Chapter 5
BIM for Sustainable Construction: A Strategic Framework for Handling Challenges of the International Green Construction Code

Wei Wu and Hui Zhou

Abstract The 2012 edition of International Green Construction Code (IgCC) is the first model code dedicated to provide clear and specific requirements with provisions to promote sustainable construction in an integrated fashion within the International Code Council (ICC) family of codes. Unlike voluntary based green building rating systems, e.g. Leadership in Energy and Environmental Design (LEED), the IgCC will be enforced once adopted by local jurisdictions. To deal with the impacts and challenges posed by the IgCC, stakeholders will need a strategic framework. The paper proposed a building information modeling (BIM) leveraged approach. It reviewed the regulatory environment of sustainable design and construction, and successful implementations of BIM in meeting such regulatory requirements. The strategic framework was constructed by: (1) analyzing the structure, contents and enforcement of the IgCC to delineate the typical code compliance workflow; and (2) identifying the critical tasks and desired project submittals for the IgCC compliance, stressing on project information generation, exchange, collection and management facilitated by the evolving project BIM model(s). Detailed IgCC compliance guidelines can then be further developed based on this strategic framework.

Keywords International green construction code • Building information modeling • Compliance workflow • Strategic framework

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5.1 Introduction

Internationally, code officials recognize the need for a modern, up-to-date code governing the impact of buildings and structures on the environment [1]. The promulgation of the 2012 International Green Construction Code (IgCC) lays a solid foundation for the architecture, engineering, construction, owner and operator (AECOO) community to enforce sustainable practices at large. The IgCC is a collaborative effort of the International Code Council (ICC), the American Institute of Architects (AIA), ASTM International, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), U.S. Green Building Council (USGBC) and the Illuminating Engineering Society (IES). As a model code, the IgCC encompasses a comprehensive set of provisions to address natural resources, materials, water and energy conservations, as well as indoor environmental quality and comfort, building commissioning, operation and maintenance for both new and existing buildings. What sets it apart in the world of green building is that it is created with the intent to be administered by code officials and adopted by governmental units at any level as a tool to drive green building beyond the market segment that has been transformed by voluntary rating systems [1].

Implementation of the IgCC is compatible with other applicable ICC building codes. But it does not prevent the use of any material, method of design, construction, system or innovative approach. In contrast, the provisions and enforcement of the IgCC are subject to the context of local jurisdictions, which affords them flexibility to meet their unique environmental and regional needs and goals. A tradeoff is that there will be no universal template for code compliance: jurisdictions, code officials, and project stakeholders have to work together to determine a realistic scenario in the IgCC adoption and enforcement. This research intends to investigate the possible leverage provided by recent development of building information modeling (BIM) in facilitating compliance with the IgCC. Base on established literature of BIM integration in sustainable design and construction, it is anticipated that jurisdictions, code officials, owners and project teams can all benefit from the BIM-centric approach. The goal of this research is to create a strategic framework of facilitating the compliance with the IgCC upon an information-rich and green construction oriented BIM platform. Detailed IgCC compliance guidelines can then be further developed based on this strategic framework.

5.2 Background

5.2.1 Regulatory Development of Sustainable Design and Construction

As of today, sustainable design and construction has developed from a specialty of a handful forward-thinking designers and constructors in the early 1990s into a gradually mainstreaming practice. This market transformation is partially attributed to increased awareness of anthropogenic impacts on the natural environment, while a major driver of the transition stems from commitments of policy makers and regulatory bodies, and eventually the advent of green building regulations. For instance, the USGBC's Leadership in Energy and Environmental Design (LEED) certification and similar programs (e.g. Green Globes by Green Building Initiative), which are voluntary in most jurisdictions, have elevated the level of design for many building types across the country. Often perceived as a de facto code, LEED has been adopted by many local jurisdictions and even federal agencies as a comprehensive green standard [2]. ICC has also been publishing the International Energy Conservation Code (IECC) since 2000, which have already been adopted in many jurisdictions. Newer and greener industrial standards have been taking on a comparable momentum. The ICC 700 National Green Building Standard [3] and the ANSI/ASHRAE/USGBC/IES Standard 189.1 [4] were milestones of these initiatives. In 2011, the first set of official mandatory sustainable design measures, named CALGreen was instated in California. Nevertheless, movement toward a model green code has been long in the making, for the sake of the following three major reasons:

- The increased importance of sustainable design and construction and the acceptance of sustainability in the mainstream of the AECOO industry.
- The imperative need to translate green aspirations into enforceable regulations.
- The need for consistency across jurisdictions to allow robust and well-informed decision-making in adopting and enforcing sustainability.

The IgCC addresses all three of these needs. It recognizes the centrality of sustainability in design and construction; it provides readily adoptable and enforceable language; and it allows for greater consistency in both its current application and its evolution. The IgCC is coordinated with the other I-codes, especially the IECC, providing the clarity and consistency of interpretation that all parties seek when designing, constructing, and inspecting a building (Fig. 5.1, [2]).

5.2.2 BIM for Sustainable Design and Construction

The integration of BIM in sustainable design and construction is witnessed along with the continuous improvement of software applications and enrichment of industry best practices. As Krygiel and Nies [5] pointed out, BIM could aid in the following aspects of sustainable design:

- Building orientation (to select the best building orientation that results in minimum energy costs)
- Building massing (to analyze building form and optimize the building envelope)
- Daylighting analysis
- Water harvesting (to reduce water needs in a building)

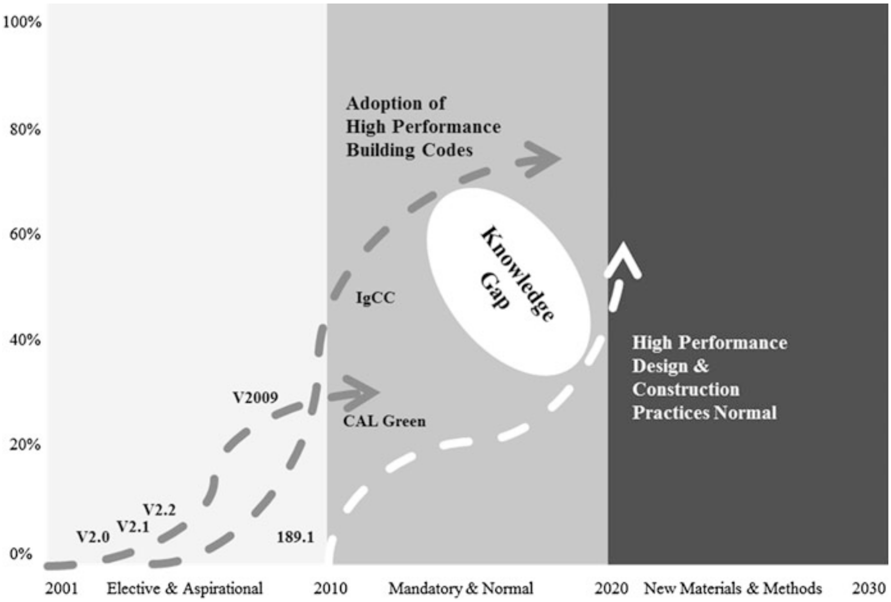

Fig. 5.1 U.S. overview – path of regulatory development in sustainable design and construction [2]

- Energy modeling (to reduce energy needs and analyze renewable energy options such as solar energy)
- Sustainable materials (to reduce material needs and to use recycled materials)

Energy performance is a major focus of green building design and construction. Policy mandates are driving increased stringency in energy codes (e.g. IECC) and standards (e.g. ASHRAE 90.1 and 189.1). Computerized simulation tools have long been utilized to configure and predict building energy performances. Traditionally, this is a laborious and expensive process. Major obstacles include the redundant input of parameters (e.g. geometry, materials and climate data) needed for the simulation from a design model into a simulation model, and the complexity of the simulation algorithm. Built upon parametric modeling principles, BIM offers designers an integrated and robust user interface, and an underlying database that captures standardized, structured building lifecycle information. Simulation results thus become more comprehensive, valid and accurate [6]. The easy linkage of BIM with Geographical Information System (GIS) empowers designers with regional specific climate information and realistic utility rates, producing meaningful energy consumption and cost scenarios according to owner’s preferences. Perceived benefits like these have engendered strong uptake and implementation of BIM in green projects – noticeably the LEED projects as reported by McGraw-Hill Construction [7, 8]. Software vendors have recognized the unique business opportunities brought by the rapid engagement of BIM in the green building market

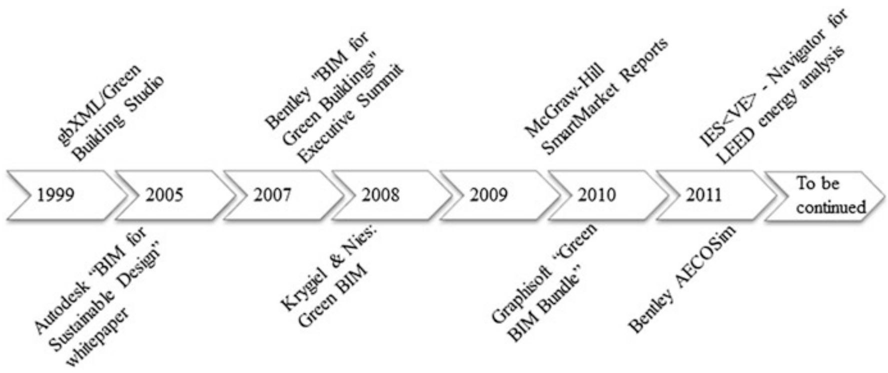

Fig. 5.2 A chronicle of BIM integration in sustainable design and construction [18]

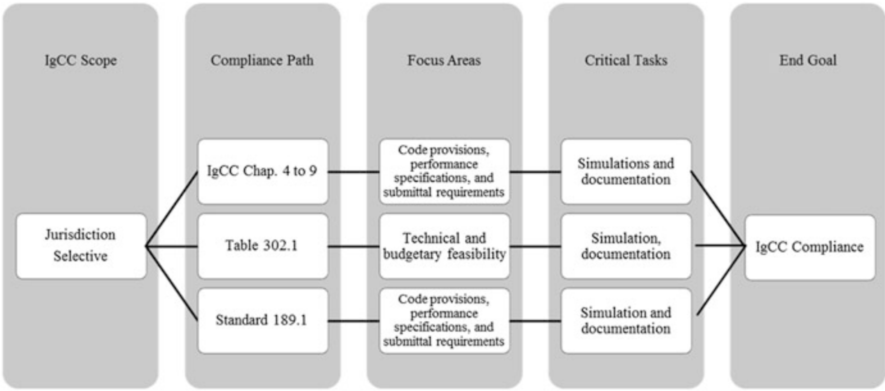

Fig. 5.3 The IgCC compliance workflow

transformation. Specialized software packages and enhancement in the forms of add-ons and plug-ins tailored for sustainability are proliferating. Fig. 5.2 illustrates a snapshot of this chronic development of the synergies between BIM and sustainable design and construction.

5.2.3 *BIM and Code Compliance*

When designers create a building information model in conformity with the code provisions, this highly dictated and rule-based BIM is likely to be utilized for code-compliance checking purpose. As Raslan and Davies [9] conjectured, BIM might become important digital assets that are not only key instruments in communicating design but also in obtaining approval from statutory bodies. The traditional manual checking of building designs for compliance against building codes was complex

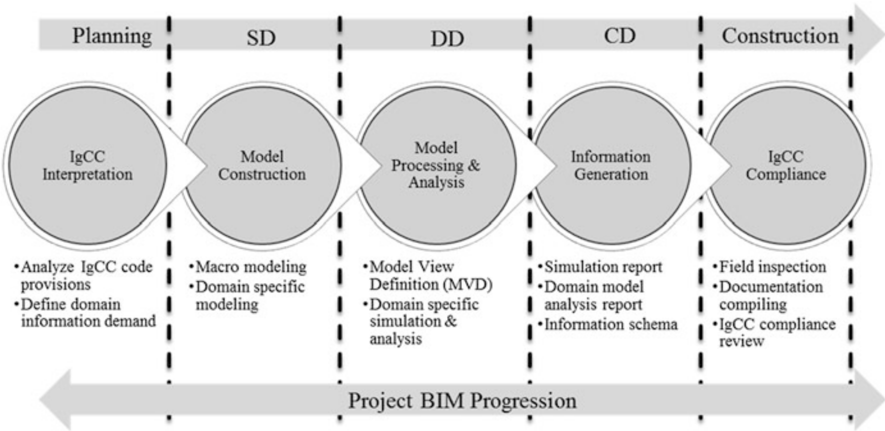

Fig. 5.4 The IgCC compliance – a BIM facilitated strategic framework

and prone to human error with significant cost implications [10]. Tan et al. [11] claimed that automated compliance checking would not only prove beneficial to designers but to also building certifiers, consultants, building code authorities, specification writers and builders.

Approaches to developing automated building code-checking have been reported in the literature for the last two decades [12]. The Construction and Real Estate NETwork (CORENET) was one of the first initiatives in automated code-checking, funded by the Singapore Ministry of National Development and carried out by the Construction and Real Estate Network since 1995 [13]. CORENET was later on emulated in Norway with the ByggSok system [14]. Driven by the Norwegian Building and Construction industry and supported by Standards Norway and Norwegian buildingSMART, the ByggSok system was heavily based on the industry foundation class (IFC) standard – an open standard of interoperability for information exchange across BIM software packages. In Australia, both the Solibri Model Checker (SMC) and Express Data Manager (EDM) were considered as possible platforms for automated code checking [15]. In the U.S., similar work on code-checking began in the United States around 2000, and a major driver of BIM and validation of BIM models is the U.S. General Services Administration (GSA). SmartCodes is another key project driven by the ICC, in conjunction with AEC3 and Digital Alchemy. This project has focused largely on addressing the problem of transforming paper-based codes into machine-interpretable rules. The rules can currently be executed using either Solibri Model Checker, or AEC3 XABIO [10]. The SmartCodes project does not support building code specific information that is not currently implemented by BIM vendors [12]. Most recently, in 2010, Fiatech launched the AutoCodes project with the objective of developing both the optimal methodology and the consistent guidelines necessary to transform the regulatory process, via applying the technology to enable automated code checking of BIM models. As of 2012, Phase 1 of the AutoCodes project focused on the

Accessibility and Egress (A&E) provisions of the ICC International Building Code Version 2009 [16].

It should be noted that BIM is a much bigger concept than conventional 3D CAD. Other than the pure representation of building geometries, BIM literally captures all the information of a building over its lifecycle in a standardized and structured manner. Based on specific query request, a unique set of information, or in a more technical term, a Model View (MV) could be isolated and extracted from BIM. When applied in code compliance, ideally each code provision might find a corresponding group of property sets in the BIM model representing the information need to validate the compliance. Truly automated code-checking is yet in development, but even in today's coexistence of manual and semi-automated code checking process, information harvested from the BIM model has proved to be valuable in facilitating consistent and accurate regulatory review.

5.3 Methodology

An overview of the IgCC structure was conducted. The general code compliance workflow was illustrated, highlighting the focus areas, critical tasks that project stakeholders ought to accomplish, and the expected outcomes. This strategic code compliance plan was emulated from the Compliance Planning Assistance (CPA) program directed by the Building Codes Assistance Project (BCAP) and the Texas State Energy Conservation Office (SECO) in their efforts to achieve 90 % energy code compliance with the 2009 International Energy Conservation Code (IECC) by 2017 [17]. In each phase of this code-compliance workflow, the possible leverage of the project BIM model(s) was outlined and discussed. Finally, the strategic framework for the IgCC compliance was established, followed by conclusions and general discussions.

5.4 Results and Analysis

5.4.1 IgCC Overview

Overview of the IgCC focused on the following aspects: (1) the scope; (2) the contents and (3) the compliance paths. IgCC applies to all occupancy-types except low-rise residential buildings under the International Residential Code. It is not applicable to equipment or systems used primarily for industrial or manufacturing purposes either (Chap. 1). The major code provisions were delineated in Chap. 4 through Chap. 11. Chapter 2 clarifies the key definitions. Chapter 3 is the core of the IgCC. It is formatted to facilitate the customization of this code to address local issues; provide options for construction which exceed the minimum requirements of this code; and provide for the implementation of best practice. Chapter 3 also suggests the overall compliance paths. Stakeholders should pay attention to the following facts:

- IgCC is a model code: it is not mandatory or enforceable until a jurisdiction elects to adopt it in that particular area
- IgCC is an adaptable code: a jurisdiction can opt to adopt part or all of the code, or even add customized amendments to it
- IgCC is an overlay code: IgCC is built upon the ICC code families (e.g. IBC, IRC, IECC) and cannot serve as a standalone code

Extra care is needed to understand the two important selectives: jurisdiction selective and the project selective. Jurisdiction selective refers to flexibility for the jurisdictions to define the scope of the IgCC to be adopted locally. The project elective refers the specific compliance path undertaken by the project team. It is important to know that an exception to Section 101.3 of the IgCC allows ASHRAE 189.1 Standard for the Design of High Performance Green Buildings, to be used to comply with the IgCC. For project teams that look for extra challenges, they may also consider Table 302.1 of the IgCC to pursue exemplary performance in sustainable design and construction. Chapter 12 and Appendix A-D provide supplementary information of the code.

5.4.2 IgCC Compliance Workflow

To elaborating the IgCC compliance workflow, this research focuses on new construction projects only, which filters out the provisions in Chaps. 10 and 11 of the IgCC. Once the local jurisdiction has established the general scope of the IgCC that is applicable to this particular area, project teams need to think about the project selective, whether they should opt to use Standard 189.1, or does the owner requires the inclusion of Table 302.1. This should happen as early in the process as possible. Ideally, a kick-off charrette should take place to involve as many project stakeholders (e.g. owner, architects, consultants, general contractors, commissioning agent, MEP contractors) as possible, to clearly define Owner's Project Requirements (OPR), and ensure the understanding of the Basis of Design (BOD) and the sustainable criteria incorporated into this project. Code officials may also be invited to clear off confusions on particular code provisions. Critical tasks in each phase of the project, especially during design, construction and inspection, need to be identified and allocated. Documentation and submittals for each set of code provisions should be proactively planned and closely managed through the project delivery. Communication and collaboration between project stakeholders should be facilitated and appreciated. Figure 9.3 summarizes the generic compliance workflow for the IgCC.

5.4.3 *BIM Facilitated Strategic Framework for the IgCC Compliance*

Leverage of BIM in the IgCC compliance workflow stems from the fact that BIM plays dual roles in a project delivery process: the information reservoir and the communication portal. As of today, most BIM software (authoring and analyzing) have been programmed to conduct sophisticated design, allow real-time responsive design option analysis, perform rigorous building simulations, and streamline extensive project information management. Interoperability standards make it also possible for stakeholders using different specialized software packages to exchange domain-specific information. Usually, a set of organically interrelated BIM models will be produced for a project, instead of a single colossal model. These distributed and specialized BIM models often fulfill a dedicated task in the project delivery, for instances, energy simulation model, water analysis model, daylighting model, quantity takeoff (QTO) model, and to name a few. The advantage of this methodology is that it significantly reduced the size of the model being handled by different discipline thus greatly increased the productivity of the job allocated to these individuals.

When a project is targeting the IgCC compliance, it is feasible for the project team to break down the compliance workflow discussed previously into critical tasks. Through a certain categorization and/or grouping, these critical tasks could be accomplished through constructing these distributed yet interrelated BIM models. These sub-models, usually called the Model Views (MVs) of the final, confederated BIM, are the key in developing automated code compliance. Besides, documentation generation has been a standardized functionality of most BIM software applications. The trick is to determine which piece of information in what form and format (schema) should be extracted. This constitutes the other critical challenge of automating code checking using BIM. Figure 9.4 illustrated the BIM facilitated strategic framework for the IgCC compliance.

5.5 Conclusions

This paper discussed the possible challenges for stakeholders in the AECOO industry to meet the compliance of the newly released IgCC. As the first international green model code, the IgCC provided an integral and consistent regulatory environment for sustainable design and construction practices. The structure, contents and enforcement of the IgCC were reviewed. A strategic framework of directing the stakeholders in the IgCC compliance workflow was created via the leverage of BIM. The key of this framework was the information generation, exchange, collection and management. The foundation to this framework was an integral project information reservoir and a robust collaboration portal enabled by BIM. Detailed IgCC compliance guidelines could be further developed based on this strategic framework in future research.

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