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Support Form-based Codes with Building Information Modeling – The Parametric Urban Model Case Study

:abstract

This study aims to develop the parametric urban model to support Form-based Codes (FBCs) by using Object-Oriented Parametric Modeling (OOPM) and Building Information Modeling (BIM). FBCs have been used to substitute conventional land-use and zoning regulations in the United States. In many cities, FBCs were implemented successfully, but excessive design constraints, difficult code making process, and missing density of FBCs are criticized. As a response to the increasing needs of parametric modeling approaches in the urban design domain, we applied BIM and OOPM techniques in two case studies. We conclude that BIM and OOPM have a great potential to support planning and design processes, and that the parametric urban model allows FBCs to be more flexible, interpretable, and interoperable.

1 Introduction

Zoning has a history of changing over time with little concern on building compatibility in the context of the United States *(Duany 2000)*. After New York City enacted the first modern comprehensive zoning ordinance, the primary pattern of land development in the United States has been suburban sprawl based on single detached houses, suburban shopping malls, and big-box stores *(Ben-Joseph 2005)*. Many scholars argue that this dominant development pattern in the U.S. may be inadequate to cope with dwindling resources and the increasing needs of sustainability *(Forsyth 2003; Hascic 2006; McLaughlin 2009)*. For these reasons, planning and zoning in the U.S. are needed to assist the transition from sprawling land developments to more compact developments.

Many studies have proven that conventional text-based regulations are inappropriate for implementation of mixed-use developments *(Ben-Joseph 2005; Parolek et al. 2008; Shane 2005; Slone 2008; Talen 2009)*. After Duany Plater-Zyberk & Company (DPZ) created Form-based Codes (FBCs) for Seaside, Florida, FBCs have been used to substitute conventional regulations. In many cities, FBCs have proven to prescribe urban form, to implement mixed-use developments, and to address place-based characteristics of sites *(Ben-Joseph 2005; Parolek et al. 2008)*.

On the other hand, Building Information Modeling (BIM) is a new approach that ties all the building components together, imbedded with information (Eastman 2008). Through shared databases and visual resources, BIM enables various sectors to communicate design intentions and coordinate construction processes. Object-Oriented Parametric Modeling (OOPM) in BIM allows users to manipulate various parameters of project models repeatedly *(Eastman 2008; Sacks et al. 2004)*.

BIM and OOPM have a great potential to support the FBCs implementation, since BIM and OOPM allows planners and citizens to test a set of scenarios with parametric techniques, predict building and block geometries with illustrations, and communicate with each other by using shared databases *(Eastman 2008; Sacks et al. 2004)*.

This study aims to develop the parametric urban model using BIM to support FBCs. Current FBCs are expected to accomplish more flexibility by changing regulation terms freely. Clear interpretation of FBCs will be achieved with graphics created by the parametric urban model. In addition, interoperability of FBCs will also be improved by sharing databases imbedded in the parametric urban model.

2 Code Reform Movements and FBCs

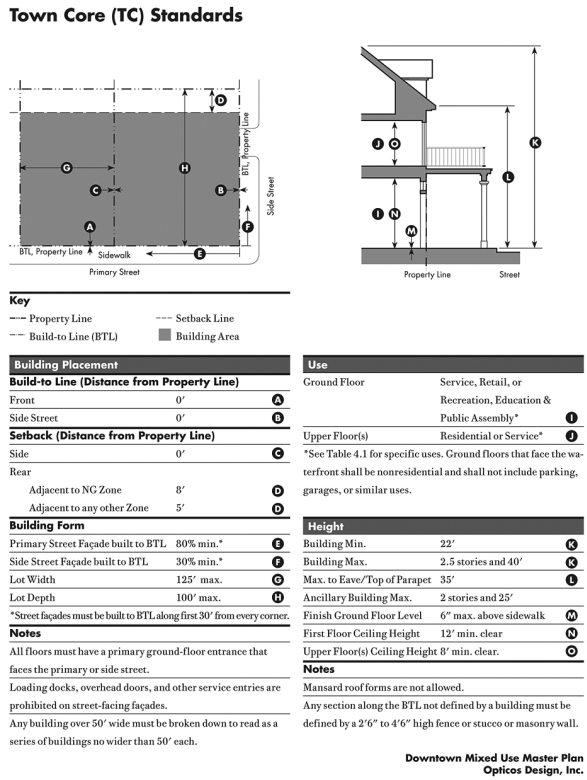
As a response to criticism on conventional zoning regulations, Duany Plater-Zyberk & Company (DPZ) created FBCs for Seaside, Florida, and FBCs are becoming increasingly popular in many communities to substitute conventional regulations. FBCs have proven to prescribe urban form, implement mixed-use developments, and address place-based characteristics of sites *(Ben-Joseph 2005; Parolek et al. 2008)*.

FBCs are not a text-based regulation; many visual resources and graphics are provided to prescribe an urban form, such as building location and volume. FBCs address the relationship between building facades and the public realm, the form and mass of buildings in relation to one another, as well as the scale and types of streets and blocks. The general components of FBCs are: (1) regulating plans, (2) public space standards, (3) building form standards, (4) administration, and (5) definitions *(Parolek et al. 2008)*. Regulating plans designate the appropriate form and scale of developments rather than only distinctions in land-use types. In regulating plans, each property is ruled by transect codes (Figure 1), which show actual development requirements such as building location, set back lines, or allowable building heights. Regulating plans are the most significant component, so most FBCs include them.

2.1 Challenges of FBCs

The main challenge of FBCs is the lack of experienced planners to produce many illustrations in local governments, while many illustrations and graphical standards are required. Currently, there are only a handful of experts that are well-versed in drafting sophisticated FBCs; therefore, additional trial and error are expected. Another limitation of FBCs is the lack of design flexibility, particularly relating to building form standards. Due to the local opposition to excessive details of building design, many FBCs omitted building form standards in their codes.

Furthermore, ignoring density in FBCs is criticized by many sectors. FBCs do not intend to deal with density



Town Core (TC) Standards

Key
Property Line — Setback Line
Build-to Line (BTL) — Building Area

Building Placement		
Build-to Line (Distance from Property Line)		
Front	0′	A
Side Street	0′	B
Setback (Distance from Property Line)		
Side	0′	C
Rear		
Adjacent to NG Zone	8′	D
Adjacent to any other Zone	5′	D
Building Form		
Primary Street Façade built to BTL	80% min.*	E
Side Street Façade built to BTL	30% min.*	F
Lot Width	125′ max.	G
Lot Depth	100′ max.	H

*Street façades must be built to BTL along first 30′ from every corner.

Notes

All floors must have a primary ground-floor entrance that faces the primary or side street.

Loading docks, overhead doors, and other service entries are prohibited on street-facing façades.

Any building over 50′ wide must be broken down to read as a series of buildings no wider than 50′ each.

Use		
Ground Floor	Service, Retail, or Recreation, Education & Public Assembly*	I
Upper Floor(s)	Residential or Service*	J

*See Table 4.1 for specific uses. Ground floors that face the waterfront shall be nonresidential and shall not include parking, garages, or similar uses.

Height		
Building Min.	22′	K
Building Max.	2.5 stories and 40′	K
Max. to Eave/Top of Parapet	35′	L
Ancillary Building Max.	2 stories and 25′	
Finish Ground Floor Level	6″ max. above sidewalk	M
First Floor Ceiling Height	12′ min. clear	N
Upper Floor(s) Ceiling Height	8′ min. clear.	O

Notes

Mansard roof forms are not allowed.

Any section along the BTL not defined by a building must be defined by a 2′6″ to 4′6″ high fence or stucco or masonry wall.

Downtown Mixed Use Master Plan
Opticos Design, Inc.

Figure 1. The transect zone standards. (Source: City of Benicia Form-based Codes, 2007) Note: FBCs use several transect zones from rural to urban center zone. Each transect zone defines requirements with drawing instances and tables.

Figure 2. Parametric Urbanism of Kartal-Pendik Masterplan. (Source: Schumacher 2008)

as a regulating tool and Floor Area Ratio (FAR) is also omitted (Parolek et al. 2008). Ignoring density is problematic for several reasons. Density has been used as an indicator to manage future demand and supply of environmental resources. For private sectors such as property owners or developers, FAR or density are useful indicators to expect the property value and development capacities. FBCs aim to improve the predictability of conventional zoning, but they do not allow users to know exact density.

3 The Need of BIM for FBCs

3.1 Parametric Modeling for FBCs

The needs of parametric modeling techniques in urban design have been discussed by some scholars and professionals. While the Architecture, Engineering, and Construction (AEC) industry has been revolutionized by BIM and OOPM, few urban planners, urban designers, and landscape designers have attempted to utilize the parametric technology.

Meanwhile, Parametric Urbanism takes the idea of using parametric modeling techniques in the domain of urban design *(Schumacher 2008).* After two architects, Zaha Hadid and Patrik Schumacher, introduced Parametric Urbanism for the Thames Gateway project, they have tried a series of new digital design techniques for Parametric Urbanism. In Kartal-Pendik Masterplan of 2006 (Figure 2), they manipulated parameters of buildings and blocks to present multiple combinations of the different development options. They explained that a parametric approach to urban design allows designers to condense complex data into solutions that exhibit highly differentiated urban patterns.

Beside theoretical approaches, many urban design supportive tools have been developed. For instance, CityCAD *(Holistic City 2010)* is a standalone urban design tool using parametric techniques. It focuses on the preliminary stages of land development planning instead of visualization of regulations. Modelur (URBS 2010) is a plug-in for Google SketchUp *(Google 2010)*. It controls urban design values such as buildable area, FAR, and building use. However, few applications have tried to utilize parametric modeling technologies to visualize land-use and zoning regulations.

BIM and OOPM have a potential for planners to reduce the time to redraw illustrations after they change FBCs requirements. Since many graphics are included in FBCs, FBCs take relatively more time to be created compared to text-based conventional regulations. In addition, because drawings represent many numeric regulations, like road width and building height, when any regulation values change, many illustrations need to be recreated. For instance, if citizens and planners conclude that the front setback should increase from 2ft to 4ft in the design charrette, road sections, building form sections, and public space sections need to be changed again. BIM and OOPM enable planners to avoid spending time to redraw illustrations again.

Figure 3. An urban design plan.

Figure 4. A GIS map.
(Source: City of Dallas)

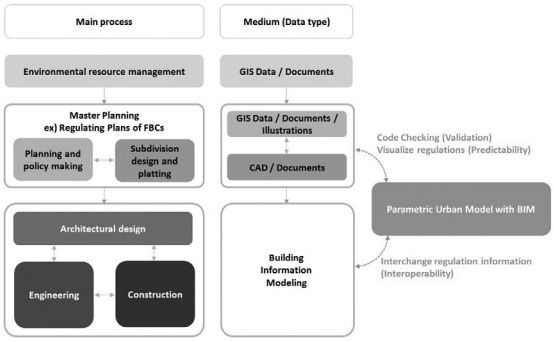


Figure 5. The conceptual model of the parametric urban model

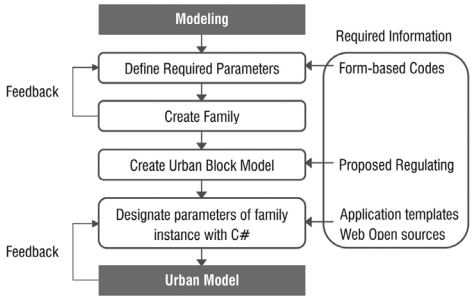


Figure 6. The development process of the urban model.

Using BIM and OOPM, FBCs will allow planners and citizens to have more opportunities to try various regulation scenarios easily.

3.2 The Data Sharing Platform for FBCs

Because FBCs are concerned with creating the physical environment, planners and urban designers need to understand the complexity of urban form and its function; therefore, considerable information is collected from various disciplines such as geospatial data, land-use, planning regulations, engineering standards, market preference data, and public opinions. They have different formats or different mediums, so data exchange between different data types impede an efficient work flow of FBCs implementation.

The difficulty of regulation interpretation and the inaccuracy of the data converting process have been discussed in urban planning and urban design. For instance, GIS data and land-use regulations are fundamental datasets for planners, subdivision designers, urban designers, and architects. They need to make their effort to interpret text-based regulations, and to convert GIS maps to CAD file formats.

Unfortunately, many GIS data, such as parcel, road, and building footprint, may not be directly used in the urban design process due to the inaccuracy. Figure 3 shows an urban design project created by cad systems. To use GIS data in this project, exporting skills and calibrating process were required because many blocks, parcels, building footprints, and roads lines were intersected or overlapped with each other (Figure 4).

Note: The urban design plan (Figure3) was created based on the GIS data (Figure 4) after inaccurate data and errors of GIS data were revised.

3.3 Web-based Codes for FBCs

As the participatory planning becomes a significant step in FBCs making process, web-based codes are regarded as a next format of FBCs *(Parolek et al. 2008)*. Web interface allows people to access regulation information in multiple ways so that many citizens can participate in their community planning. For instance, any citizen can participate in the design and planning charrette from long distance with their computer. Designers can save the project information on the FBCs webpage, and the site provides the code relevant to the project. Property owners can enter their property address and the site can provide appropriate information. Web-based FBCs can be used as the shared data base by various sectors.

3.4 Support FBCs with BIM

How can the parametric model support FBCs? The parametric urban model will be created to support FBCs to overcome existing limitations by using shared databases and appropriate illustrations. Public sectors will use this tool as FBCs code checking methods to know density and block geometries. Private sectors will use three-dimensional FBCs for a clearer understanding of regulations. Citizens will understand the future growth of their neighborhood through various graphics (Figure 5).

4 The Parametric Urban Model for FBCs: a Case Study

In this chapter, we present two case studies to discuss how to support FBCs with BIM, how to apply parametric modeling technologies for FBCs, and how to create prototype of urban model. The first block model shows the potential of OOPM to control many parametric variables together, which affect buildable volumes and block densities. The second model presents how to manipulate multiple blocks with additional applications.

4.1 Object-Oriented Parametric Modeling

First of all, OOPM is the most significant technique in this study. OOPM is used to manipulate many numeric requirements of FBCs, which enables users to assign parametric value easily. OOPM has numerous benefits in terms of the ability to generate design alternatives and eliminate errors in current practice *(Sacks et al. 2004)*. Today, a number of parametric modeling tools exists, such as ArchiCad *(GRAPHISOFT, 2009)*, MicroStation *(Bentley 2009)*, and Revit *(Autodesk 2010)*. This study uses Revit Architecture 2010 *(Autodesk 2010)*.

4.2 Parametric Variables from FBCs regulations

The first step is to define parametric variables for the urban model. Case studies on FBCs are conducted to define appropriate variables, and application files relevant to this study are studied (Figure 6). This case study includes generic regulation requirements as parametric variables (Table1).

Model Category	Variables
Road	Width
Block	Curve Width, Curve Depth, Curve Corner Radius
Landscape and Pedestrian	Landscape Width, Alley Width, Pedestrian Width
Building Geometry	Width, Depth, Number of Floors

Table 1: Parametric variables.

With selected parametric variables, we create two urban block models (Figure 7-10), which show public space, buildable space, and private open space. As we change parametric values in the Family Types window (Figure 8), some parameters are interacted with each other by the equations. For instance, when landscape and pedestrian width increase, building width and building depth decrease. When block width and depth increase, building width and depth increase. This relationship can be edited again by changing equations in the window.

Figure 7. Street view.

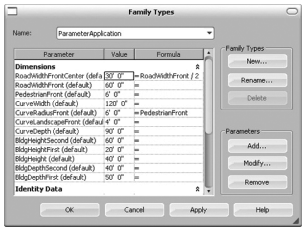


Figure 8. Parametric variables.

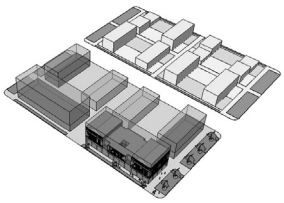


Figure 9.
Block model (low density).

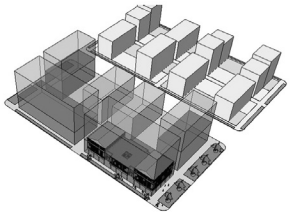


Figure 10.
Block model (high density).

In addition, this model is possible to be used as a code checking system for designers and planners. The building at the corner of the street shows the relationship between allowable volume and the building (Figure 7).

Note: This parametric model can visualize a building design and allowed buildable volume together. Regulation requirements can be manipulated in the parametric urban model to simulate various scenarios.

4.3 Application Programming Interface

The next step is to control parametric variables by using Application Programming Interface (API). Revit Architecture *(Autodesk, 2009)* provides the API environment that supports users to create applications by using computer languages.

This urban block model shows how to control all parametric variables repeatedly. This urban model consists of over twenty blocks, but all blocks are created with one model. To do so, many parametric values, such as directions, block width, block depth, building height, and road width, are designated differently (Figure11-14). To manage all blocks together, an application is created with C# language. This application enables one urban block model to present multiple scenarios with different density and building geometries. The advantage of this application is that whenever we change any parametric values, many regulation options can be visualized.

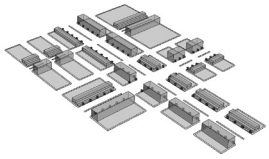


Figure 11.
Bird eye view (Scenario1).

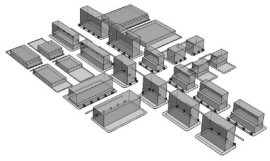


Figure 12.
Bird eye view (Scenario2).

Figure 13.
Street view (Scenario1).

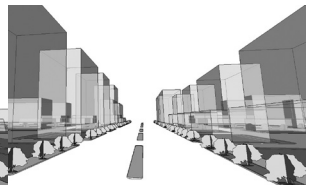


Figure 14.
Street view (Scenario2).

5 Conclusion and Further Research

While FBCs have substituted conventional zoning regulations in the U.S., limitations and challenges of FBCs still exist. As a response of the increasing needs of parametric modeling approaches in the urban design domain, we applied BIM and OOPM techniques in two case studies to support FBCs.

This research led us to prove the potential of BIM and OOPM to support FBCs. The parametric urban model provided the opportunity to efficiently manipulate parametric variables as well as to represent diverse development options.

The study to link FBCs and BIM is still in its infancy. However, using BIM and OOPM for FBCs is expected to provide the three dimensional regulations for the clear interpretation, the intuitive code checking systems, and the communication platform for the participatory planning.

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