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# Impacts of innovation in performance based building code

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## **ABSTRACT**

The purpose of this study is to assess the benefits and the unintended consequences of innovation in performance-based building code with an emphasis in New Zealand building code. Also, this paper examines how innovative approach has affected the safety clause in the building code. An integrative literature review approach was used to explore the impacts of innovation in performance-based building code practice. Although the innovative approach in performance-based building code allows for creativity, flexibility in both design and construction, the use of new technological concepts and new construction materials, there remains significant challenges that need technical guidelines and training to overcome. The findings show the difficulties in achieving compliance through the use of innovation while trying to improve resilience in the built environment. The study concludes that innovation may have unintentionally affected the safety clause in the building code. Hence, the study recommends innovation impact analysis before building code amendment. The study used secondary data collection. Hence, there is need to use primary data collection to validate the findings from this study. The study is unique in its approach to explore the impact of innovation in performance-based building code in New Zealand and beyond.

**Keywords** - Innovation, performance-based building code, safety, flexibility, compliance, resilience, impact analysis.

## 1 INTRODUCTION

Many countries have moved from prescriptive based to performance building code in search of a robust approach to the minimum the effect of natural hazards in the built environment. The transition driver to performance-based building code is based on innovation and is expected to allow for cheaper products, creative design and construction (Foliente, 2000). The conventional building code describes the step by step procedures of how to achieve building requirements. In contrast, the performance-based code only states the building performance during and after a disaster. Furthermore, the conversion is underpinned to the inherent barriers with prescriptive building code relating to the acceptance of new products, construction materials and efficient building system (Martin sexton & barrett, 2005). The application of new technologies and better quality for structural performance and fire safety makes it easier for the paradigm shift to performance-based building code (Duncan, 2005; Haberecht & Bennett, 1999).

The 1991 Building Act enactment came with the conversion of New Zealand building code to performance-based building, that came into force in 1992. The transition comes with an innovative clause that meets the societal expectation and sustainability of the built environment (Duncan, 2000). Innovation consists of new ideas, breakthrough or the application of existing knowledge or methods in a unique format (Uma et al., 2003). Furthermore, the introduction of an innovative approach in performance-based building code created an additional pathway to achieve compliance, although prescriptive aspect was retained. In essence, performance-based building code only creates an enabling environment where the ideas of innovation could be sustained while allowing the building code practitioners to be creative, flexible and use alternative solutions to achieve compliance. Even though it can be argued that innovation improved compliance (Meacham, 2010b), it also created room for debate and placed the building code officials on the spotlight of making decisions on new concepts that are out of 'deemed to satisfy' while considering the liability of such action (Duncan, 2000). As innovation continues to gain popularity around the globe, J. Duncan (2005) noted the need for extensive technical training for both the regulators and the regulated to implement the option of innovative ideas embed in performance-based building code. The option of innovation could be redundant or wrongfully utilised without adequate training and supervision.

Presently, no country has a full performance-based building code in practice (Becker, 2008), because the prescriptive procedure is still retained (Duncan, 2000). In New Zealand, the prescriptive based building code is retained as an acceptable solution, which is widely used for building methods and systems (MBIE, 2014). This could be as a result of the unforeseen challenges surrendering the application of innovation in practice, regarding compliance and other related barriers that prevent the full implementation of innovation. Accordingly, Duncan (2000) pointed out that these barriers made countries to blend the performance-based building code with prescriptive building code. With this approach, the innovative hurdles are eliminated while improving on the benefits of innovation (Meacham, Tubbs, Bergeron, & Szigeti, 2003).

This study seeks to assess the benefits and the unintended consequences of an innovative approach used in performance-based building code. The study also examined how innovation unintentionally affected the safety clause in the building code. This study presented the findings from an integrative literature review (Torraco, 2016) perspective that an innovative method in the performance-based building code needs to be developed, certified and supervised by the appropriate entities. Achieving compliance through the use of an innovative method demands that both the regulated and the regulators must have adequate training, especially the building officials that will certify the new concepts.

## 2 BENEFITS OF INNOVATIVE APPROACH IN PERFORMANCE-BASED BUILDING CODE

The introduction of an innovative approach in the application of building code requirement was welcomed in the building industry. The innovative clause paved the way for performance-based building code, which

New Zealand is among the pioneers (Meacham Brian, 2008). With such acceptance, the innovation method cut across many areas in the building industry, such as building performance, construction materials, design, construction and administration. The paradigm shift to performance-based regulation is as a result of the additional opportunities the innovative clause offered to the industry (Meacham, 2010a). However, Humpreys (1985) stressed that innovative system would not bring an immediate solution to the challenges faced in the building industry. Hence, innovation should be well understood and developed up to the point that it could be sustainable regarding implementation and demonstrating compliance.

Many are of the opinion that prescriptive regulation makes it difficult to introduce the use of innovative methods in the building industry (Eisenhardt, Foliente, 2000; Duncan, 2000; Humpreys, 1985), especially regarding flexibility in design and construction aspect (Armstrong, Wright, Ashe, & Nielsen, 2017; Martin sexton & barrett, 2005; Meacham, 2010a). Duncan (2000) opined that the introduction of innovation helped to achieve the safety clause stipulated in the building code.

Furthermore, innovative ideas allow the building code users to create solutions that can withstand the impact of natural hazards compared to conventional regulatory practice (Armstrong et al., 2017), as some challenging tasks require a unique approach. Accordingly, this requires the application of building code users ingenuity to attain the needed outcome (Duncan, 2000). Also, Armstrong et al. (2017) noted that innovation allows the code users to explore new areas and develop solutions that could be mainstreamed in practice. Although these newly developed methods may need additional verification process to demonstrate compliance and it is entirely dependent on the approval of the building officers.

Accordingly, innovation in performance-based building code offered varieties of opportunities that can be used to achieve compliance. In the New Zealand context, these compliance pathways are evident in the alternative solution and verification method. Further, this compliance pathway solved the problem of the analytical method to some extent (Greenwood, 2007), while some work needs to be done to improve the innovative process (Armstrong et al., 2017). Validating the innovation techniques used in the building sector before acceptability of such method is essential to minimise the impact of unintended consequences of innovation (Humpreys, 1985). Therefore, this crucial process does not impede the use of innovative ideas in design, construction, new materials, methods and product (Wright, 1983), instead, it ensures that innovative practices that could protect the built environment are reasonably implemented.

Many in the building industry believed that innovation saves cost and promote productivity in the building sector (ABCB, 2016; Armstrong et al., 2017; CIE, 2002; Meacham, 2010a). The cost could be as a result of providing smart solutions that overcome the barriers set by prescriptive building code. On the contrary, some think that innovative contributed to the rising cost with an increase in design cost, construction and in return increased the housing cost (Eric Baczuk, 2016; Listokin & Hattis, 2005). Moreover, there is always cost attached in verifying innovative solutions to demonstrate compliance, especially in a small market environment such as New Zealand (Dermott McMeel & Kevin Sweet, 2016; Duncan, 2002). Although, the innovative solutions in performance-based building code promote global trade among member nations that use performance-based regulations (Meacham, 2009; NCC, 2015).

### **3 UNINTENDED CONSEQUENCES OF INNOVATION**

The innovative approach embeds in performance-based building code is not without some unforeseen challenges that could hinder the full implementation of innovation in performance-based building code. However, many are in the illusion that the introduction of innovation in the building sector would solve all the existing lapses in the prescriptive regulation (Meacham, 2010a; Paul Everall, 2003).

Transiting from prescriptive to performance regulation could require additional professional skills, especially when it comes to interpreting and verifying innovative solutions. Conversely, some of the building code

users lack the essential knowledge and professional skills needed to implement innovative methods and solutions in practice (Coglianese, Nash, & Olmstead, 2003; Nilson & Olson, 1981; SBCCI, 1992). Hence, building officials are placed under pressure to determine whether innovative solutions are adequate or acceptable (Duncan, 2005). The pressure on both the regulated and regulators to prove that innovative solutions meet the performance specifications could lead to a diverse interpretation of performance criteria (Dermott McMeel & Kevin Sweet, 2016; Meacham, 2010a). Furthermore, where the building officials are not knowledgeable about the proposing innovation, it may cause time and money (Duncan, 2005; Meacham, 2010a), thereby making innovation disadvantaged.

Performance-based building code comes with a flexibility clause that allows building code users to implement innovative solutions (Becker, 2008; Coglianese et al., 2003; Duncan, 2005; May, 2003). However, when this flexibility is not adequately regulated with an emphasis on accountability and liability, could cause unintended catastrophic situations such as weather tightness experienced in the New Zealand and other similar cases in the United States, Canada and the United Kingdom (Hunn, Bond, & Kernohan, 2002; Meacham, Bowen, Traw, & Moore, 2005; Meeks & Brannigan, 1996; Mumford, 2010).

The primary aim of building code is to promote the property, health and safety of the public; however, it seems challenging to assess the point where the introduction of an innovative clause in performance-based regulation crosses the line with safety. Meacham (2010a) noted that health and safety performance is lacking in some building designed with innovative methods. Further, Meacham (2009) acknowledged that there exist deficiencies building safety, while (Babrauskas, 2000) pointed out that the drop in safety level is the consequences of transiting to performance. The deficiency also could be as a result of parallel interpretations to performance criteria.

#### **4 INNOVATION IN BUILDING CODE AND THE WAY FORWARD**

Innovation in building code brings flexibility (Armstrong et al., 2017; Bowen & Thomas, 1997; May, 2003; MBIE, 2016), allows new technologies and encourages solutions that would not have been possible with conventional building regulation (Duncan, 2002; Maugard, Duffaure-Gallois, & Rubinstein, 1998; Meacham, 2010a). However, some unintended consequences and barriers limit the potentials that come with innovative solutions. The way forward for innovation in performance-based regulation requires the elimination of these limitations.

Extensive training of the building code users and the regulators of building control system are essential (Duncan, 2000; Meacham, 2010a), as innovative solutions are still developing in the building industry (Meacham, 2010a). Accordingly, both the building code users and the regulators need a high level of competence and training, as innovative methods may be complex with regards to the technical requirements and assumptions (Cooke, 1979; Dermott McMeel & Kevin Sweet, 2016; Gann, Wang, & Hawkins, 1998; Martin sexton & barrett, 2005; Meacham, 2010a). Also, an engaging consultation between the regulators and the regulated in the building industry are essential for a successful application of innovation solution in performance-based building code (Raman, 1997). Hence, training would educate the building code users on how to apply innovative solutions in design, construction, compliance and other related issues. Further, the training will equip the building officials on the best practice to assess performance criteria for innovative methods in accordance with the building code requirements.

Duncan (2005) acknowledged that innovative methods should be subject to customers satisfaction and societal expectations. However, these innovations have to be balanced with safety in other to achieve a resilient built environment. Balancing between safety and innovation ensures that innovative solutions are well guided to minimise any possible errors. It is inevitable to achieve a balanced, innovative solution with safety, without the required regulatory system. Hence, there is no need to apply innovative methods when the

regulatory system and the regulators are not in support of it (Duncan, 2000). However, the regulatory system could be amended to accommodate the use of an innovative solution where safety can be prioritised.

In delivering the kind of built environment anticipated by the relevant stakeholders in meeting the societal expectation using an innovative solution, well-defined regulations that are implementable is needed. In some cases, too rigorous regulations hinder the growth of innovation in the UK and the USA (Eisenberg, Done, & Ishida, 2002; Gann et al., 1998), which led to criticism against regulation (Porter, 1990). To achieve the primary objective of performance-based building code on innovation, the building sector needs an efficient building regulatory system that encourages innovation, while ensuring buildings are safe, healthy and durable (MBIE, 2019). Hence, there is need to have building code requirements that are understandable and can be applied practically by the users.

Complying with the building code requirements when using innovative methods could be challenging. Hence, there is a need for the third party to independently cross-check designs, construction and products before certification (Meacham, 2010a). The review process would ensure that competence, quality and performance criteria's are raised to maintain safety in the built environment while encouraging innovation. The independent reviewers will be professionals who are certified by the appropriate entities with the aim of reducing any risk of errors (Meacham, 2010a), especially in the design of complex structures (Cooke, 1979). Developing a robust verification method and alternative solution that can accommodate more innovative solutions including complex designs and constructions methods would encourage the building code users to use innovative ideas and boost the knowledge of the regulators in approving such designs.

## **5 BARRIERS TO INNOVATION IN THE BUILDING INDUSTRY**

Building with innovative methods is crucial in the construction industry, especially as the globe is fast advancing with technological ideas. The application of these innovative method determines to what extent it would be successful if enabling environment is provided with adequate facilities. Hence, eliminating the barriers that limit the innovative potentials could increase the success rate of innovation embed in performance-based building code. Furthermore, these barriers to innovation in the building industry could be as a result of unexpected changes attributed to the innovative approach.

Accordingly, the lack of preparedness to take care of unexpected changes that might come with innovation could amplify the barriers to innovation (Armstrong et al., 2017). In the context of New Zealand, Meacham (2010a) reported that innovation was introduced into the system without effective supervision that later led to poor designs, construction and construction materials and products that are not up to the required performance level, as stipulated in the building code. The inadequate supervision may be because of less experienced professionals in innovative practices relating to the design and construction method. Also, due to difficulties in verifying innovative designs, it has primarily been pinned to the expert's interpretation (B. J. Meacham, 2010b), which led to having a different interpretation on one subject (Duncan, 2005; Lundin, 2006; Meacham Brian, 2008). Multiple interpretations could exist where the building code requirements and regulations may be rigorous, as innovative solutions are still undergoing development. Accordingly, The implementation of innovative technologies is usually faced with lack of policy to back its usability, lack of appropriate design guidelines, and absence of evidence-based performance of the innovative approach to convince relevant stakeholders (Uma et al., 2013). Rogers (1995) described the attributes that surrounds innovative techniques as complexity, compatibility, relative advantage, observability and trailability.

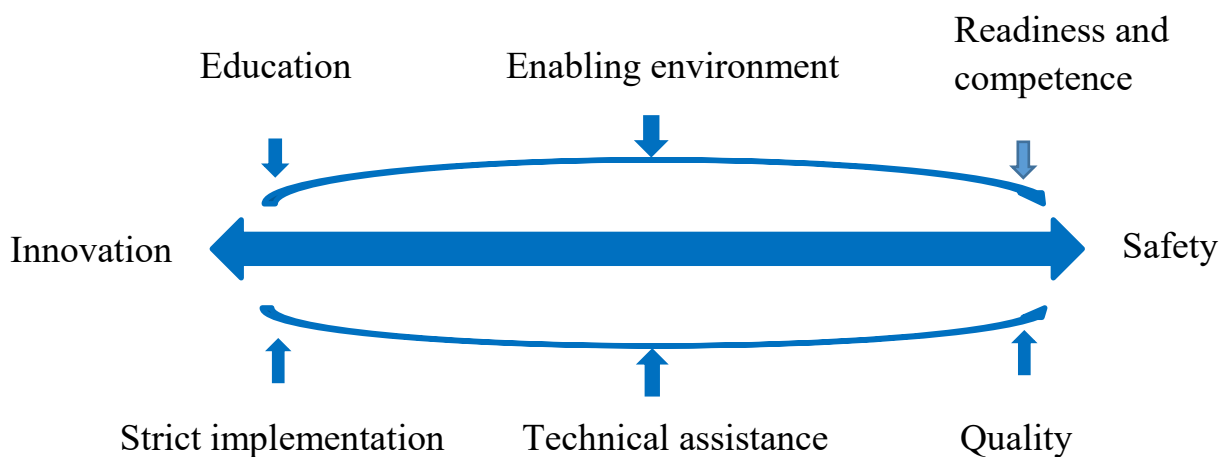
In some cases, the building requirements are not clearly defined to show the performance criteria (Saunders et al., 2012), which may lead the building code users to make some technical assumptions that are not fact-based (Gann et al., 1998). However, regulations in the building industry could improve innovative methods when rightfully applied. Hence, building requirements and regulations should be used to assist in improving and promoting the use of innovative methods rather than hampering the development (Duncan, 2000).

Many building code users still operate with prescriptive mindset while using performance-based building code, while some building officials also use prescriptive regulation mindset in assessing innovative building solutions (Armstrong et al., 2017; Duncan, 2005; Meacham, 2010a). The use of mindset that is not measurable to the performance-based building code may discourage the use of innovative solutions. However, the prescriptive mindset could be eliminated through training, adequate preparations and awareness among the regulated and the regulators.

## 6 INNOVATION AND SAFETY IN THE BUILDING CODE

Performance-based building code created an innovative approach in building code practice. There are concerns that some buildings constructed with performance-based code are lacking health and safety measures (Meacham, 2010a). Following an example of the leaky building report in New Zealand (Hunn et al., 2002), which showcased the need to balance innovation and safety becomes necessary to reduce the challenging impacts associated with innovation in the use of performance-based building code. The issue can be addressed by considering how the innovative clause in performance-based building code is applied both in design and construction with regards to the safety of the occupants and the building.

Balancing innovation and safety clause creates greater productivity and efficiency in the building regulatory system. However, the concept of balancing innovation with safety requires an approach that is understandable by all, procedural and user-friendly centred. This is essential as the performance-based code only specifies the functional and performance requirements for building constructions and other related works. In Figure 1, the factors that contribute to balance innovative methods and safety is illustrated.



*Figure 1: Balancing innovation and safety in the building industry.*

Safety clause in building regulatory system may always be affected whenever innovation concept in performance-based code is applied without adequate information and training of the users. This is evident in the case of the leaky building saga in New Zealand, as the new system of performance-based building code was not fully understood both by the users and the regulatory team (Duncan, 2005). MBIE (2018) noted the deficiency in knowledge and training gap in the building code system of the country. Hence, recommendations following the incidence were majorly centred on having proactive training and awareness sensitisation at all level (Duncan, 2005; Meacham, 2010a). Apart from educating code users, providing adequate technical assistance helps the code users to apply caution while receiving external help on fulfilling the code requirements. However, without such provision, balancing the technological advancement under performance-based building code against safety precautions may be problematic.

It is important to recognise the place of providing sustainable policy and creating an enabling environment that would guide the use of innovative methods under performance-based building code. The policies should be interpretative, functional and enforceable within the building control system. This approach will encourage strict implementation, which could help in minimising the impact innovation may have on safety. Similarly, regulating innovation to improve safety measures demand quality construction materials and products. Considerably, innovation may have unintentionally affected safety requirements stipulated in the building code regulations; however, innovation has improved the performance of the building regulatory system.

## 7 CONCLUSION

The benefits and unintentional impacts of innovative concepts embedded in performance-based building code are critically analysed to improve safety and building performance throughout the building life cycle. The study reviewed the need for technical guidelines, proactive training and innovation impact analysis to enhance building performance in the built environment. Innovation under performance-based building code may have affected the safety precautions unintentionally as a result of the flexibility clause; it has also provided some performance efficiency and encouraged the implementation of new concepts required to drive the building industry. However, the study identified the barriers to innovation as it centred on how to verify the innovative solutions, both designs and construction materials and the fear of liability. Duncan (2000) added that innovative ideas might be limited due to barriers created by some building code regulatory system. To this extent, this study advises that the barriers to innovative approaches, including building policies identified in this study should be eliminated in its fulness.

The study argued that introducing new concepts in the building system requires adequate preparation and enabling interactive environments where the ideas can drive. This may help to reduce challenging situations in the application of innovative methods.

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