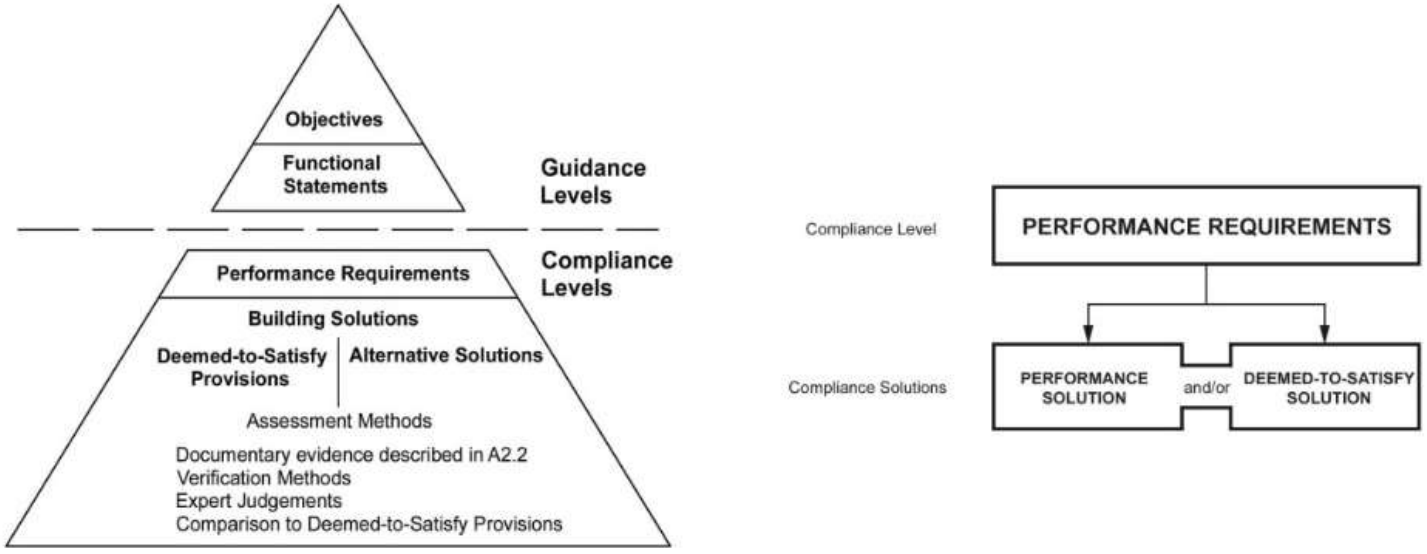

Fig.3: NCC changes to compliance structures (2015 left and current 2016 right) [39, 40].

6. Conclusion

The history of building code development in various countries showed the efforts to have a safe built environment. Experience gained from disaster and research innovation created the quest to have a building code that is flexible in implementation and appreciates creative changes in the construction industry. These have caused a tremendous paradigm shift from the conventional prescriptive based building code to the performance-based approach. Despite the advantages accorded to performance-based building code, there are still difficulties in demonstrating quantifiable compliance without reliance on prescriptive solutions. The study showed that it is a good practice to establish a building code, however, enacting and enforcing building code without regular updates will amount to waste of time within a short period. These further revealed that non-amended building code is a disaster on its own. Non-improvement of building code creates gaps that endanger the lives and properties and notifies the primary purpose of building code practice. Review and amendment of building code should be a critical and integral of pre-disaster planning to prevent loss of lives and properties. Building code modification aims to reduce disaster risk in line with building back better principles, which includes integrating disaster risk reduction activities into the existing standards to have buildings that are resilient to earthquakes and other related extreme loading conditions.

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