EXPLORING THE USE OF THREE-DIMENSIONAL URBAN SIMULATION TO MODEL FORM-BASED CODES REGULATIONS

By

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To my parents

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LIST OF ABBREVIATIONS

3D	Three dimensional
CAD	Computer Aided Design
CGA	Computer Generated Architecture
ESRI	Environmental Systems Research Institute
FAR	Floor Area Ratio
FBC	Form-based Codes
FBCI	Form-Based Codes Institute
GFA	Gross Floor Area
GIS	Geographic Information System
VR	Virtual Reality

Abstract of Thesis Presented to the Graduate School
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Geodesign emphasizes cooperation among professionals from different background. In such a collaborative working process, multiple varieties of different types of information are being exchanged and evaluated. However, individuals who lack in a planning and design background have difficulties understanding all of the information correctly, especially when working with planning regulations that include complex details, such as Form-based Codes (FBC).

Therefore, this thesis aims at developing an easy way of sharing detailed planning information in Form-based Codes by building a procedure modeling template with CityEngine software. Three primary research questions are generated: (1) How can the zoning regulations in FBC be transferred into three-dimensional (3D) modeling? (2) How well can zoning regulations be represented by 3D models? (3) What are the potential uses of rules-based 3D modeling in urban planning?

The methodology of this thesis seeks to create a computer generated architecture (CGA) code-based template that can be applied to all FBC transect zoning regulations. The principle of CGA code is explained and the process of generating

associated CGA scripts is displayed. Gainesville, Florida is used as a case study to test the scripts. It is shown in later chapters of this thesis the 3D modeling results of five FBC transect zones within study area. 3D modeling with CityEngine is proved to be an efficient method for massive modeling process. This thesis discusses the advantages and disadvantages of the modeling procedure introduced, including the further uses of the FBC 3D models, such as the collaboration with other urban planning theories, and further analysis with ArcScene.

CHAPTER 1
INTRODUCTION

In the planning profession, urban sprawl is not a new concept. Modern use of the word “sprawl” was found as early as 1937 by one of the first urban planners in southeastern America, Earle Draper (Nechyba & Walsh, 2004). Years since Draper's introduction of the concept of urban sprawl have seen the public’s concern over the issue has grown. Over the years, urban sprawl has raised problems including air pollution, traffic congestion, water over- consumption, loss of wildlife habitat, and increased risk of health issues such as obesity. Form-based Codes were created to improve the built environment, enable a better development pattern, as well as fighting to stem the tide of urban sprawl. FBC create the most desirable urban form for each neighborhood by regulating elements, including building forms and functions, streets, green spaces, and landscapes. The purpose of FBC is to create more mixed-use, pedestrian-friendly communities (Kim, 2010). FBC provide a clear direction of new development to developers (Parolek, Parolek & Crawford, 2008). Compared to the conventional planning methods, FBC focus on creating predictable physical form (Parolek, Parolek & Crawford, 2008). As an urban planning tool that derived from New Urbanism, FBC have been proven effective in many cities and communities since 1980s (Kim, 2010).

The concept of Geodesign was brought up as a trend of collaborative cooperation among professionals from different backgrounds. As an urban planning process, FBC themselves are a Geodesign project. Information sharing plays an important role in any collaborative cooperation. 3D city models provide an effective and clear way for displaying visualized concepts and communication. Unlike other 3D modeling software, CityEngine works based on CGA scripts, therefore it works better with situations that emphasize the mass modeling of buildings which share the same zoning regulations rather than focus on the details of individual buildings. The work flow of CityEngine differs from other 3D modeling software in that the majority of work done in CityEngine is script writing, or in another words, CGA rules that generate the template for the buildings. Once the rule files are prepared, city models can be generated very quickly. FBC regulate the buildings' forms, functions, as well as both streets and landscapes. The characteristics of FBC make them suitable to work with CityEngine. Additionally, the sharing advantages of CityEngine improve the experience of involving the public to participate in the planning process.

From the above point of view, the best way to integrate FBC with CityEngine is to create a CGA rule file template that works with most of the FBC situations. The methodology part of this thesis is to transfer FBC regulations into CityEngine CGA scripts. The city of Gainesville, Florida has been reviewing a FBC draft from the Littlejohn consulting firm. The content from Gainesville FBC draft is used to test the template created in the methodology part.

CHAPTER 2
LITERATURE REVIEW

Definition of Form-based Codes

> Form-based codes foster predictable built results and a high-quality public realm by using physical form (rather than separation of uses) as the organizing principle for the code. They are regulations, not mere guidelines, adopted into city or county law. Form-based codes offer a powerful alternative to conventional zoning. (http://www.formbasedcodes.org/what-are-form-based-codes)

The key to understanding Form-based Codes is that it is a planning regulation that considers urban forms in a comprehensive way. Instead of segregating land use into small pieces, Form-based Codes emphasize how to associate building façades with the public realm (http://www.formbasedcodes.org/what-are-form-based-codes). The key elements of Form-based Codes commonly include:

> Regulating Plan;
> Public Space Standards;
> Building Form Standards;
> Administration;
> Definitions
> (http://www.formbasedcodes.org/what-are-form-based-codes).

Unlike conventional planning, Form-based Codes are a kind of urban planning regulation that is against urban sprawl or suburban (Parolek, Parolek & Crawford, 2008).

History of FBC

Over the last century, land use zoning regulations in the United States have changed evolutionarily (Parolek, Parolek & Crawford, 2008). In the early twentieth century, urban planning was "based on the authorities of cities to exercise their police power" (Parolek, Parolek & Crawford, 2008). Current planning practice started by separating houses because of efforts to prevent fire spreading (Parolek, Parolek & Crawford, 2008).

Urban sprawl first started after people returned from World War II. Baby boomers created an increasing demand for single family housing, which has a total system of separating working and residential areas (Parolek, Parolek & Crawford, 2008). The separation of living and working areas required a longer distance of commuting. Single family housing was consuming more land to meet the residents' requirements. The increasing travel distance led to an inadequacy of the existing roads, which resulted in further road expansion. The design of urban roads focused more on how to reduce the traffic jam situation than make it a walkable place for pedestrians (Parolek, Parolek & Crawford, 2008).

As the disadvantages of conventional planning became more apparent, FBC appeared as an alternative zoning method for the conventional zoning methods. In the 1980s, a group of planners and architects "dedicated to revitalizing and promoting walkable, mixed-use, sustainable communities as described in the principles of Smart Growth and the Charter of the New Urbanism worked both individually and collaboratively to conventional zoning" (Parolek, Parolek & Crawford, 2008, p. 9).

Discussion about FBC

Advantage of FBC

As discussed above, FBC appeared because people started to realize that conventional planning was inadequate. The comparison of FBC and conventional planning are shown in the table below.

Table 2-1. Comparison of conventional planning and Form-Based Codes (Parolek, Parolek & Crawford, 2008, p. 13)

Conventional Planning and Zoning Codes	Form-based Codes
Auto-oriented, segregated land-use planning principles	Mixed use, walkable, compact development-oriented principles
Organized around single-use zones	Based on spatial organizing principles that identify and reinforce an urban hierarchy, such as the rural-to-urban transect
Use is primary	Physical form and character are primary, with secondary attention to use
Reactive to individual development proposals	Proactive community visioning
Proscriptive regulations, regulating what is not permitted, as well as unpredictable numeric parameters, like density and FAR	Prescriptive regulations, describing what is required, such as build-to lines and combined min/max building heights
Regulates to create buildings	Regulates to create places

To conclude the table above, compared to conventional zoning regulations, which cares more about the micro aspects of urban design and land use segregation, FBC focuses more on the connection between the community and the street façade in a macro point of view.

Disadvantage of FBC

Because of the nature of FBC, some architects tend to think that FBC is a factor of restriction when designing individual buildings. Urban planners often consider the macro view of the community and city, while architects focus on the details of design. This conflict has raised some questions about to what extent the urban form should be coded. The fear is the codes are going to have an overpowered impact on the details of urban design. The truth is, as long as the FBC is kept at a basic level, which means it only has an influence on the spatial location of the buildings and keeps the urban order, the code is flexible for urban designers. David Walters (2007) figures that “over the years that many outspoken critics calling loudly for looser standards, and ‘creative freedom’ and ‘flexibility’ is merely s mechanism to conceal bad, or at best mediocre, design under a smokescreen of ‘creativity’” (Walters, 2007, p. 95). There were other people concerning about the over-use of FBC. Katherine Woodward (2013) states that the initial idea of FBC is to aesthetically please the pedestrians with building façade and street views rather than focusing on the function of the building. Walters (2007) then argues that FBC includes some basic ideas of what a well-functioning community should be. Thankfully, there are architects who found their balance between the consistency with the codes and the creativity of building. One of the examples is the Catalan architect Antonio Gaudi. Gaudi was able to create buildings that are famous for their creative architecture elements without breaking the city codes (Walters, 2007).

History of the Use of 3D Modeling in Urban Design

Real Model 3D Modeling

“Visual simulation is a form of representation in which things that do not exist, but are contemplated, and represented or simulated allowing the user virtually to peer into the future” (Kwartler & Longo, 2008, p. 5). Since Kevin Lynch came up with the idea of explaining urban dynamics using graphics, urban planners have been searching for methods to represent the complex city forms with visualization. The methods have changed from simple physical models to more complicated visualized computer simulation models (Kim, 2005). The first simulation tool that was used to build 3D architecture were physical models made with wood or Styrofoam in different scales. (Kim, 2005) The scaled models are used in public decision making, visual analysis, and other fields. However, the disadvantages of these models are that they cannot provide the actual eye level view while walking around the city. In order to overcome these disadvantages, full-size mock up models were created. (Kim, 2005)

Computer-assisted 3D Modeling

Over the past 30 years, computer-assisted urban planning and design have been developing (Kwartler & Longo, 2008). No matter how the three dimensional simulation methods changed, they all follow three steps: data collection, 3D modeling, and presentation or analysis (Kim, 2004). The first idea of Geographic Information System (GIS), or the so called "GIS before GIS" (Kwartler & Longo, 2008, p. 7), is developed by Ian McHarg. McHarg's (1969) book *Design with Nature*, documented the process of a new planning process, which was to determine the suitability of a land by layering different geo-referenced sheets on top of each other. This way he could tell whether an area of land was suitable for new development by analyzing factors such as whether or not that land had critical species activity or was agriculture- use land (McHarg, 1969).

Computer-based GIS analysis has been around at least since the1960s (Coppock & Rhind, 1991). As the computer technology matures, 3D software for modeling and presenting such as Virtual Reality (VR), Computer Aided Design (CAD), Sketchup CommunityViz, CityEngine are starting to be recognized.

Introduction of CityEngine

CityEngine is a relatively new 3D modeling software. "Esri CityEngine is a stand-alone software product that provides professional users in architecture, urban planning, entertainment, simulation, GIS, and general 3D content production with a unique conceptual design and modeling solution for the efficient creation of 3D cities and buildings" (http://resources.arcgis.com/en/communities/cityengine/01w90000000m000000.htm). For the function and usage of CityEngine, please see the ESRI CityEngine webpage.

As a software that is designed for both urban planners and architects, CityEngine has been widely used in many cities and projects.

The Evolution of Geodesign

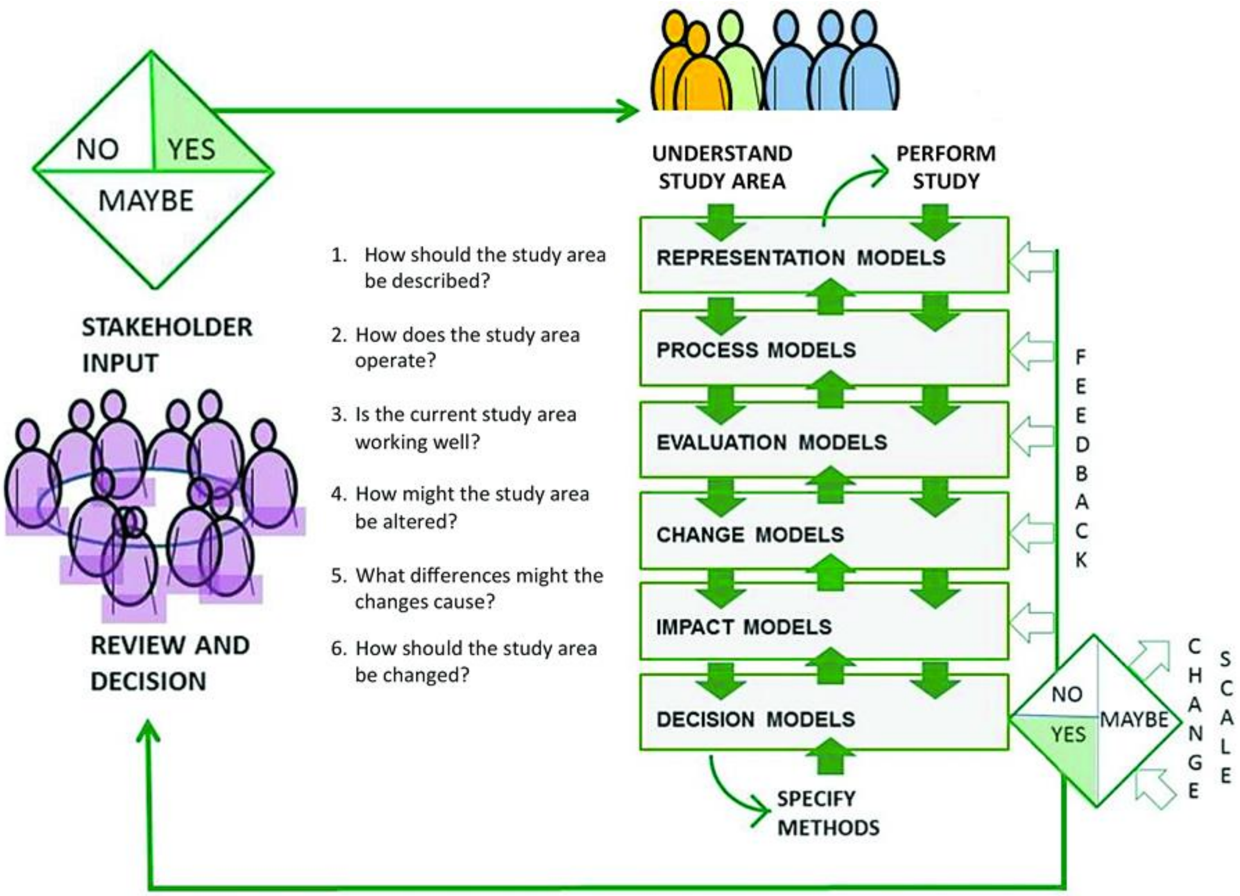


Figure 2-1. The stakeholders, the Geodesign team, and the framework for Geodesign. Source of image: Steinitz, C. (2012). A Framework for Geodesign. Changing Geography by Design, p. 25.

Geodesign is not new, but it is different (Steinitz, 2012). The definition of Geodesign is "a design and planning method which tightly couple the creation of design proposals with impact simulations informed by geographic contexts, systems thinking, and digital technology" (esritv, 2010). According to Steinitz, this is not the first time that professional planners cooperated with scientists. Ian McHarg's book *Design with Nature* influenced urban planners, landscape architects, and other scientists (Steinitz, 2012). Carl Steinitz (2012) created the Geodesign framework, which is a workflow for Geodesign studies. In his book, Steinitz states that it is unlikely that Geodesign becomes a profession. Geodesign is a corporation of architecture, landscape architecture, and urban planning. There is no reason to merge these well-developed seperate fields into one. On the other hand, Geodesign should be a concept that is understood and accepted by architects, landscape architects, and urban planners (Steinitz, 2012).

Summary of Literature Review

The literature review of Form-Based Codes, current 3D modeling methods, and Geodesign methods reveals that FBC is an effective zoning method that can decrease the speed of the expansion of urban sprawl. As a zoning method focusing on function, FBC divides the zoning area into different districts, and applies rules and regulations to parcels and buildings to restrict population densities by applying limitations (both a minimum and a maximum number) on variables such as lot area, building stories, and so on. FBC are against urban sprawl and prone density in urban center area. Thus increasing the number of parcels which are zoned as mixed-use is important. However, from the presentation point of view, a zoning plan or a 2D zoning map is not as direct and impressive as urban models that transfer all the rules and regulations in the zoning plan into 3D models. For the general public, 3D models are also an easier way to understand the master plan. Among current 3D modeling software, CityEngine has the ability to generate models based on rules files written in Computer Generated

Architecture (CRA) rules, which makes it work better with zoning regulations that provide specific numbers.

Therefore, visualizing FBC with CityEngine is a good method. In addition, creating a better presentation is a part of Geodesign methods.

CHAPTER 3
METHODOLOGY

This thesis aims to both test and assess the usage of three-dimensional modeling based on Form-based codes (FBC). Three primary research questions are generated: (1) How can the zoning regulations in FBC be transferred into 3D modeling? (2) How well can zoning regulations be represented by 3D models? (3) What are the potential uses of rule-based 3D modeling in urban planning?

According to the research focuses above, the methodology of this thesis is composed of two parts. First, a comprehensive analysis of case studies to generalize the 3D modeling process with CityEngine; second, designing the method to incorporate FBC into CityEngine rules based on the previous case studies.

General Introduction of the Work Flow of CityEngine

"ESRI CityEngine is a stand-alone software product that provides professional users in architecture, urban planning, entertainment, simulation, GIS, and general 3D content production with a unique conceptual design and modeling solution for the efficient creation of 3D cities and buildings."(http://resources.arcgis.com/en/communities/cityengine/01w90000000m000000.htm)

CityEngine allows the user to generate 3D city models procedurally. The core of CityEngine is the scripts that are collectively called Computer Generated Architecture (CGA), which is a computer language that creates the 3D models. CityEngine is an integrated modeling tool that allows users to work on basic information such as existing parcels, streets, terrain then generate the models and export them back to GIS for further analysis. It is also possible to share the models through ArcGIS online.

CityEngine allows users to:

- Generate 3D building models based on their 2D information
- Modify 3D data
- Geodesign in 3D based on GIS information and planning regulations
- Further analyze the modified data from Geodatabase
- Share 3D information through Web scene

The method used for this thesis is to create scripts in CityEngine that fit the general requirements of FBC, then modify and apply these scripts to the study area based on the specific regulations of Gainesville's FBC.

Here is the explanation of the scripts used in this thesis:

Basically, CityEngine works using three steps. First, CityEngine provides tools to create streets and polygons. Second polygons are divided into different lots based on default values or user-defined values.

Here is a square representing a parcel that will be developed. It is generated with the "Rectangular Shape Creation" tool. The user can subdivide the lot into parcels based on certain criteria. In this example, the lot is subdivided as follows: the minimum lot area is 2000 square meters, the maximum lot area is 4000 square meters, and the minimum lot width is 30 meters. The figure below shows the result of the subdivisions of the lot.

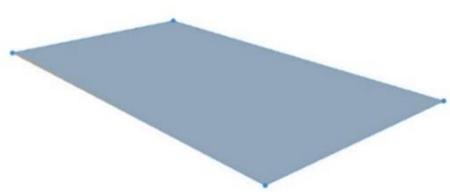


Figure 3-1. Example lot.

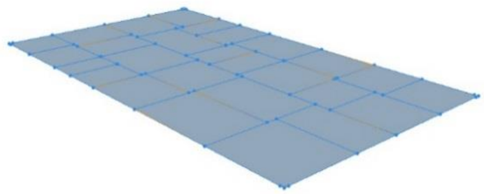


Figure 3-2. Example lot subdivided.

Secondly, CityEngine provides both textual and visual ways to create and view the scripts. Here is an example of what the rule scripts look like in both views.

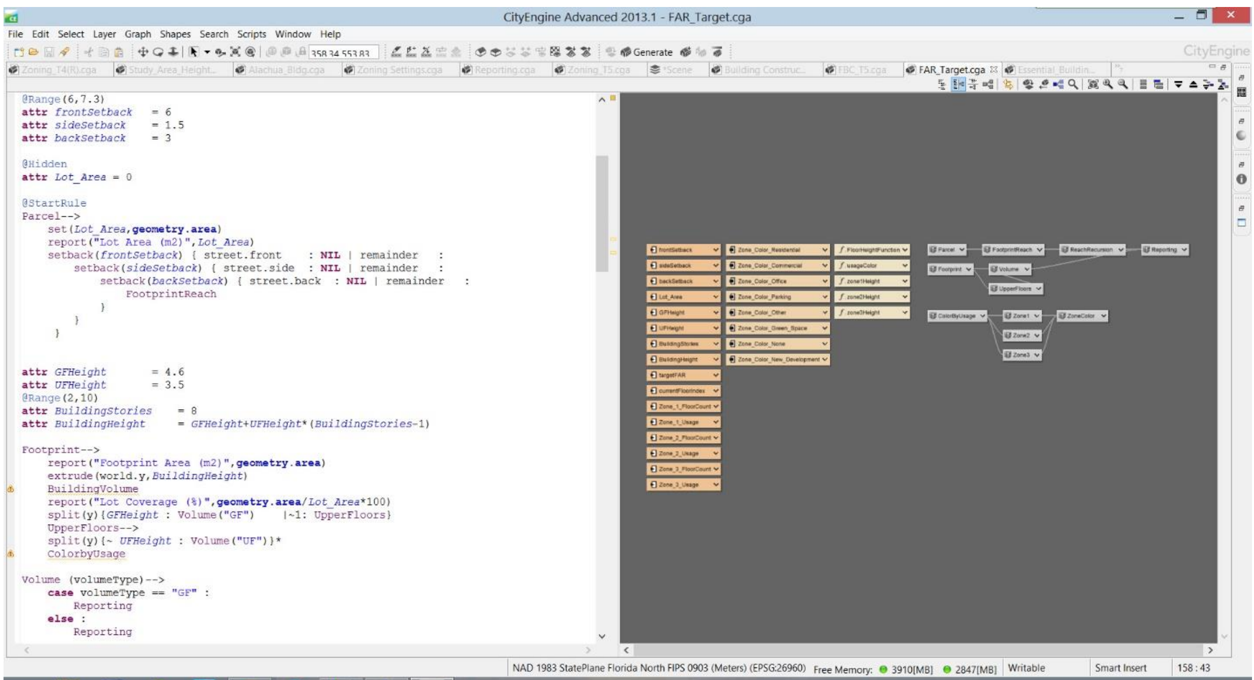


Figure 3-3. Two types of rule script view.

Rule scripts can be created using either window. If generated in the textual window, it is about writing the script itself. If generated in the visual window, the user can add a new rule file, attributes, constants, and functions by right- clicking in the window. The purpose of the duel rule generation system is to let users have a wider range of choices based on their own scripting level or their preferences of different user interface. As mentioned above, CityEngine does not have a complete CGA code scripting manual so far. This duel rule generation system provides a chance to learn how CGA code works while working with it. After talking to several CityEngine developers, it was noticed that the textual way is preferable in the more complicated projects. From the author's personal experience, the generation of CGA code in the textual perspective has much more flexibility than in the visual way. However, for users who have less of a computer programming background, creating a rule in the visual window generates the corresponding CGA language structures automatically in the textual window. The user can then start modifying the code content instead of worrying about the structure errors, which is a quicker and easier way for beginners to start creating rule scripts. Here is a very simple example of how the textual and visual views are related in this case. One of the basic rules when transferring a 2D shape into a 3D model is to generate the building height. If Shape A is the target building footprint, the 3D building height should an integer that varies between 12 feet to 36 feet. These lines of code can achieve that goal.

```
version "2013.1"


@Range (12,36)
attr BuildingHeight = 24

@StartRule

Lot-->
    extrude (BuildingHeight)
```

Figure 3-4. Script example 1 in textual view.

The "attr BuildingHeight" element creates an attribute that will appear in the inspector once the rule file is assigned to a specific object. "@Range (a, b)" means that the range of the attribute value will not exceed 12 or 36 when generated automatically. "24" is a value that is being assigned to the object as the default. “Lot -> extrude (BuildingHeight)” gives the command that the object should be extruded with the “BuildingHeight” attribute value.

These are the basic lines of code that give Shape A a default height of 24 feet. Let us take a look at the corresponding code created in the view window automatically.

Figure 3-5. Script example 1 in visual view.

After applying this rule file to Shape A by dragging and dropping, Shape A is generated into a 3D mass, which is the first step of any 2D to 3D generating process.

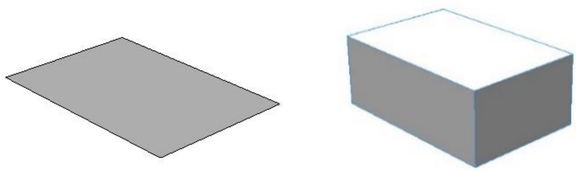
A  B

Figure 3-6. Results of script example 1. A) Before the rule files are applied, B) after the rule files are applied.

When clicking on the 3D model, it will show in the inspector window the rule file name that is associated with the model, the start rule of the model, and all of the attributes with their values. Start rule is the term for the specific line of rules that the user wants to create models with. One rule file can have multiple start rules, such as lot, footprint, etc. Therefore, it is important to assign the correct start rule based on the character of the object.

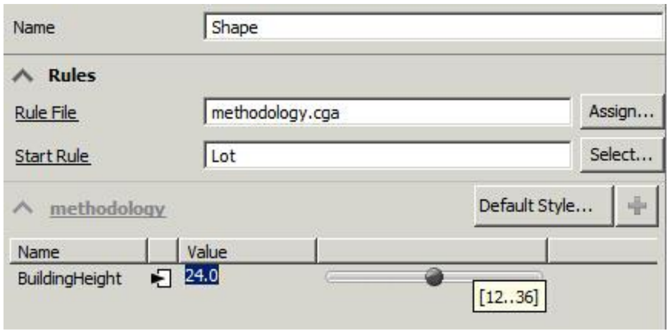


Figure 3-7. Inspector window of script example 1.

The third step of CityEngine's working flow is to assign the rule files to the building. There are two ways to do it. One method is to drag and drop the rule file from the navigator window to the selected object; the other one is to click the "Assign…" button next to Rule File, and assign the rule file manually.

CGA Code Design for This Thesis

Source of the Codes Used

Literature is reviewed to see how 3D modeling can be used in urban planning, especially in this case and in FBC zoning regulations. Some of the codes being used in this research are modified from their original form in Redlands Redevelopment 2013. Redlands Redevelopment 2013 is a template made by the Environmental Systems Research Institute (ESRI) to demonstrate the use of CityEngine in urban planning and design. The Redlands Redevelopment 2013 focuses on the redevelopment of an abandoned mall located in downtown Redlands, CA. The purpose of the modeling process is to create scenarios based on both existing buildings' LiDAR data and new zoning regulations that display the before and after downtown redevelopment (Redlands Redevelopment 2013, 2013). Because there is neither a user manual nor a script writing manual of CityEngine published yet, Redlands Redevelopment 2013, the only official

CityEngine example, was used as a study resource for this thesis. The developers of CityEngine have being notified of the modification of their codes, and authorized the use of it in this thesis.

CGA Code Modifying and Creating Process

The literature about Form-based codes (FBC) is further reviewed to see that the FBC zoning process corresponds with the procedural planning process. This is the reason why CityEngine, a rule-based software, is suitable for creating 3D city models for FBC zoning regulations. In addition to this, one of the great benefits of rule-based urban design is that once a standard rule file is created, it can be applied to similar situations without changing the basic structure but only the content of the rule file. According to the website of the Form-based codes Institute (FBCI), FBC regulates types of streets and buildings, including the number of floors, setbacks, the Floor Area Ratio (FAR), etc. (http://formbasedcodes.org/definition). Thus, the methodology of this thesis is to create a standard template of the CityEngine Rule file that fits with some of the FBC zoning criteria.

The research for the use of the GIS's ability to analyze FBC planning is on-going for the author. This thesis shows the research that has been completed to date. As mentioned previously in the literature review, applying FBC criteria into CityEngine scripts is a new topic. Though it is the author’s goal to be able to create a template that meets all of FBC’s zoning regulations, this thesis only covers part of FBC’s regulations due to the time that this amount of research consumes.

The general FBC’s zoning regulations being covered are: building height, number of stories, land mixed use type, building setbacks, and Floor Area Ratio (FAR)- which includes reporting both the current FAR from an existing building and generating a building based on a given FAR.

The rule file scripts are as follows (Note that because of the pre-settings of other existing projects in the author's computer, the corresponding system of this project is in meters.):

```
const Zone_Color_Residential = "#FFFF00"
const Zone_Color_Commercial = "#FF0000"
const Zone_Color_Retail = "#FFC0CB"
const Zone_Color_Office = "#0000FF"
const Zone_Color_Parking = "#BEBEBE"
const Zone_Color_Other = "#FFFFFF"
const Zone_Color_Green_Space = "#009B00"
const Zone_Color_None = "#FFFFFF"
const Zone_Color_New_Development = "#47A9A6"
```

Figure 3-8. FBC template CGA code, color setting.

At the beginning of the script, several constants are set to represent the color of different zonings. CGA uses a different code to represent the colors which can be found in CityEngine forum online. In this template, nine types of zoning are being considered.

```
@Range(6,7.3)
attr frontSetback    = 6
attr sideSetback     = 1.5
attr backSetback     = 3
```

Figure 3-9. FBC template CGA code, setbacks setting.

```
@StartRule
Parcel-->
    set(Lot_Area,geometry.area)
    report("Lot Area (m2)",Lot_Area)
    setback(frontSetback) { street.front    : NIL | remainder   :
        setback(sideSetback) { street.side  : NIL | remainder   :
            setback(backSetback) { street.back  : NIL | remainder   :
                Footprint
            }
        }
     }
```

Figure 3-10. FBC template CGA code, footprint generation.

Except for the report part, the scripts above cut a footprint out of a parcel based on given setbacks. Setting different setbacks as attributes gives users flexibility to change the building footprint as they need. “NIL” in the code means to delete the rest. When running the Parcel command, the line of code “setback (frontSetback) { street. front: NIL | remainder:” means to set a setback from street front with the given attribute number, then delete the rest of the shape, which is the shape between street front and the setback. Then run the second line of code, which does the same thing to the remainder with the street side setback. Last but not least, the third line of code cuts the remainder from previous code with the setback from the back street and creates the building footprint. There are several ways to get a building footprint. One way is to import the existing footprint from ArcGIS. The second way is to hand draw the building footprint. The third way was the method that was used here, which was to cut the footprint out of a parcel based on different setbacks. This third method is being used because it fits with the concept of procedural planning, provides users with more flexibility, and ultimately saves time.

```
attr GFHeight          = 4.6
attr UFHeight          = 3.5
@Range(2,10)
attr BuildingStories      = 8
attr BuildingHeight       = GFHeight+UFHeight*(BuildingStories-1)
```

Figure 3-11. FBC template CGA code, floor height, building height, and number of stories setting.

```
Footprint-->
    report("Footprint Area (m2)",geometry.area)
    report("Lot Coverage (%)",geometry.area/Lot_Area*100)
    extrude(world.y,BuildingHeight)
    BuildingVolume
    split(y){GFHeight : Volume("GF")     |~1: UpperFloors}
    UpperFloors-->
        split(y){~ UFHeight : Volume("UF")}*
    ColorByUsage
```

Figure 3-12. FBC template CGA code, mass information reporting.

The code above generates the 3D building model and splits it into different floors. The attributes “GFHeight” and “UFHeight” represent the ground floor height and the upper floor height. Number of building stories is an integer between 2 and 10. The default value is 8. Therefore the whole building height can be calculated with the formula shown above. The footprint can be extruded based on the known building height value. The “split” function basically divides the building volume one step at a time. It first divided the whole building volume into two, between the ground floor part and the rest. It then divided the rest of the upper aspect into different floors according to the given upper floor height value.

Considering that FBC encourages mixed land use in some of the areas, this template will include code that allows users to change the zoning use of different floors in the same building. The concept is to separate the same building into different zones, and change the use of each of the zones by changing the number of stories assigned and give it a certain color.

```
usageColor(usage) =
    case usage == "Residential" :  Zone_Color_Residential
    case usage == "Commercial" :  Zone_Color_Commercial
    case usage == "Office" :  Zone_Color_Office
    case usage == "Parking" :  Zone_Color_Parking
    case usage == "Other" :  Zone_Color_Other
    case usage == "Green Space" :  Zone_Color_Green_Space
    case usage == "New Development" :  Zone_Color_New_Development
    case usage == "None" :  Zone_Color_None
    else: Zone_Color_None
```

Figure 3-13. FBC template CGA code, zone color assigning.

```
@Group ("USAGE",1)  @Range(0,10)
attr Zone_1_FloorCount = 3

@Group ("USAGE")
@Range("None", "Commercial","Retail", "Office", "Residential", "Parking", "Green Space", "New Development", "Other")
attr Zone_1_Usage = "Commercial"

@Group ("USAGE")  @Range(0,10)
attr Zone_2_FloorCount = 2

@Group ("USAGE")
@Range("None", "Commercial","Retail", "Office", "Residential", "Parking", "Other")
attr Zone_2_Usage = "Parking"

@Group ("USAGE")  @Range(0,10)
attr Zone_3_FloorCount = 5

@Group ("USAGE")
@Range("None", "Commercial","Retail", "Office", "Residential", "Parking", "Other")
attr Zone_3_Usage = "Other"
```

Figure 3-14. FBC template CGA code, building function setting.

```
//////Calculate each zone height/////////

zone1Height =
    case Zone_1_FloorCount == 1:
        GFHeight
    else :
        GFHeight + (BuildingStories - Zone_1_FloorCount )* UFHeight

zone2Height =
    case Zone_2_FloorCount > 0 && Zone_2_Usage != "None":
        rint(Zone_2_FloorCount) * UFHeight
    else: 0

zone3Height =
    case Zone_3_FloorCount > 0 && Zone_3_Usage != "None":
        rint(Zone_3_FloorCount) * UFHeight
    else: 0
```

Figure 3-15. FBC template CGA code, building function color zones split.

```
ColorByUsage -->
    split(y) {zone1Height: Zone1 |
        zone2Height: Zone2 |
        zone3Height: Zone3 }

Zone1 -->
    case Zone_1_FloorCount == 1:
        ZoneColor(usageColor(Zone_1_Usage), false)

    else:
        split(y) {GFHeight :
            ZoneColor(usageColor(Zone_1_Usage), false)
            | {UFHeight:
            ZoneColor(usageColor(Zone_1_Usage), false)}* }


Zone2 -->
    split(y) {UFHeight: ZoneColor(usageColor(Zone_2_Usage), true)}*


Zone3 -->
    split(y) {UFHeight: ZoneColor(usageColor(Zone_3_Usage), true)}*



ZoneColor(usageColor, isLastZone) -->
    color(usageColor)
```

Figure 3-16. FBC template CGA code, building function zones color assign.

These sets of above code separate the building volume into different zones. Each zone height equals the number of stories in each zone multiplied by the corresponding floor height. This ensures the separation of each zone coincides with the separation between two stories. Then the code in Figure 3-17 shows how users can interact with the types of mixed- use land. By changing the number of floor counts in each zone and the type of use of it, users can change the mixed- use element of a building very easily.

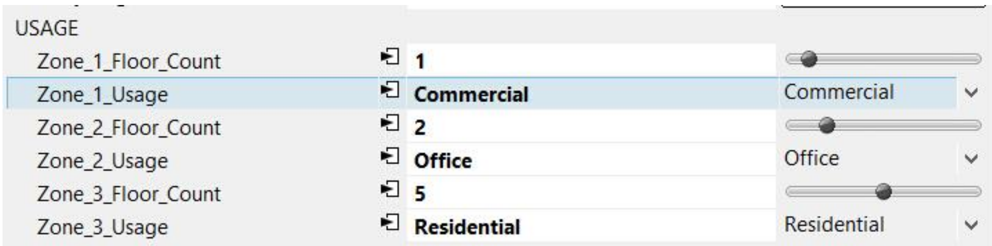


Figure 3-17. FBC template CGA code, inspector window.

Here is what the building looks like when one applies the above rule files to the parcel.

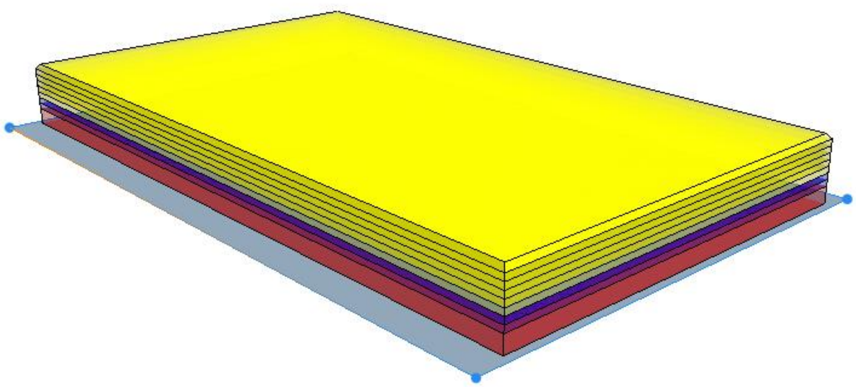


Figure 3-18. FBC template CGA code, template result.

The last factor in the template is the FAR of the building. As mentioned above, the goal of this part is to report the FAR of a generated building, and to generate a building based on a given FAR.

Here is the code of calculating FAR from an existing building.

```
@Hidden
attr Lot_Area = 0
```

```
@StartRule
Parcel-->
    set(Lot_Area,geometry.area)
    report("Lot Area (m2)",Lot_Area)
    setback(frontSetback) { street.front    : NIL | remainder   :
        setback(sideSetback) { street.side  : NIL | remainder   :
            setback(backSetback) { street.back  : NIL | remainder   :
                Footprint
            }
        }
     }
```

```
Footprint-->
    report("Footprint Area (m2)",geometry.area)
    report("Lot Coverage (%)",geometry.area/Lot_Area*100)
    extrude(world.y,BuildingHeight)
    BuildingVolume
    split(y){GFHeight : Volume("GF")     |~1: UpperFloors}
    UpperFloors-->
        split(y){~ UFHeight : Volume("UF")}*
    ColorByUsage
```

```
Volume (volumeType)-->
    case volumeType == "GF" :
        Reporting
    else :
        Reporting
```

```
Reporting-->
    report("GFA",geometry.area(bottom))
    report("FAR",geometry.area(bottom)/Lot_Area)
```

Figure 3-19. FBC template CGA code, FAR calculation.

For these above codes, the attribute “Lot_Area” was set up first, then spaces are filled with the value calculated from the area of the selected parcel. The command in CityEngine only works in a downward flowing direction, which means that once the object is split, the command only works on the split parts. In other words, the value of the whole object should be obtained before it splits, which is why in this case the placement of “report” is important. In order to get information for potential further study, this template collects the parcel area, footprint area, parcel coverage (which is equal to the footprint area divided by the parcel area multiplied by 100), gross floor area (GFA), and floor area ratio (FAR). The definition of FAR is the total area of a building divided by the total area of the lot the building is located on. (http://www.investopedia.com/terms/f/floor-area-ratio.asp)

Reports

Report	N	%	Sum	%	Avg	Min	Max	NaNs
FAR	6	0.00	4.16	0.00	0.69	0.69	0.69	0
Footprint Area (m2)	1	0.00	1368.25	0.00	1368.25	1368.25	1368.25	0
GFA	6	0.00	8209.51	0.00	1368.25	1368.25	1368.25	0
Lot Area (m2)	1	0.00	1972.05	0.00	1972.05	1972.05	1972.05	0
Lot Coverage (%)	1	0.00	69.38	0.00	69.38	69.38	69.38	0

Figure 3-20. FBC template CGA code, report.

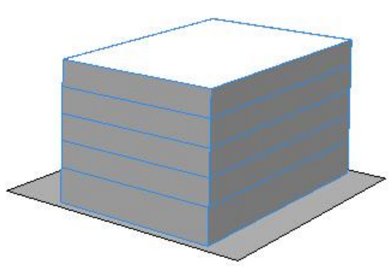
In this case, the FAR of the generated building is 4.16, when the GFA is 8209.51, and lot area is 1972.05.

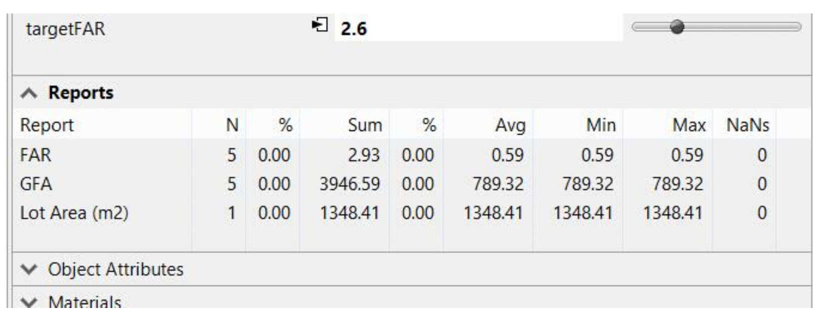
In another case, if a certain FAR is given, these extra code can help to generate the building.

```
attr targetFAR = 2.6

@Hidden
attr currentFloorIndex = 1

FloorHeightFunction =
    case currentFloorIndex == 1 :
        GFHeight
    else :
        UFHeight


FootprintReach-->
    ReachRecursion( targetFAR * Lot_Area ) #the GFA value we want to reach

    ReachRecursion( restArea )-->
        case restArea < geometry.area(bottom) :
            Done.
        else :
            extrude(world.y, FloorHeightFunction)
            set(currentFloorIndex, currentFloorIndex + 1)
            Reporting
            comp(f){top : ReachRecursion( restArea - geometry.area ) | all : NIL}
```

Figure 3-21. FBC template CGA code, target FAR.

These code did a loop with the "Recursion" function. The concept behind these codes is the equation "GFA = FAR * Lot_Area". The recursion loops through one floor number at a time. If the rest area, which means the target GFA calculated based on the given target FAR, is smaller than the actual GFA of the building, then stop the loop. Otherwise, if the rest area is bigger than the actual GFA, then keep building up one floor at a time until the rest area is smaller than the actual GFA.





targetFAR 2.6

Reports

Report	N	%	Sum	%	Avg	Min	Max	NaNs
FAR	5	0.00	2.93	0.00	0.59	0.59	0.59	0
GFA	5	0.00	3946.59	0.00	789.32	789.32	789.32	0
Lot Area (m2)	1	0.00	1348.41	0.00	1348.41	1348.41	1348.41	0

Object Attributes

Materials

Figure 3-22. FBC template CGA code, target FAR report.

Here is the result of applying the “Target_FAR” rule to a random parcel. In the inspector window, the attribute “targetFAR” is set to a default value. In the report window, the number of FAR is 2.93, not 2.6. The reason for the error is because in this scenario, the footprint of the building is not changeable, and the height of each floor is not changeable either. CityEngine cannot generate a “half floor” when the floor number associated with the accurate target FAR number is not an integer. CityEngine will automatically round it up or down to an integer. There are other potential scenarios of generating buildings with accurate FAR numbers. These scenarios will be discussed in the later chapters of this thesis.

CHATER 4
RESULTS OF USING 3D MODELING FOR GAINESVILLE FBC AREAS

This chapter discusses the current conditions of the study area in terms of natural and built environment, economic situation, FBC regulations, and 3D modeling results for different zones.

Study Area Background

Gainesville is located in Alachua County, near the center of Florida. According to the United States census bureau, the population of Gainesville in 2010 was 124,486 people, and the estimation of the population in 2013 is 127,488 people. As the primary location of the University of Florida, Gainesville attracts thousands of people every year.

Currently, the city of Gainesville is still working on the proposal for Form-based Codes to better express the shape and function of public areas by introducing multiple transect zones. In an interview that Thomas Hawkins, Commissioner of the City of Gainesville, did with the *Gainesville Sun* in 2011, higher density development was mentioned, and Hawkins assured that public's opinion will be highly valued in the proposal process. The proposal is now still in a drafting stage (http://www.smartgrowthamerica.org/2013/12/11/gainesville-fl-city-commissioner-thomas-hawkins-on-land-use-and-economic-development/). The City of Gainesville Land Development Code Update/ Form-based codes was drafted by Littlejohn, a consulting company founded in 1989, located in Nashville, Tennessee, which is involved in multiple fields including engineering, planning, and environmental conservation (http://www.leainc.com/about-us/history.html). The City of Gainesville's FBC draft, as introduced on Littlejohn's website, "incorporated Form-based codes principles for the downtown and surrounding areas" (http://www.leainc.com/portfolio/430/gainesville-land-development-code-update-and-form-based-code.html). The FBC draft was formed considering the existing community characters, priorities of each neighborhood, and the consistency with the Comprehensive Plan. Multiple graphics, maps, and tables were used to illustrate the FBC areas and criteria.

The City of Gainesville Planning and Development Service Department acknowledged that the FBC applicable area including the city core and other outlying areas are intended to be developed as pedestrian-friendly neighborhoods. The proposed FBC areas are shown in the following map.

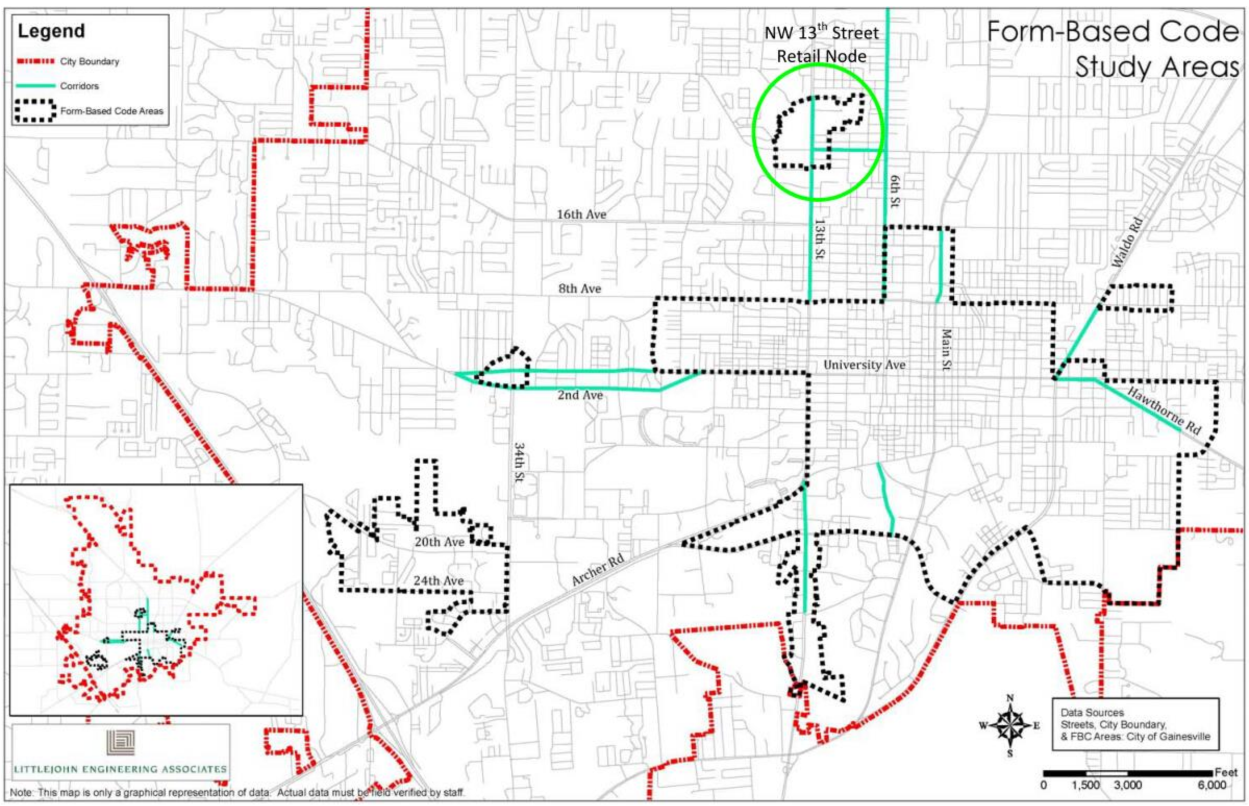


Figure 4-1. Gainesville FBC area. Source of image: Littlejohn Engineering Associates. (2012). City of Gainesville Land Development Code Update/ Form-Based Code Draft.

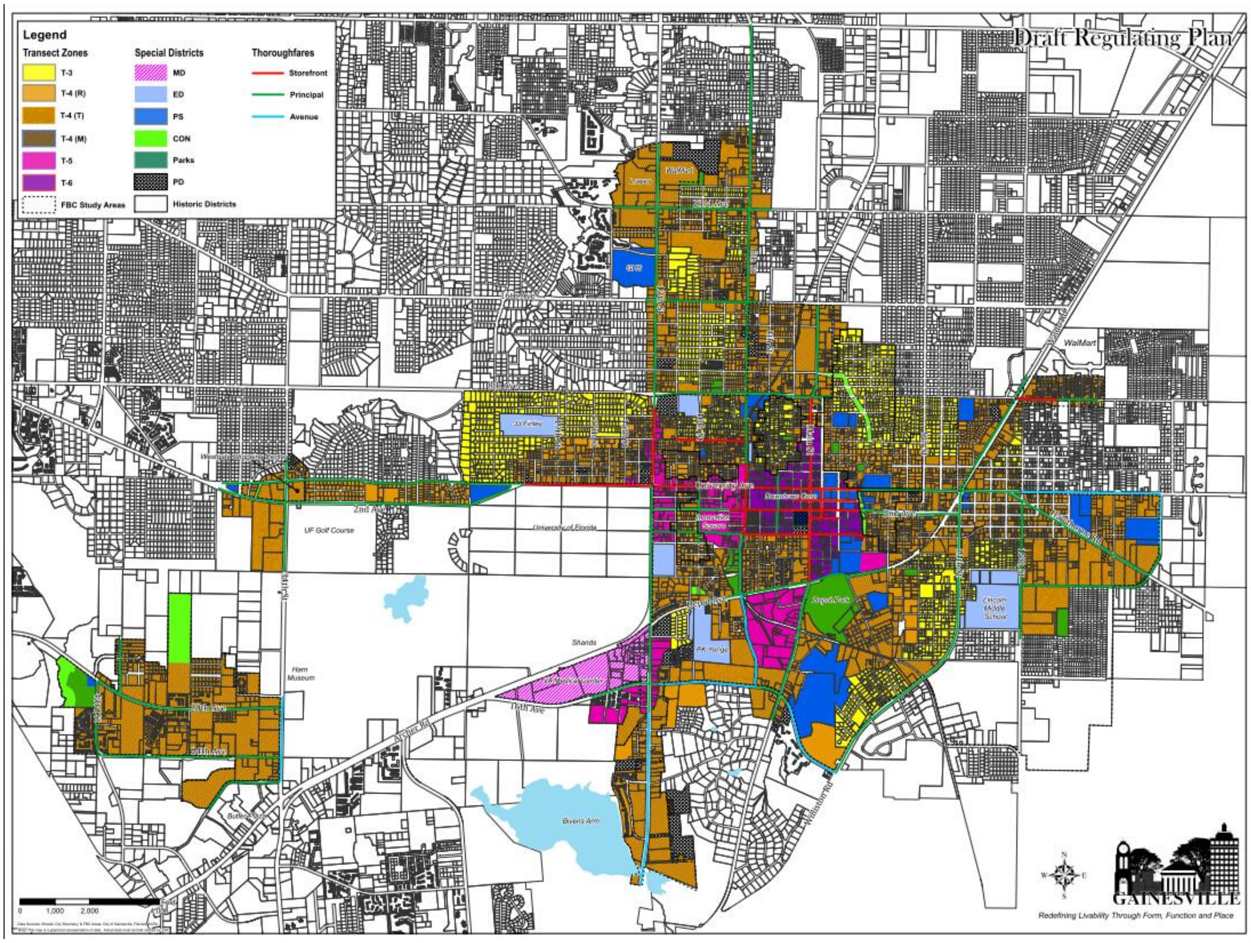
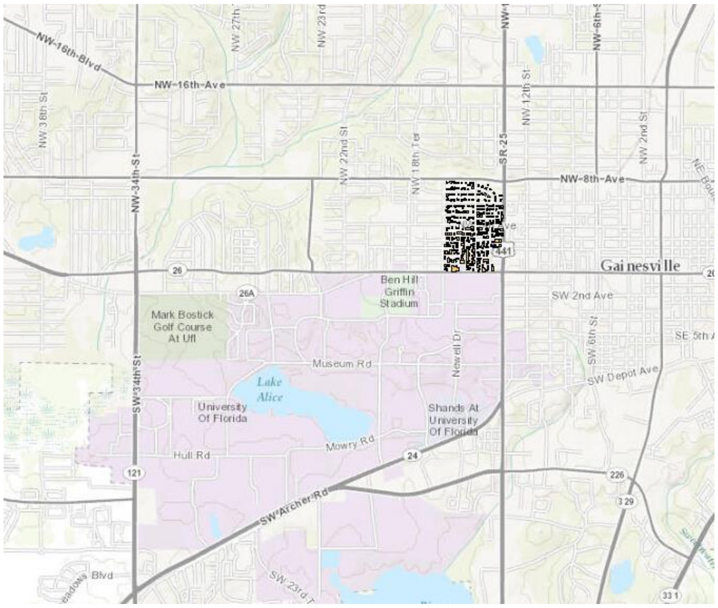


Figure 4-2. Gainesville FBC proposal transect zones. Source of image: Littlejohn Engineering Associates. (2012). City of Gainesville Land Development Code Update/ Form-Based Code Draft.

Figure 4-2 above is the summary of the proposed FBC applicable areas within the city limits of the City of Gainesville. The FBC areas are separated into different transects types. This map was used to insure the study area was covered by the FBC land use zoning code. The green circled area in Figure 4-1 was used in the proposed draft as an example of how the FBC works. Once the proposal is approved by the city, it is planned that the FBC will be applied to the whole areas. As in this thesis, the definition of study area is the parcels within University Avenue, 13th street, northwest 8th avenue, and northwest 17th street.

A



B

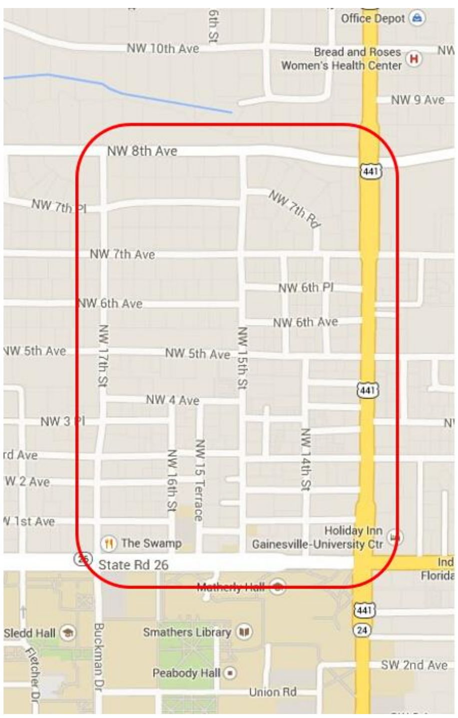


Figure 4-3. Study area. A) Farther view of study area, B) closer view of study area.

The reasons to choose these parcels as study areas are: First, the area chosen is within the FBC applicable area; second, based on the zoning code showing in Figure 4-4, the study area covers five types of FBC transects, which are T3, T4(M), T4(T), T4(R), and T5. These five types of transects are the most used within the FBC applicable areas.

A

B

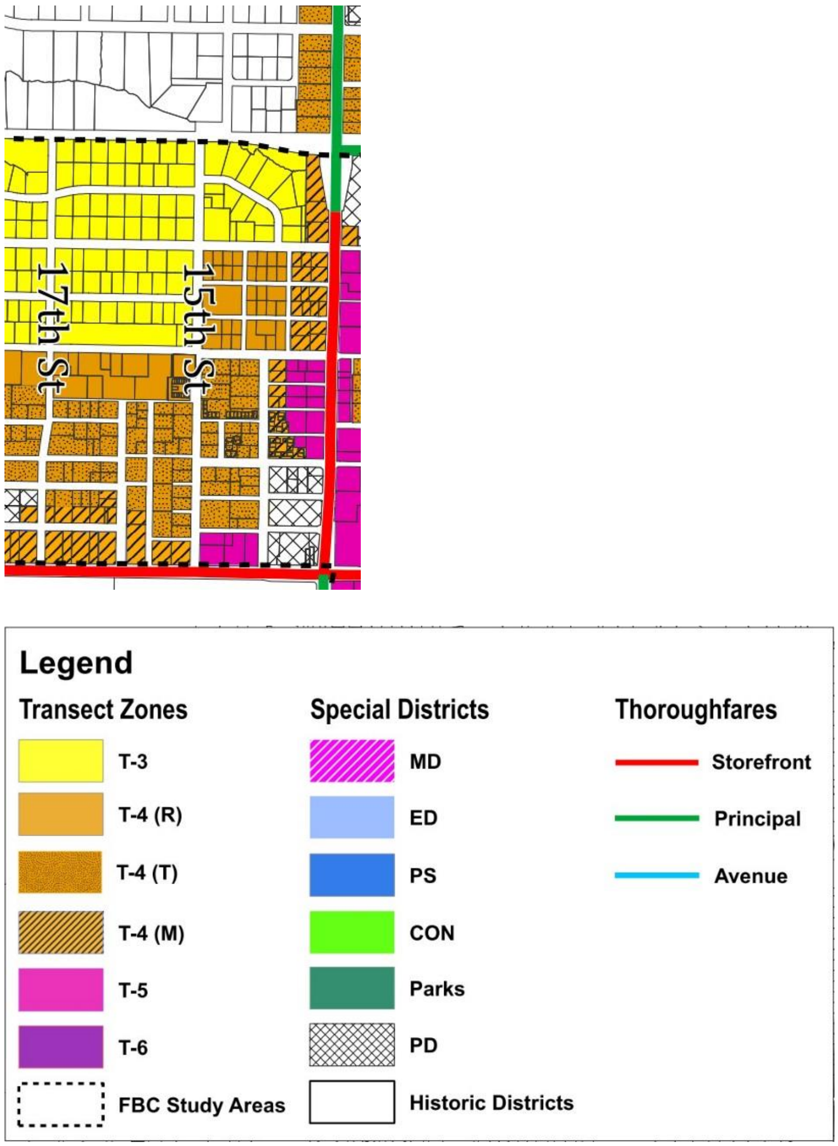


Figure 4-4. Study area with FBC transect zones. A) Transect zones with study area, B) legend. Source of image: Littlejohn Engineering Associates. (2012). City of Gainesville Land Development Code Update/ Form-Based Code Draft.

Study Area Overview

The study area contains 295 existing buildings. Among which 100 buildings do not have an associated number of stories record.

Figure 4-5. Buildings with no height information.

One of the methodologies used in this thesis is the analysis of the 3D buildings' changes before and after FBC rules are being applied to the parcels. In order to generate the existing building models, the author documented the number of stories manually through field observation on site, and organized the results into the existing attribute table of the study area. After the existing building footprints were imported into CityEngine, with simple rules applied, the existing building models were generated as showing in the following Figure 4-7. The building footprint data and parcel information is from Alachua County Property Appraiser.

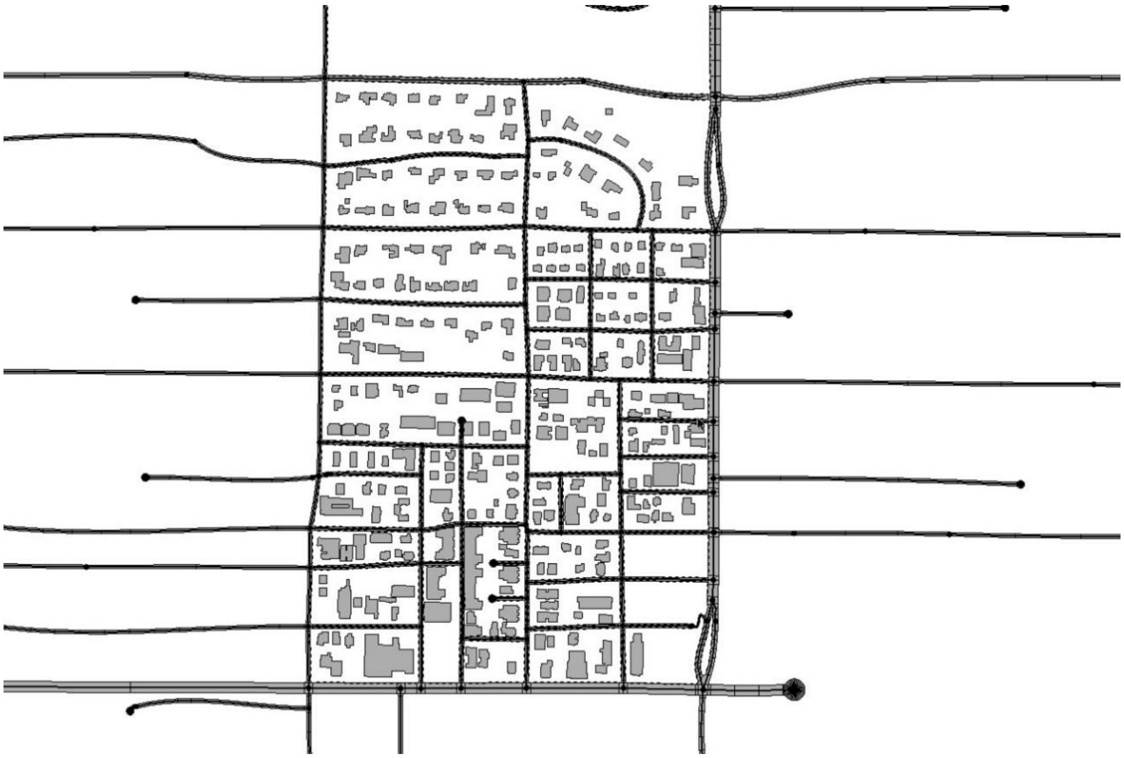


Figure 4-6. Study area building footprint in CityEngine.

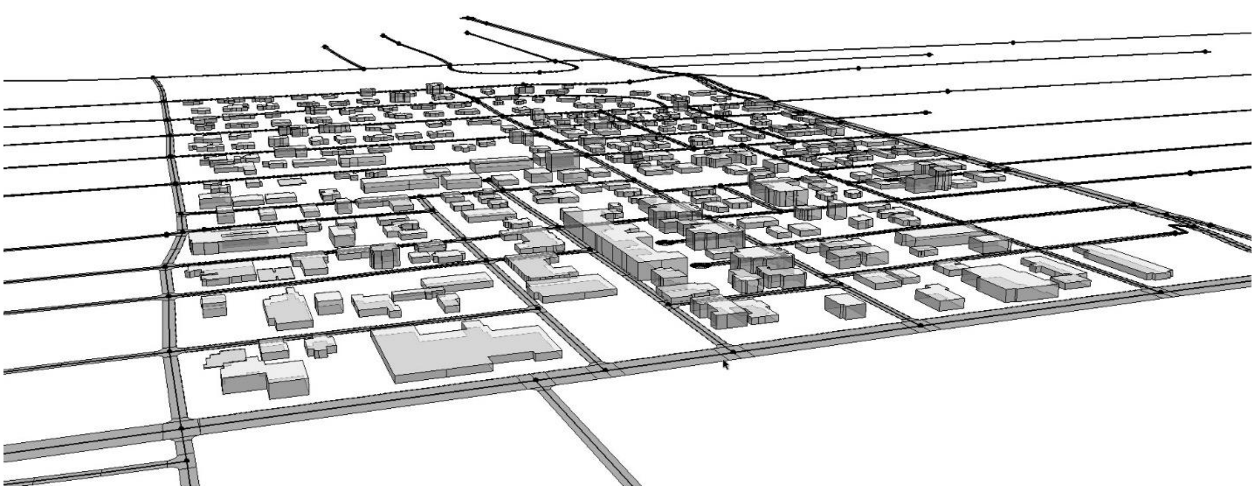


Figure 4-7. Existing buildings in study area.

Figure 4-7 above will be used as the “before” scenario when compared to the neighborhood conditions after FBC rules are applied.

Study Area with FBC

The FBC proposal drafted by Littlejohn includes a regulating plan, which functions as the implementation guidelines which identify each transect zones in specific city areas. A transect is “a geographical cross-section of a region that reveals a sequence of environments that ranges from rural to urban” (City of Gainesville Land Development Code Update/ Form-Based Code Draft, 2012, p. 5). Transects exist to ensure there is a diversity of building functions, civic space types, as well as appropriate characteristics within each community (City of Gainesville Land Development Code Update/ Form-Based Code Draft, 2012). In general there are six types of transect zones: T1 Natural Zone, T2 Rural Zone, T3 Suburban Zone, T4 General Urban Zone, T 5 Urban Center Zone, and T6 Urban Core (City of Gainesville Land Development Code Update/ Form-Based Code Draft, 2012).

Table 4-1. List of Gainesville’s FBC transect zones’ description. Source of image: Littlejohn Engineering Associates. (2012). City of Gainesville Land Development Code Update/ Form-Based Code Draft.

	T3 Sub-urban	T4 General Urban	T5 Urban Center	T6 Urban Core
Density	low density residential area; adjacent to higher density mixed use zones	consists of mixed use, mostly residential urban areas; wide range of building types	higher density mixed use buildings; contains retail, offices, and apartments	highest density and height development; greatest diversity of uses
Setbacks	deeper setbacks	variable		
Street	irregular streets aligned to natural environment are allowed	streets with curbs and sidewalks define medium sized blocks	tight network of street; wide sidewalks	have steady street plants
Other	outbuildings area allowed	includes T4M (mixed), T4R (residential), and T4T (transit)	buildings set close to sidewalks	buildings set close to the wide sidewalks

In Gainesville's FBC proposal, FBC applicable areas are divided into four transect zones: T3, T4, T5, and T6. A description for each of the zones can be concluded within the following Table 4-1.

It is stated in the Gainesville FBC draft that not all of the transect zones follow the property line. If the property is within two or more transect zones, it is must designed in a way that the certain portion of the building meets the assigned transect zone regulations. After examining the study area, there is no property that has more than one of the transect zones assigned.

The transect zone development standards charts are as follows:

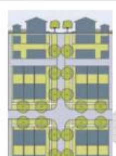
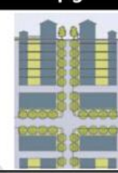
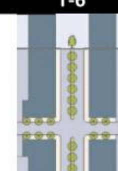
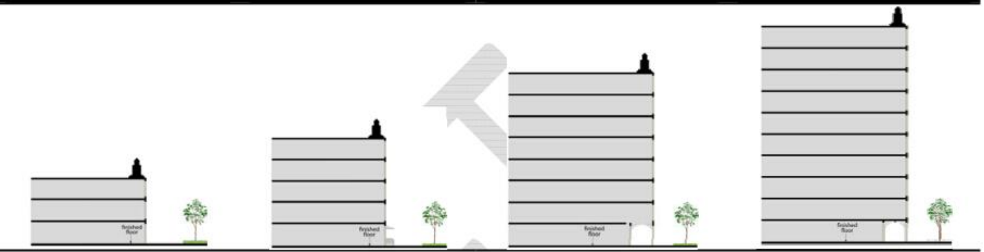
	T-3	T-4	T-5	T-6
A				
BLOCK STANDARDS				
Block Length (max.)	600'.	500'	450'	450'
DENSITY/INTENSITY*				
Building Coverage (max.)	60%	70%	80%	100%
Intensity (FAR/Density)	Must comply with Future Land Use Element			
Floor Area (max. 1st Floor)	NA	30,000 sq. ft.	NA	NA
LOT CONFIGURATION				
Lot Width.)	40' min/120' max	18' min.	18' min.	18' min.
BUILDING FRONTAGE				
Primary Frontage (min.)	50%	60%	70%	80%
Secondary Frontage (min.)	30%	40%	50%	60%
SETBACKS**				
Front/Street Side	12' min/20' max. Res. Garages 20 min.	8' min/20' max. Res. Garages 20 min.	8' (Build-to-Line)	8' (Build-to-Line)
Side (min.)	7.5'.	0' in T-4M/5' in T-4R	0' or 7.5'	0' or 7.5'
Rear (min.)	20'	3' or 15' (alley) 10' (no alley)	3' or 15' (alley) 10' (no alley)	3' or 15' (alley) 0' (no alley)
CIVIC SPACE (Sec. 30-5.13)				
Requirement per site	25% min.	15% min.	10% min.	5% min.
Playground	YES	YES	YES	YES
Plazas	NO	NO	YES	YES
Squares	NO	YES	YES	YES
Greens	YES	YES	YES	NO

Figure 4-8. Specific regulations for Gainesville FBC transect zones. A) Part I, B) Part II. Source of image: Littlejohn Engineering Associates. (2012). City of Gainesville Land Development Code Update/ Form-Based Code Draft.

B



	T-3	T-4	T-5	T-6
BUILDING HEIGHT				
Minimum	NA	NA	24 ft.	24 ft.
Maximum	3 stories	5 stories (8 with bonus*)	8 stories (10 with bonus*)	10 stories (12 with bonus*)
FLOOR HEIGHT				
First Floor (min non resid./res)	12'/NA	12'/NA	15'/12'	15'/12'
Additional Floor(s)	NA	8 ft. min.	8 ft. min.	8 ft. min.
Base Floor Elevation (Res)	1.5 ft. min.	1.5 ft. min.	1.5 ft. min.	1.5 ft. min.
PRIVATE FRONTAGE ZONE (Section 30-5.12.D)				
Storefront	NO	YES	YES	YES
Gallery	NO	YES	YES	YES
Arcade	NO	NO	YES	YES
Forecourt	NO	YES	YES	YES
Stoop	YES	YES	YES	YES
Porch	YES	YES	NO	NO
Street walls	YES	YES	YES	YES
Fences	YES	YES	NO (unless adjacent to residential district)	NO (unless adjacent to residential district)

Figure 4-8. Continued.

As mentioned in the methodology chapter, researching the transferring specific FBC criteria into CityEngine scripts is on-going. It is the author's goal to be able to generate building models that fit every one of the FBC standards. Current with the time this thesis is written, the standards that can be applied as scripts are building height, floor height, setbacks, and FAR.

Gainesville FBC Results

It is more convenient to apply CityEngine rules to a layer instead of selecting individual features. Therefore before being examined in CityEngine, six new layers were exported from the parcel shape files of the study area based on different transect zones. Then each layer was assigned the designed rule template introduced in the methodology part. Due to the working environment settings from previous projects, the unit associated with CityEngine is meters. All of the data was transferred into meters before being processed in CityEngine. Here is a table listing all of the parameters used in the visualization process.

Table 4-2. Summary of study area's transect zones' regulations which are applicable with CityEngine FBC template

	Building Height		Floor Height		Setbacks		
	Minimum	Maximum	First Floor (min residential/ non-residential)	Additional Floor(s)	Front/Street Side	Side (min)	Rear (min)
T3	NA	2 stories	NA/ 3.0	NA	3.7 min / 6.1 max	2.3	6.1
T4(R)	7.3 meters	4 stories (with bonus)	NA/ 3.7	2.4	2.4 min / 6.1 max	1.5	3.0
T4(T)	7.3 meters	6 stories (with bonus)	NA/ 4.6	2.4	2.4 min / 6.1 max	1.5	3.0
T4(M)	7.3 meters	8 stories (with bonus)	NA/ 4.6	2.4	2.4 min / 6.1 max	0	3.0
T5	2 stories	10 stories (with bonus)	3.7/4.6	2.4	2.4	2.3	3.0

T3 Sub-urban

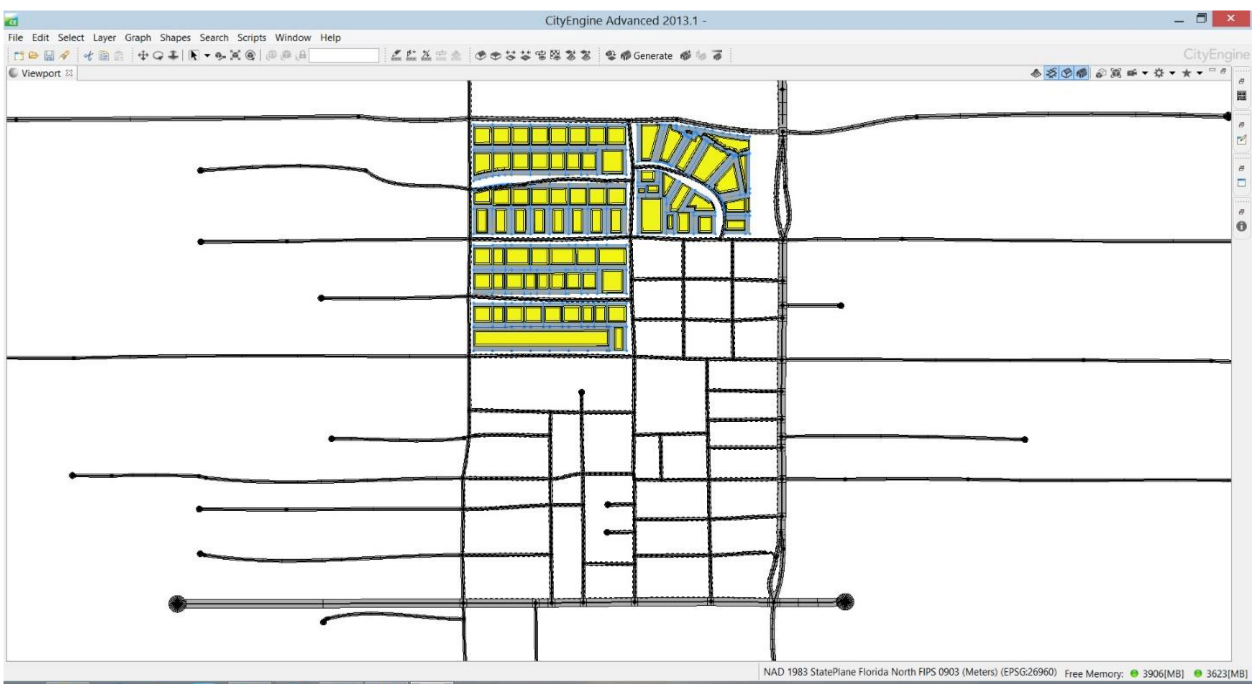


Figure 4-9. 3D modeling results of T3 transect zone within study area.

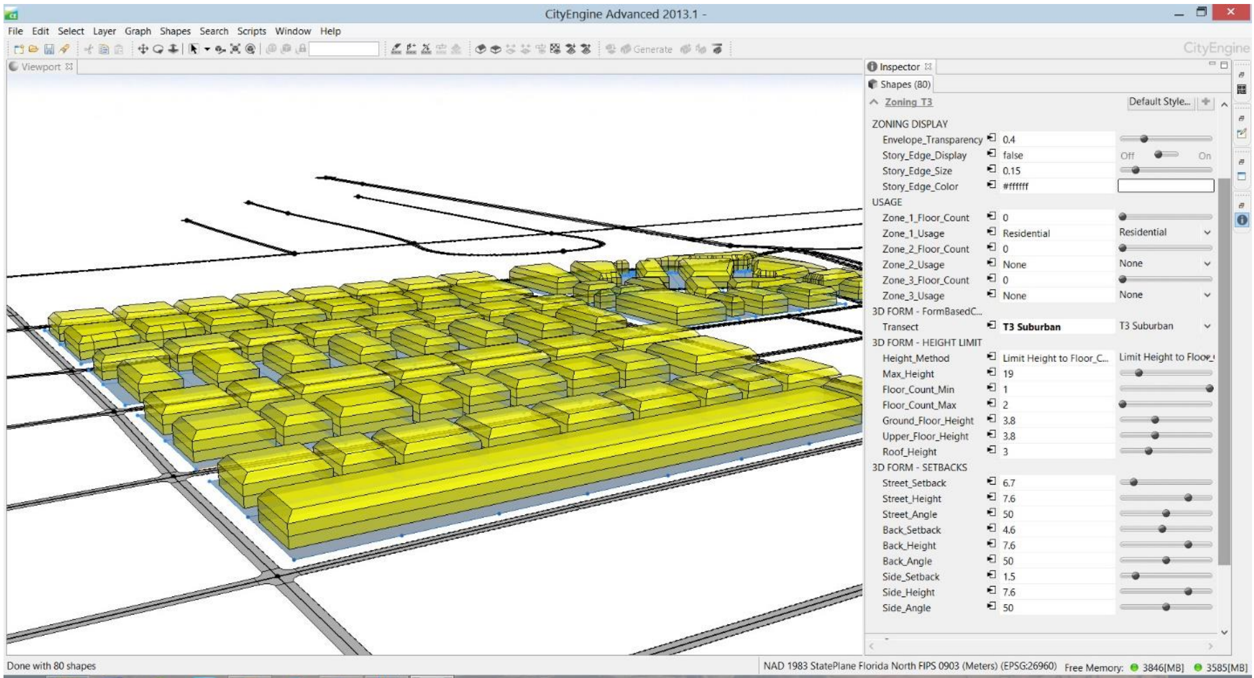


Figure 4-10. T3 area with inspector window.

The area of the red circled parcel below in Figure 4-10 is 99317 square feet. If it is built as a whole parcel, the result is as shown in the figure above. However, as a parcel zoned in the suburban area, it is not likely to only build one building such as this on just one parcel. Therefore the parcel is subdivided based on the minimum number of the lot width, which is 40 feet (12.2 meters) in this case. Results show that multiple buildings are generated on that parcel, on which the scale is more consistent with buildings adjacent.

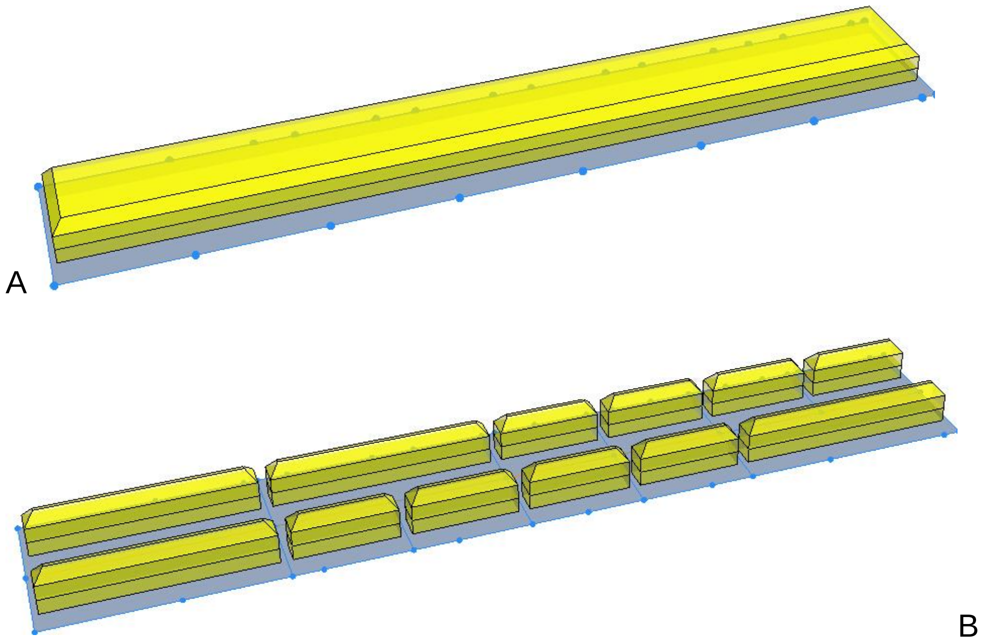


Figure 4-11. Results of parcel subdivision. A) Before subdivision, B) after subdivision.

T4 (R) General Urban (Residential)

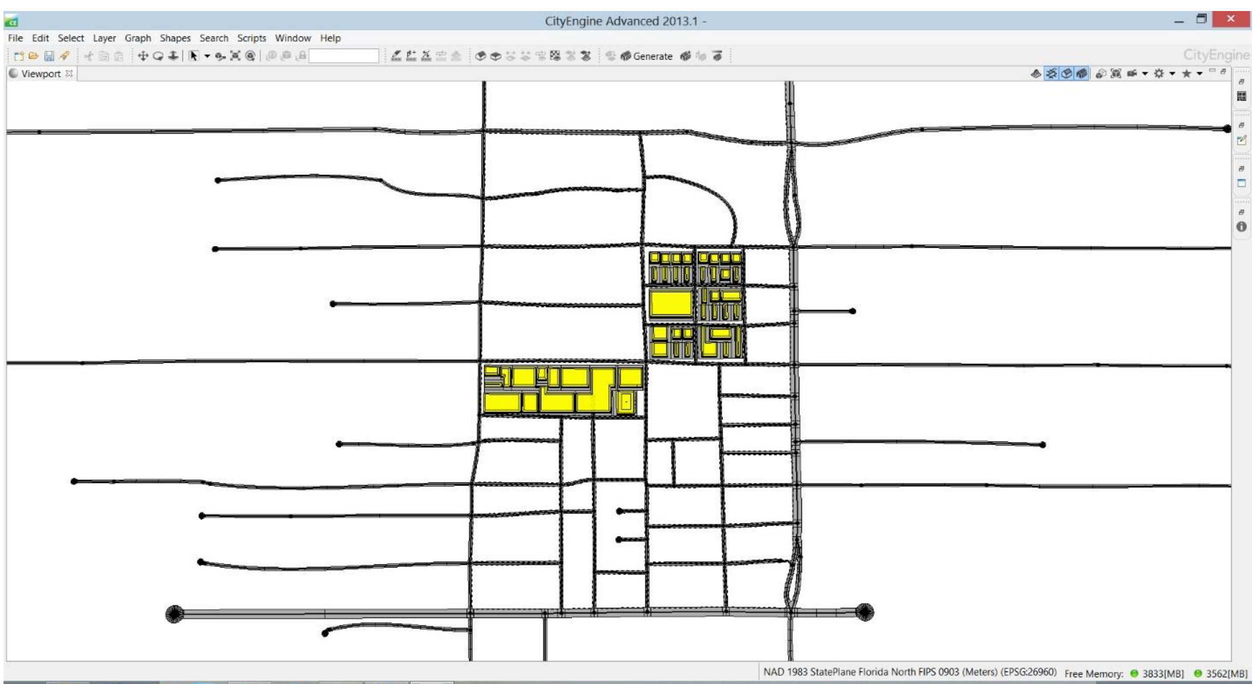


Figure 4-12. 3D modeling results of T4(R) transect zone within study area.

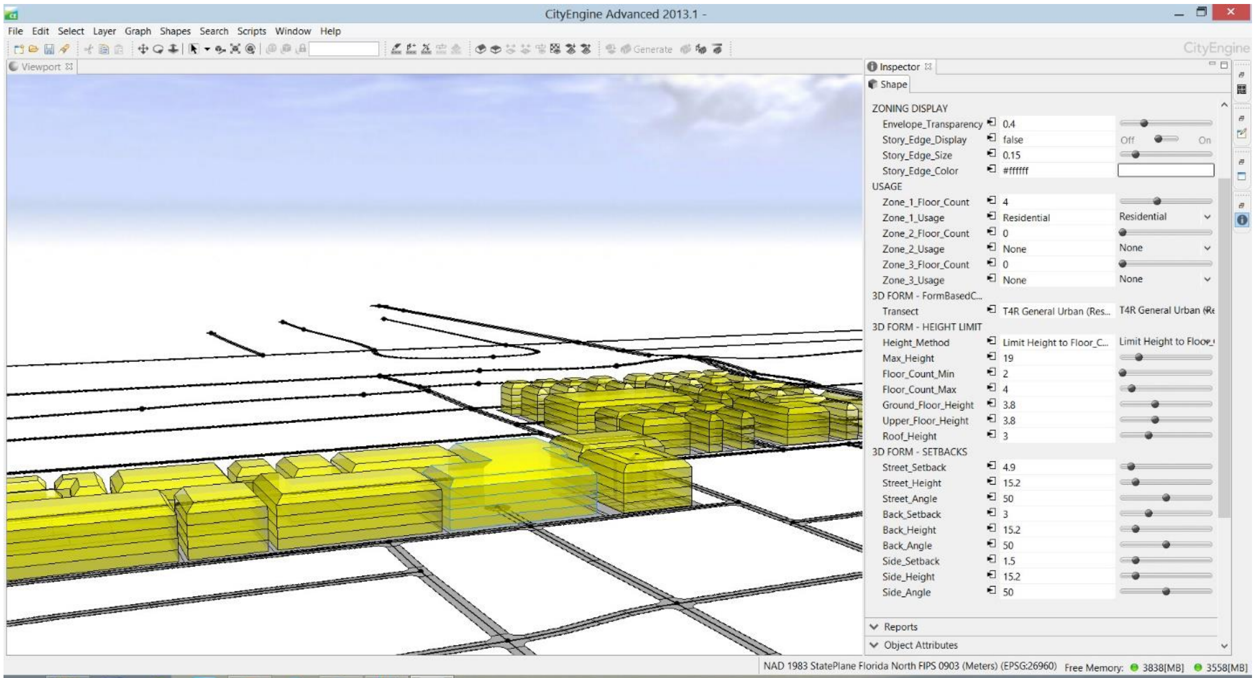


Figure 4-13. T4(R) area with inspector window.

T4 (M) General Urban (Mixed)

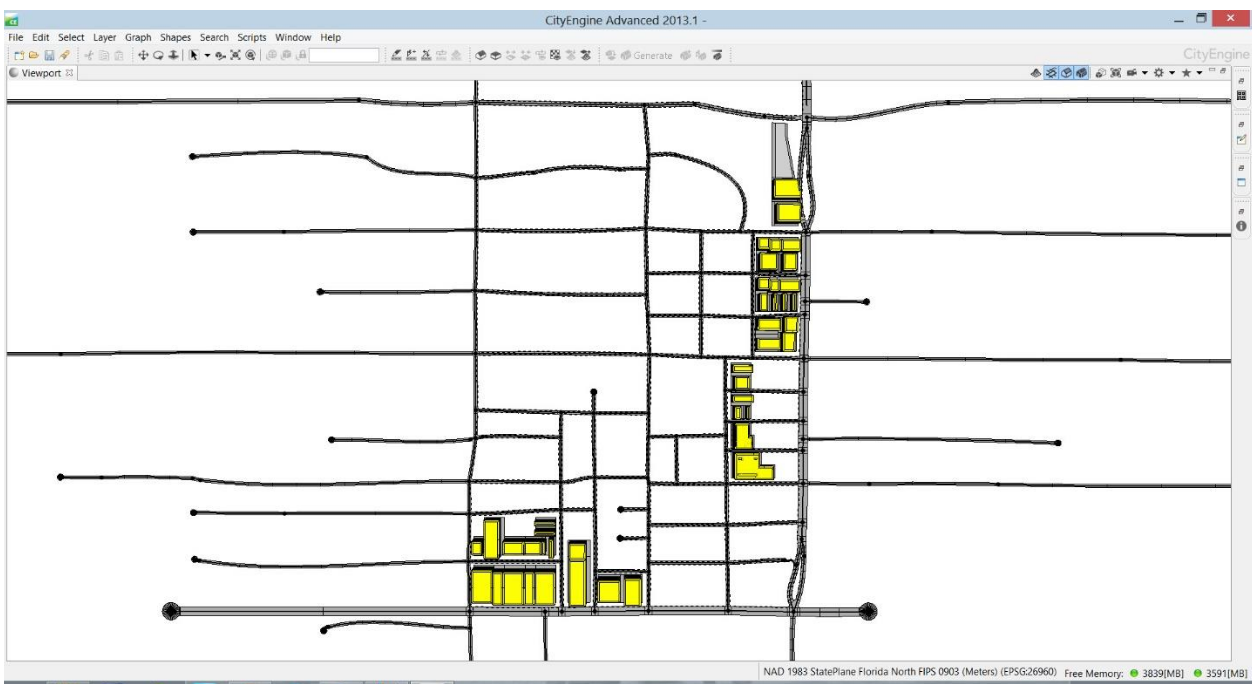


Figure 4-14. 3D modeling results of T4(M) transect zone within study area.

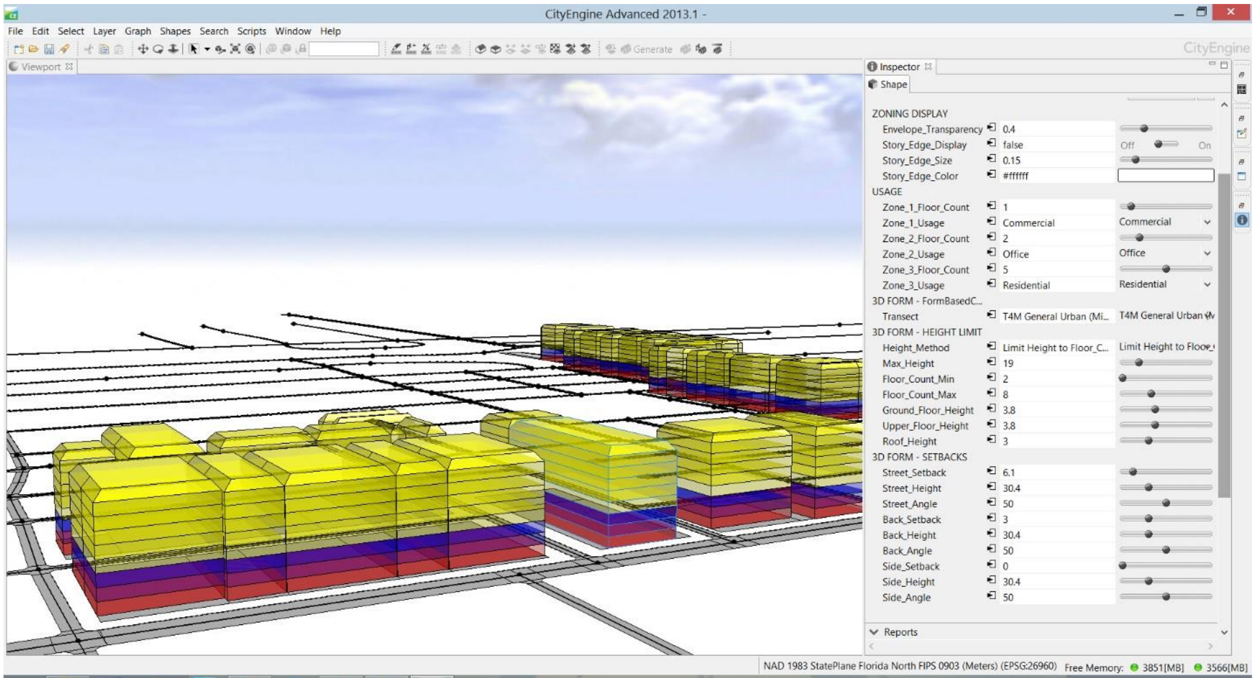


Figure 4-15. T4(M) area with inspector window.

T4 (T) General Urban (Transit)

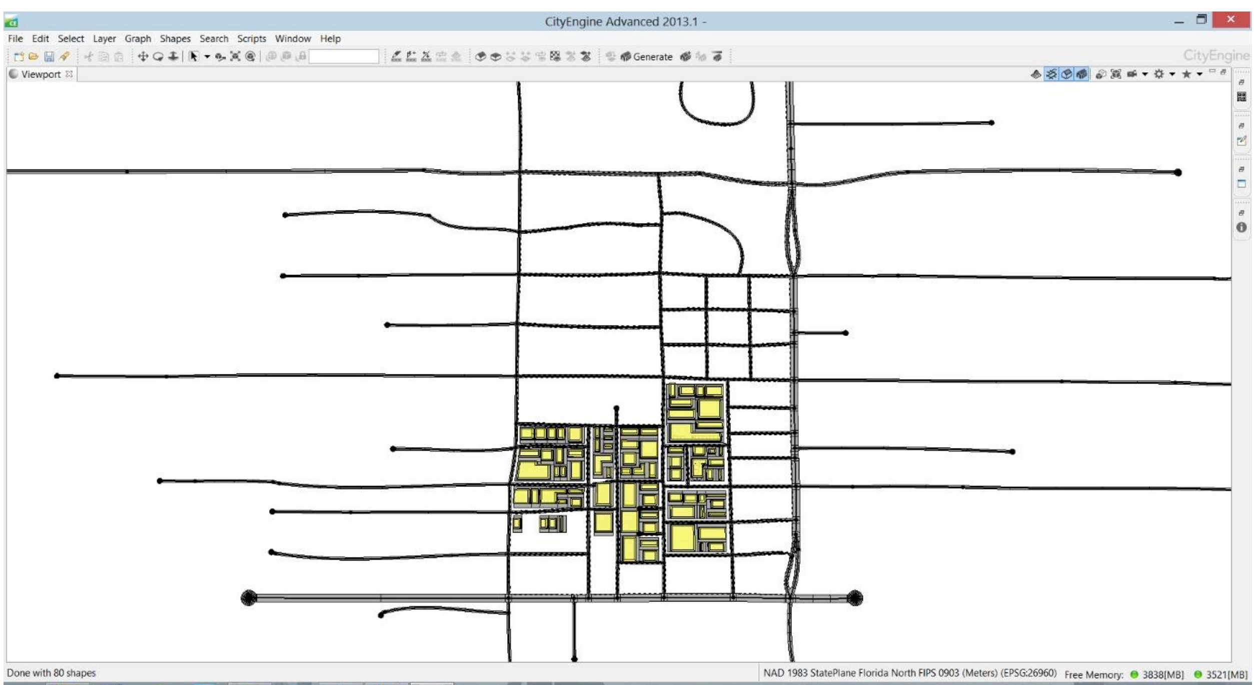


Figure 4-16. 3D modeling results of T4(T) transect zone within study area.

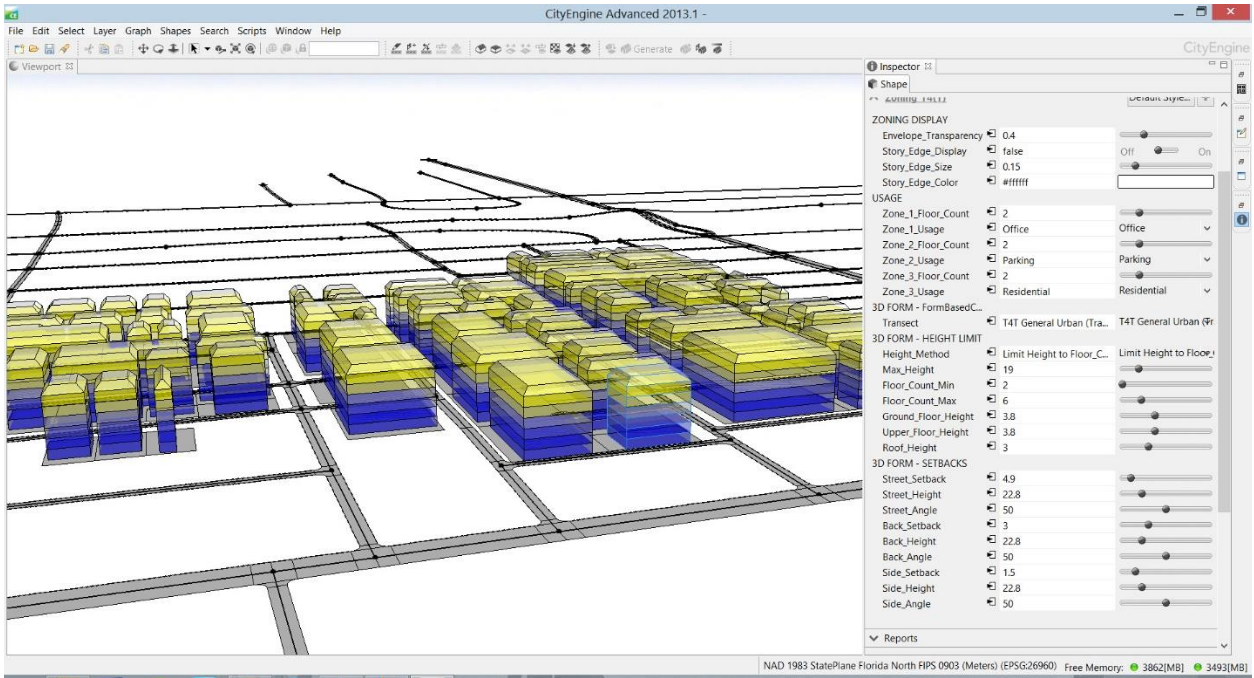


Figure 4-17. T4(T) area with inspector window.

T5 Urban Center

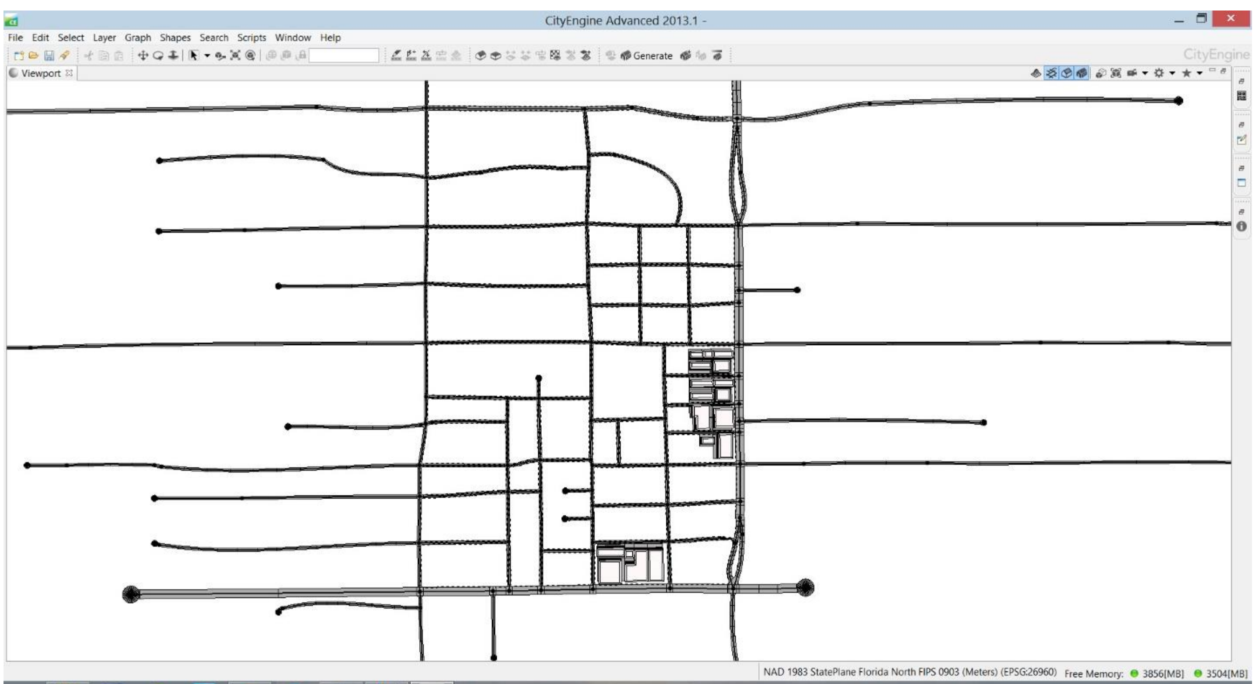


Figure 4-18. 3D modeling results of T5 transect zone within study area.

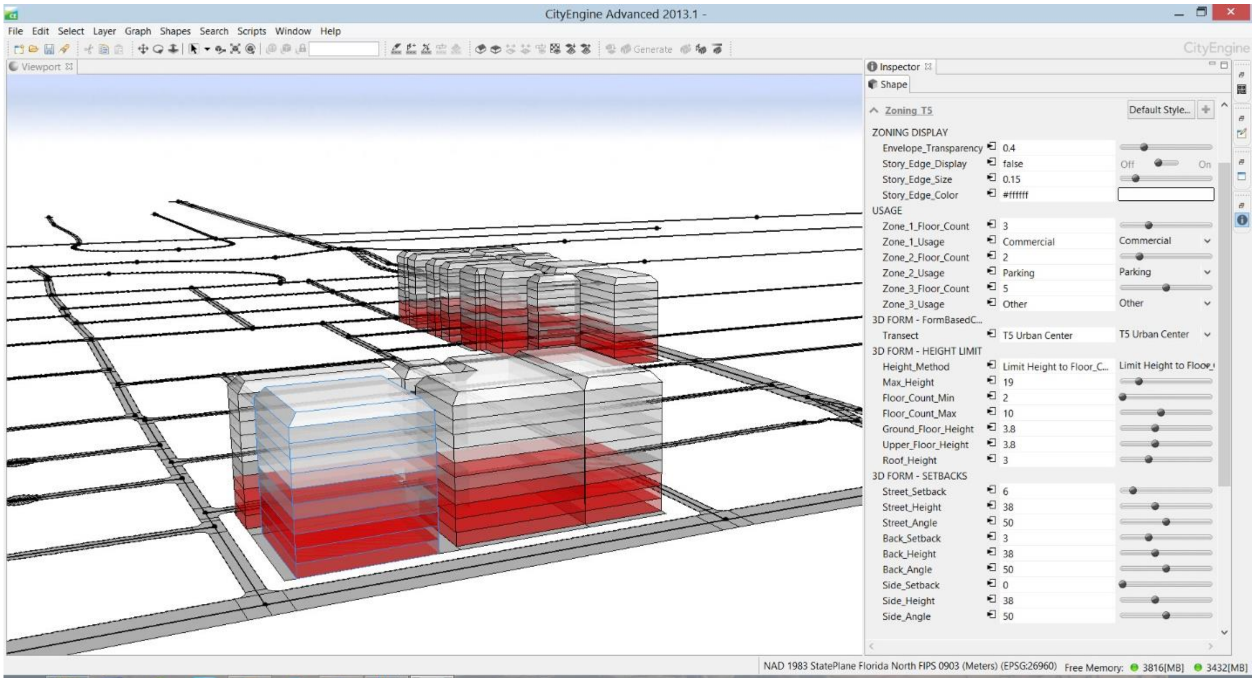


Figure 4-19. T5 area with inspector window.

Study Area FBC Results

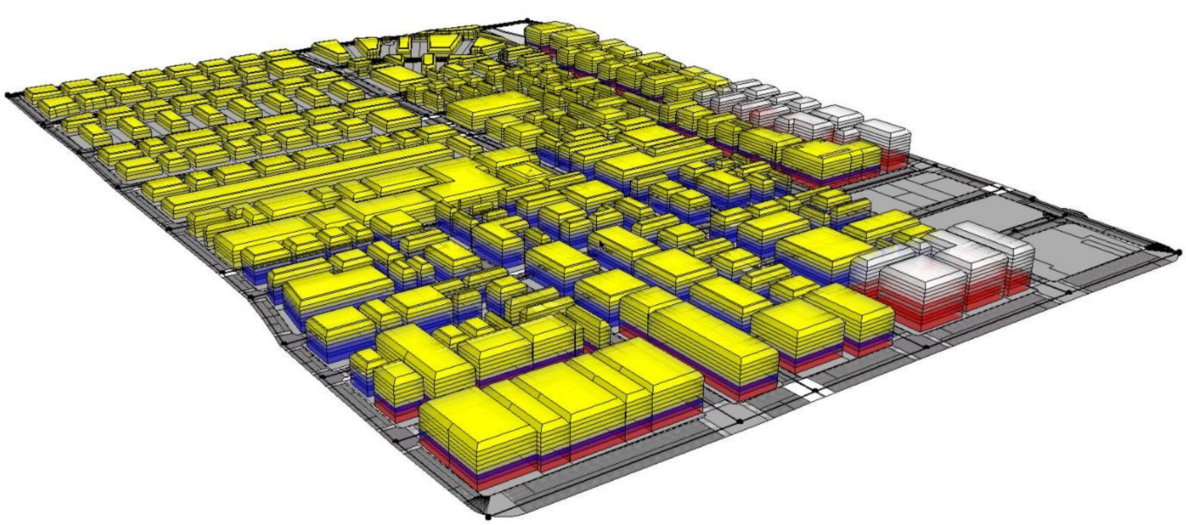


Figure 4-20. Study area FBC 3D modeling results.

The models displayed above are building envelopes that are allowed to be built within the range of the FBC. They can be, but are not necessarily, the actual buildings' shapes. However, any future developments of the study area have to be built inside of the envelope range. As mentioned above, the purpose of FBC is to decrease urban sprawl and to increase the density. In addition, FBC regulates the urban form by setting regulations such as minimum and maximum building height, and setbacks in each transect zones. After being compared to the existing building models, FBC models have increased the urban density.

CHAPTER 5
DISCUSSIONS AND FURTHER STUDIES

This chapter evaluates the effect of applying FBC regulations to CityEngine 3D modeling. Both advantages and disadvantages of the method will be discussed. In addition, this chapter will explain how the research results can be approved, and how the research results can be used with other urban planning processes.

Evaluation

This thesis introduced a method to create 3D city models in procedure planning results display. After being compared to the existing building models, the FBC models show a gradually increasing density among transect zones.

Advantages

First of all, 3D modeling is a more direct way to show planning results. In this case, the transparency of the building materials provides the chance for users to check whether the existing buildings or new development designs fit into the FBC development envelope.

Secondly, the FBC 3D modeling template created in the methodology part provides users with the convenient user interface in which the function of a building can be controlled, which includes both the use type of each floor and the number of floors in each type. In the example below, user can adjust the number of floors in each “zones” of a building by dragging the control bar in the inspector window, or by typing the number directly. The building model changes accordingly.

Thirdly, in order to better sharing the modeling results, CityEngine comes with generating web scene function. Web scene is “limited extent 3D scenes that can be shared on the web via ArcGIS Online or your own web server.”

(http://events.esri.com/uc/QandA/index.cfm?fuseaction=answer&conferenceId=CCAEEE69-1422-2418-7F1D0EB8490B776D&questionId=4911) CityEngine web scene can also be published to online GIS, where people can have the access to view and leave comments on the models. If not published, web scene can be viewed offline on the host's computer. From the public's participation point of view, checking a CityEngine web scene does not require CityEngine installed. As long as the model creator shares the browser link with public, people can easily view the models by opening a browser. In the real planning review process, certain link of a design's web scene can be provided to the public. Public can leave comments right at a certain building model in the web scene. For a redevelopment plan such as the Gainesville FBC plan, displaying both before and after scenarios with the swipe function in the web scene makes it easier for people to understand the plan visually.

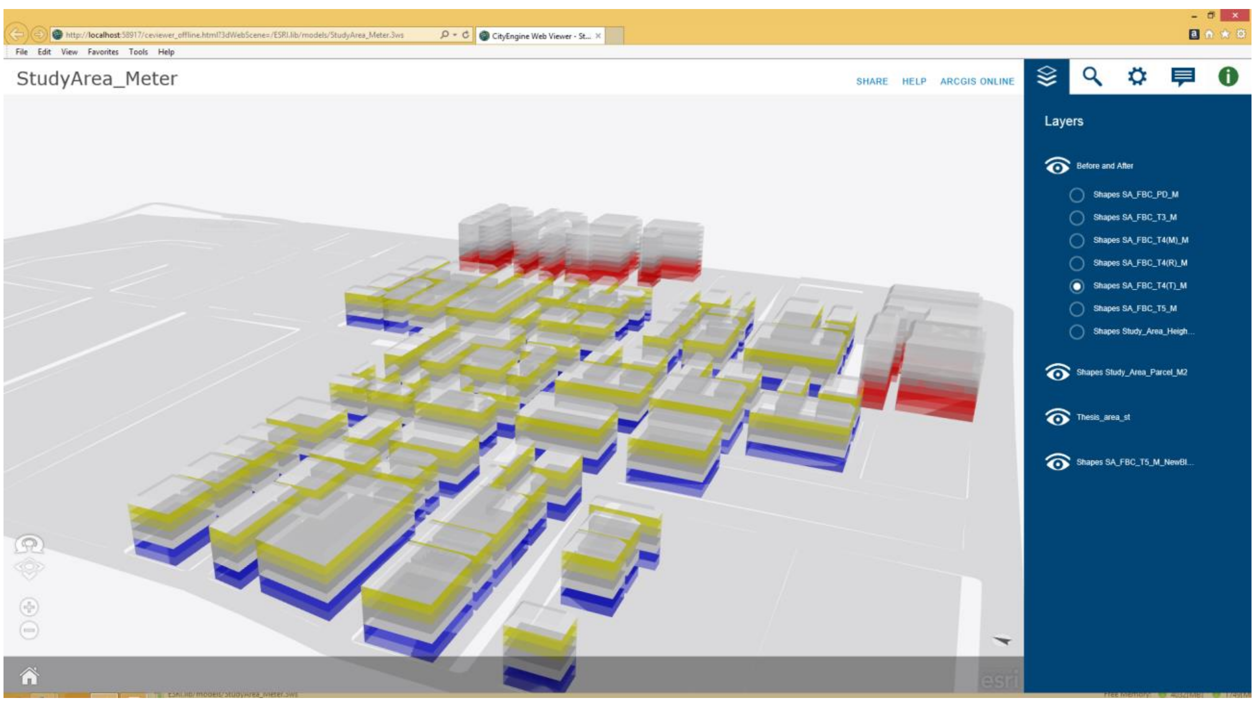


Figure 5-1. Web scene generated from the results.

Last but not least, CityEngine works better with large scale procedure modeling. Compared to other software, rule-driven modeling method takes less time when working with unified regulations.

Disadvantages

CGA coding process takes time for users who do not have computer programming background. The purpose of the methodology part of this thesis is to create a template that covers all the criteria of FBC. When applied to different cases, users just need to adjust the attributes' values. However, not all the regulations in FBC are covered in this thesis. It is the author's goal to cover as many regulations in the future study.

The created scripts can be improved. Some attributes can be added to user inspector window to make the user interaction friendlier, such as the transparency of the model. Because of the size of existing parcels, some of the building models are too narrow. In future studies, one of the methods is to better the scripts to only build buildings on parcels that are not smaller than a certain number. Otherwise user will receive a warning and change the parcel size manually.

When being imported into ArcScene, applied with "CityEngine" tools, massive CityEngine models cannot be regenerated easily. Compared with CityEngine, ArcScene lacks the ability of procedurally generating massive models. However compared with ArcScene, CityEngine is not flexible at 3D analysis. It would make users' work easier if the 3D analyzing skills of CityEngine could be improved.

Further studies

3D modeling is a tool to visualize urban planning results or theories. FBC 3D models can be used with other urban planning processes.

First, for urban designers, FBC 3D models offer a design frame that fits zoning regulations for each parcels. When comparing the urban design to the zoning regulations, it is easy for designers to make adjustment. For land use planners, generating buildings with given FAR helps to visualize the actual buildings based on future population density and allocation situations. It is in the author's future research goals to combine land use suitability results and population allocation results with FBC 3D visualization. For this part, the future study will focus on examining the consistency of FBC with land use suitability. Then build buildings based on population projection and allocation results. In addition, compare the building to the FBC building envelope, and make adjustment to the buildings that violate the zoning regulations.

Second, research is needed regarding how to better engage the public in the policy and decision making process. Further studies can focus on using web scene to involve public into planning review process, especially on how to make it realistic for public to select a certain building by searching the parcel id in the attribute table, swipe the window to view the urban form changes, and leave comments on the new development or plan.

Finally, future research is needed to focus on the analysis of CityEngine results with GIS abilities. Further 3D analysis can be performed on the built 3D models. With ArcScene's 3D analysis abilities, shadow map of a building from certain time of the day can be generated. Advanced analysis such as skyline barriers, observer points, and visibility provide the opportunity to predict the future impact of the new development. Figure 5-2 shows the shadow map created for Philadelphia's new development, indicating the shadow impact on the park nearby. ArcScene results can be shared through web scene as well. This additional function adds to the importance of 3D display in public participation process.

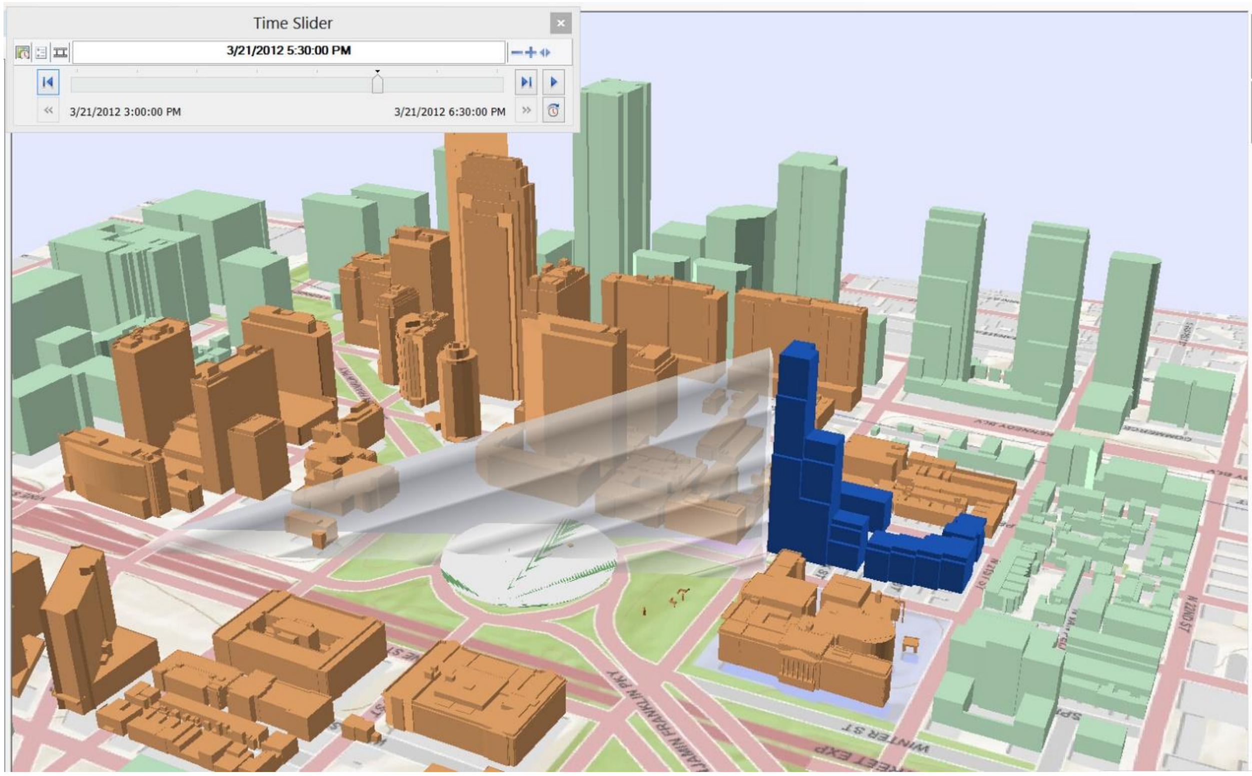


Figure 5-2. Arcscene screenshot from Philadelphia example.

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BIOGRAPHICAL SKETCH

As the province that has the most minority groups in China, Yunnan is known for its culture diversity and urbanization complexity. Growing up in the capital city of Yunnan Province, Leilei Duan experienced rapid changes and recourse exploitation in her hometown. With an initial interest in obtaining skills to make cities better places to live in, Leilei received a bachelor’s degree in urban management at East China University of Science and Technology. Leilei pursued a Master of Arts in urban and regional planning at University of Florida to better understand the important factors in urban planning. Concentrating in GIS and land use analysis, Leilei will continue her research career as a doctoral student of urban and regional planning at University of Florida.