A Praxis on Parametric Design;
An Exploration of CityEngine as a Tool in the Development of Urban Design Scenarios

by

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"A landscape architecture that sees the world as emergent and self-creative is one that will help to build a republic of humans and non-humans that explore their common world, adjusting it and improving it as they go"

(Bruno Latour, *Politics of Nature*. 2004)

"A landscape architecture that does not design for a single moment in time but instead aims to establish a directed initial framework based on preexisting conditions, will allow natural landscape systems to evolve through "uncontrollable sequence[s] of successional changes and adaptations".

(Rod Barnett, *Emergence of Landscape Architecture*. 2013)

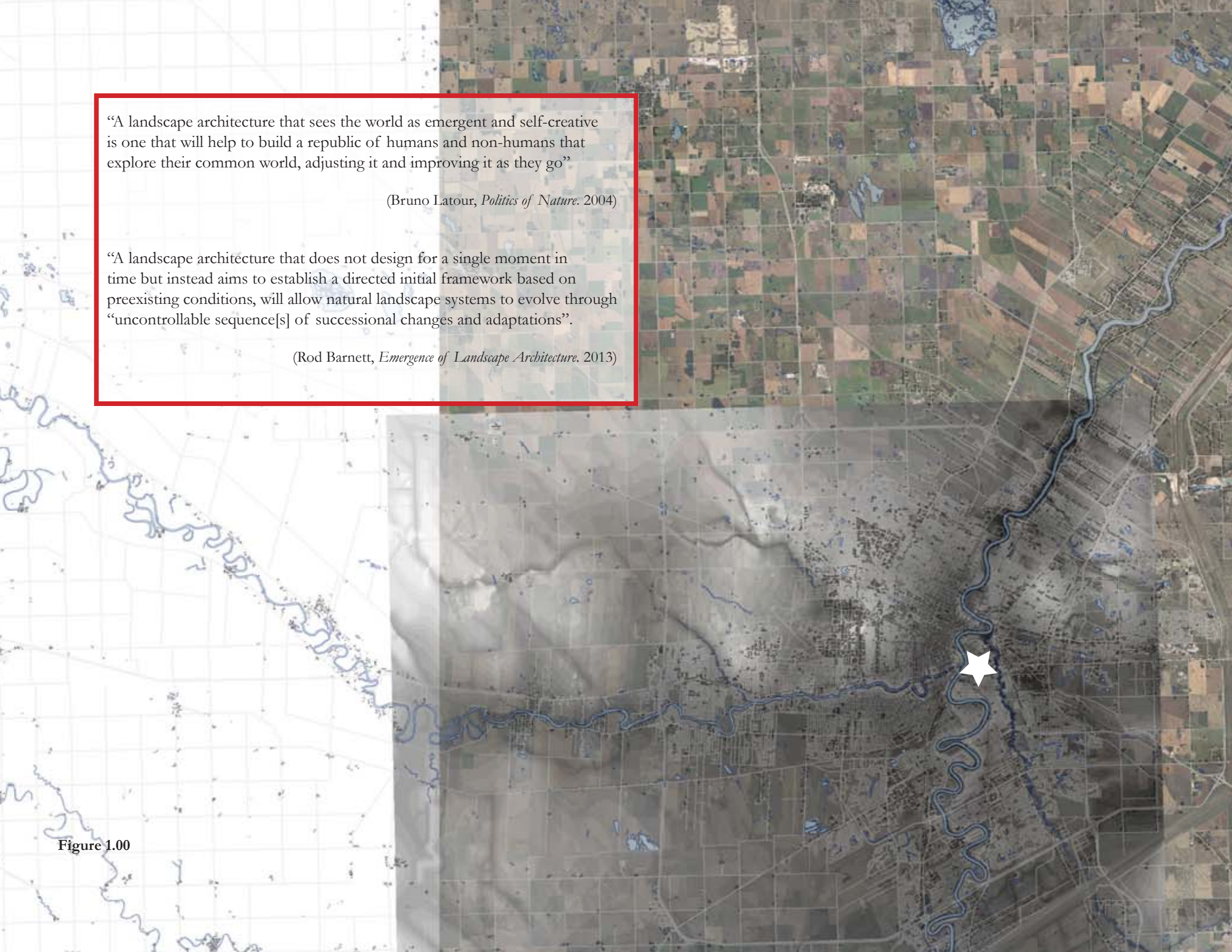


Figure 1.00

1.0 Introduction

I do not believe that landscape architects should create final products, but rather frameworks through which natural existing phenomenon can coexist, evolve and adapt, and bring together an evolving final existence. The world is not static; the image which we design on paper will never exist exactly the way in which we imagined and there are certain aspects, which we cannot account for or control in the natural world. Given this belief, this practicum is not intended as a final design; but rather constructed as praxis; an exploration of a parametric modeling software and its use as an integral part of the natural design thinking process; a simulation tool rather than a representational conclusion.

This exploration has granted me the understanding of a practical tool with the capabilities of generating multiple iterative urban frameworks that can be manipulated through variables and shared with multiple parties. The iterations generated may have potential to be constructed as the initial installed design framework, but it is the natural processes such as wind patterns, seed dispersal, animal migratory patterns that flow through the framework that have the potential to bring together an evolving "final design."

2.0 Thoughts on Landscape and Urbanism

The city and landscape used to be clearly separated, however "[given] the complexity of the rapidly urbanizing metropolis, [continuing] to oppose nature against culture, landscape against city – not only as negational absolutes but also in the guise of benign, complementary overlaps – is to risk complete failure of … mak[ing] any real or significant contribution to future urban formations" (Corner 28 2006).

As we simultaneously enter the Anthropocene and the urban age, the city will need to "subsume and homogenize its surrounding landscape in an economic and 'technological blitzkrieg' [as] the various scapes [are currently] in conflict with boundless definition" (Corner 26, 2006) As long consumerist living ideals continue to exist and people continue to want to raise their families in the suburbs, development will continue to sprawl out from the city centres. As development continues to expand outwards, it becomes even more imperative that all development be integrated with a full understanding of the ecological context of the land it is built upon and incorporate ecological processes for the health and stability of the city and the earth. The functionality and the processes of the landscape become more important than the aesthetic. The emergence of open systems within urban infill projects needs to be considered.

Landscape urbanism becomes a "lens through which the contemporary city is represented and a medium through which it is constructed" (Waldheim, 15, 2006) As landscape moves towards creating the overall framework of the contemporary city, it is imperative that we as landscape designers move towards a more thorough understanding of the medium through which we create.

The practice of landscape urbanism is about much more than the presentation of natural processes. It articulates the seemingly disparate realms of experience with the convergence of natural processes and the economic, social, political and the aesthetics of urban and rural conditions. Landscape urbanism plans the frameworks of the city's infrastructure to integrate the natural processes (wind, sunlight, food chains). It considers the self-creating nature of the world that functions and allows for a multiplicity of relationships to arise. It enables the capacity of the horizontal surfaces of the urban to "function as ecological vessels and pathways (Corner, 24, 2006) through both space and time.

By viewing the landscapes in which we exist, as a coalescent framework of a multitude of processes, these landscapes become phenomena rather than objects. They are no longer capable of being completely understood or defined and therefore there is no true and correct perspective, just different perspectives. While it is up to the landscape architects and designers to design and install the initial framework, the growing urban population will continue to add more insights on what is required of the environment.

3.0 Understanding Parametrics and CityEngine

Technology used in landscape architecture and urbanism as well as land development is always advancing and as the profession evolves it becomes imperative that available tools be tested and if conceivable, incorporated into the design process. One such tool that has recently emerged in the realm of landscape architecture is parametric modeling.

Parametric modeling is an associative process that generates geometry from sets of initial parameters designed with formal relations. It is founded on the principles of parametric statistics, which assumes data comes from a probability distribution that makes inferences about each of the parameters within the distribution. Parametric modeling allows for the use of variables and algorithms – based on parametric statistics - to generate a hierarchy of mathematical and geometric relations in order to produce a multitude of iterative and associative solutions for the same design problem. The associative nature of the model comes from the inferences being made by the parametric mathematical probabilities. It allows a change of a single variable by the user to infer and impact changes in multiple additional variables and in doing so "[begins] to assist design decisions in the earlier stages of schematic design and design development". (Wang, 350)

While there is a steep learning curve and the initial set of rules takes a substantial amount of time to create, the prospective technological capabilities of parametric modeling systems seem to indicate a technological advancement for landscape architecture, urbanism and development. The associative and procedural nature of the program exponentially reduces the overall time required to produce multiple design scenarios in comparison to more traditional tools such as hand drawing or other computer aided design software by automating a number of the base level decisions.

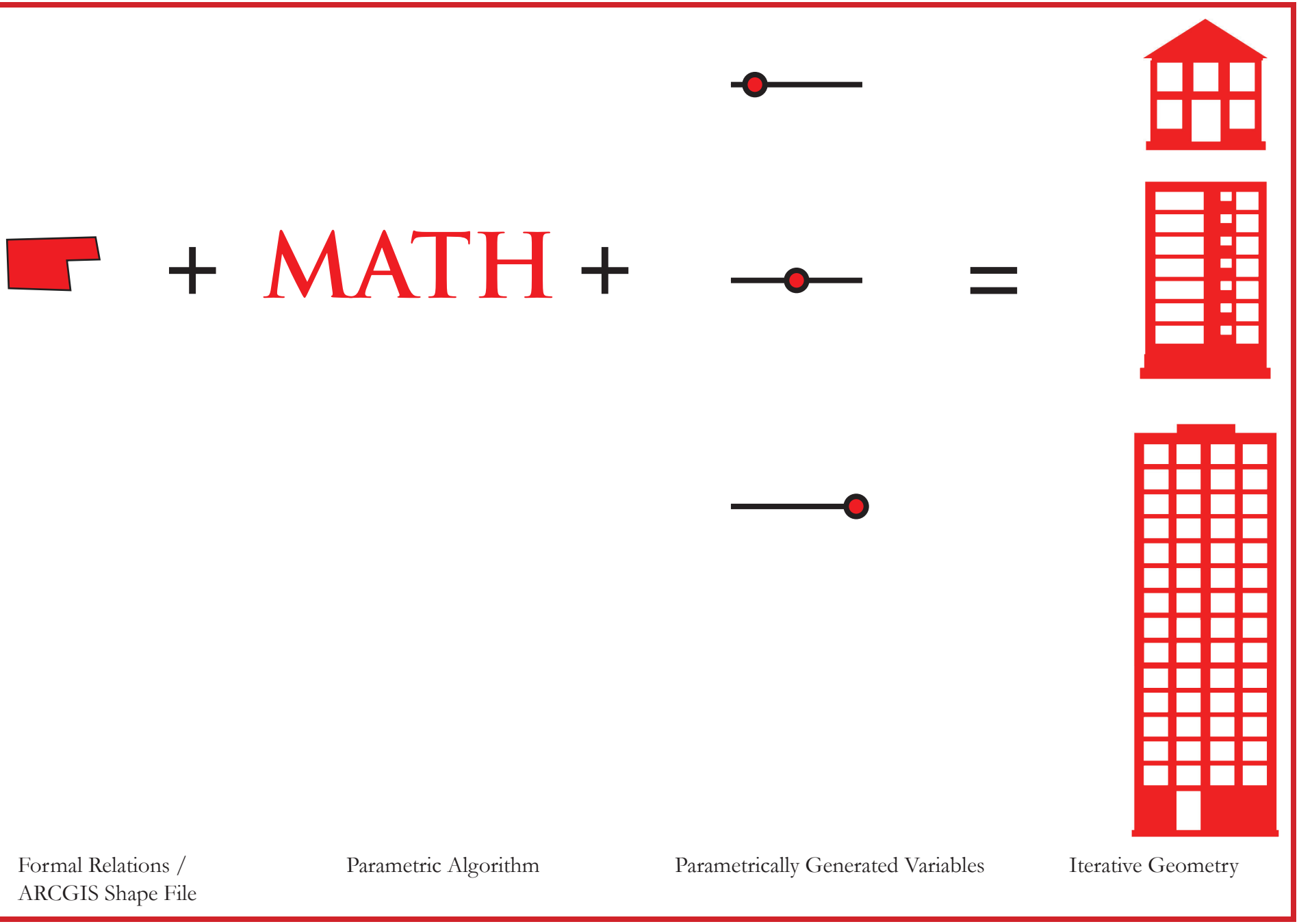

+ MATH +
=
Formal Relations /
ARCGIS Shape File
Parametric Algorithm
Parametrically Generated Variables
Iterative Geometry

Figure 3.01

CATIA

AutoDesk
3DS MAX

AutoDesk
Maya

AutoDesk
Revit

AutoDesk
Dynamo

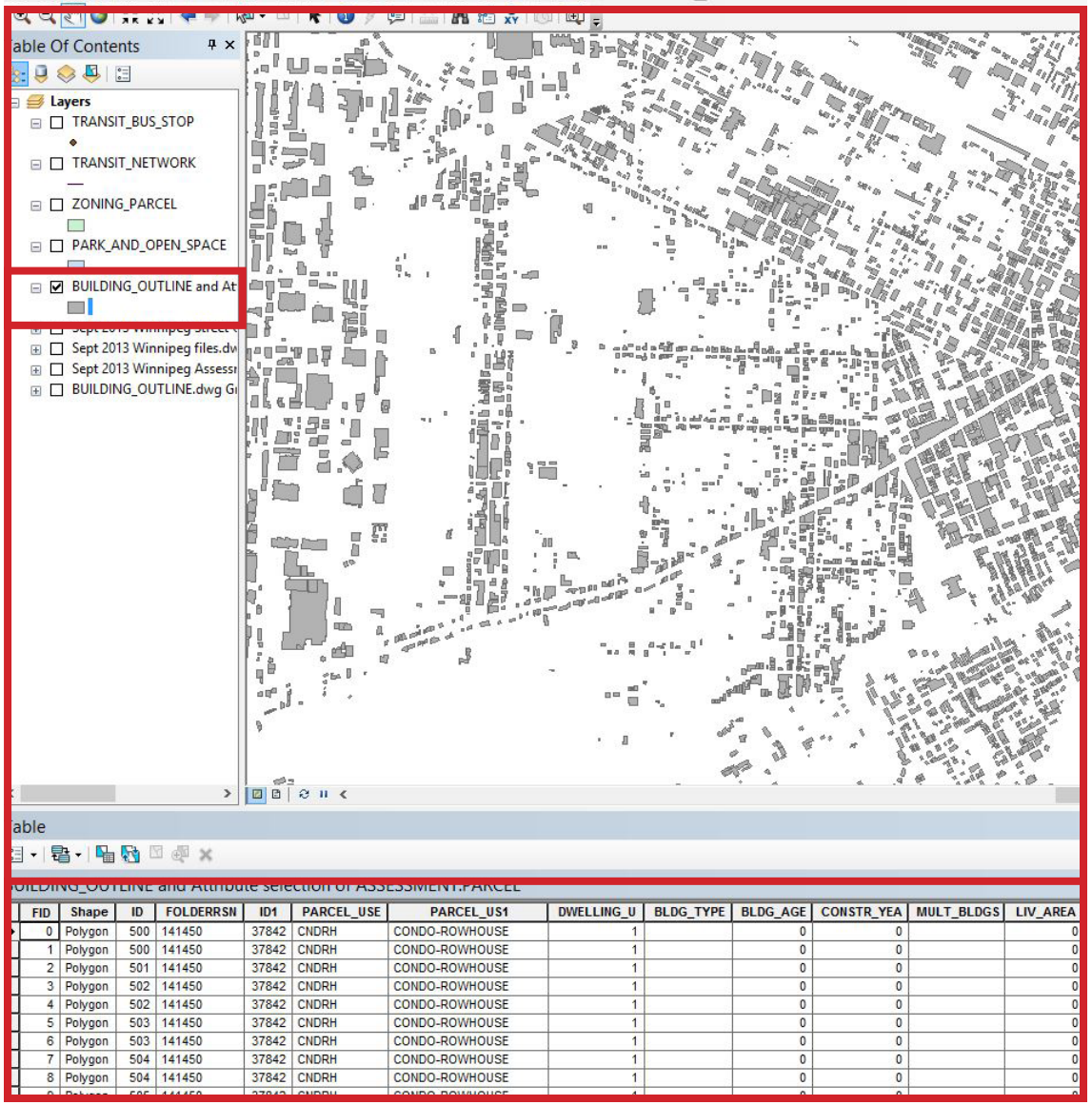
Grasshopper 3D

While there are several parametric modeling software products available, I have chosen to explore ESRI's CityEngine as its basic essence is founded in landscape architecture. It is developed by landscape architects and planners who were students of Jack Dangermound, the developer of ESRI, ArcMap and ArcGIS. Dangermound was a student of Ian McHarg and it is McHarg's principles of landscape planning that originally outlined ways in which development can be guided by ecological processes. CityEngine's fundamental link to ArcGIS allows data created in it to be geographically referenced, projected and linked. It also allows the data to be interconnected through imports and exports while being saved in the internal cloud. The interconnectivity capabilities of the program allow for a single CityEngine file to be shared with multiple users through ArcGIS, allowing for analysis to be completed on the project even without access to the program itself.

Figure 3.02

CityEngine gives the designer the ability to present a client with real time visual permutations and numerical reports of a project framework based on the clients thoughts of a particular variable(s). As an example, if a client wished to see how the streetscape changed based on having two entrances into their building from the street, instead of one, the associative process has the potential to instantaneously demonstrate not only the look of the clients building, but also the impacts that has on the streetscape in front in terms of hardscapes and plantings. It would also generate the difference in cost depending how the initial parameters are set up.

The fundamental link between ArcGIS and CityEngine begins with a basic understanding of ArcGIS. ArcGIS usually depicts a series of shape data within the city or region. The City shape files normally include, roads, buildings, green space, and utilities. In Winnipeg's building layer, each shape file depicted here includes a series of metadata or associated data that lends itself to multiple analyses. The metadata typically included within the building shape file is location, usage, address, population, building height and image of the exterior. It is generally depicted in a Table in ArcGIS.



FID	Shape	ID	FOLDERRSN	ID1	PARCEL_USE	PARCEL_US1	DWELLING_U	BLDG_TYPE	BLDG_AGE	CONSTR_YEA	MULT_BLDGS	LIV_AREA
0	Polygon	500	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
1	Polygon	500	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
2	Polygon	501	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
3	Polygon	502	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
4	Polygon	502	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
5	Polygon	503	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
6	Polygon	503	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
7	Polygon	504	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0
8	Polygon	504	141450	37842	CNDRH	CONDO-ROWHOUSE	1		0	0		0

Figure 3.03

Understanding this and watching a number of examples depicting existing city frameworks being generated through the metadata, such as this example of Philadelphia, my preconceived understanding of the program were slightly optimistic. At the outset of this practicum the purpose of understanding the parametric software was to be able to quickly generate the existing City framework in order to provide a base level City data set. This base level framework was to inform an additional assemblage framework of a smaller area that would be intrinsically linked to both CityEngine and ArcGIS data.

At the commencement of this undertaking, I understood CityEngine to operate by importing shape files, turning on a switch to create representational 3 dimensional forms based on the inherent metadata within the 2 dimensional shape data, and then to manipulate these forms through a series of preinstalled parametric variables. This all become dependent on the metadata sets associated with the shape files being complete.

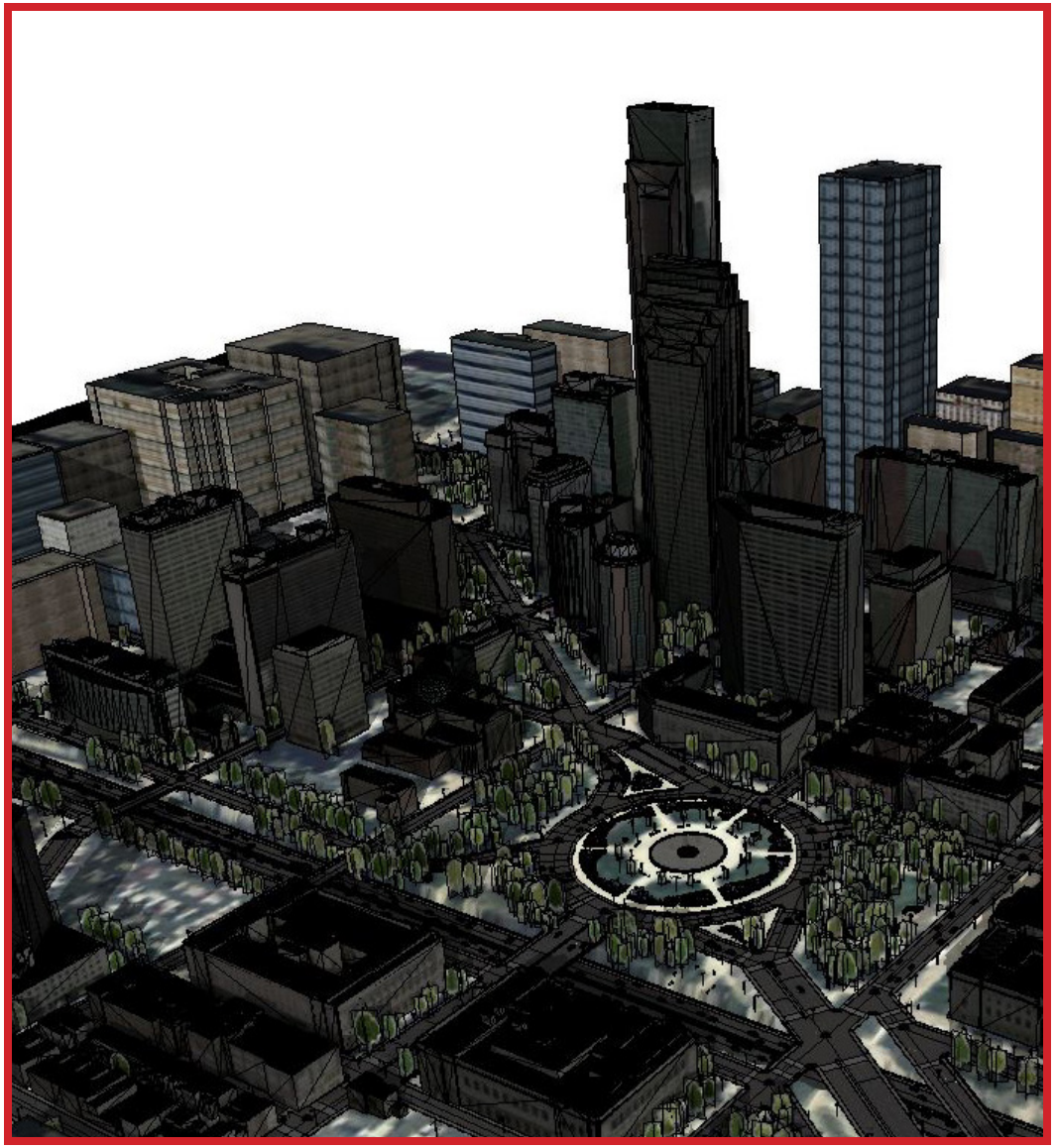
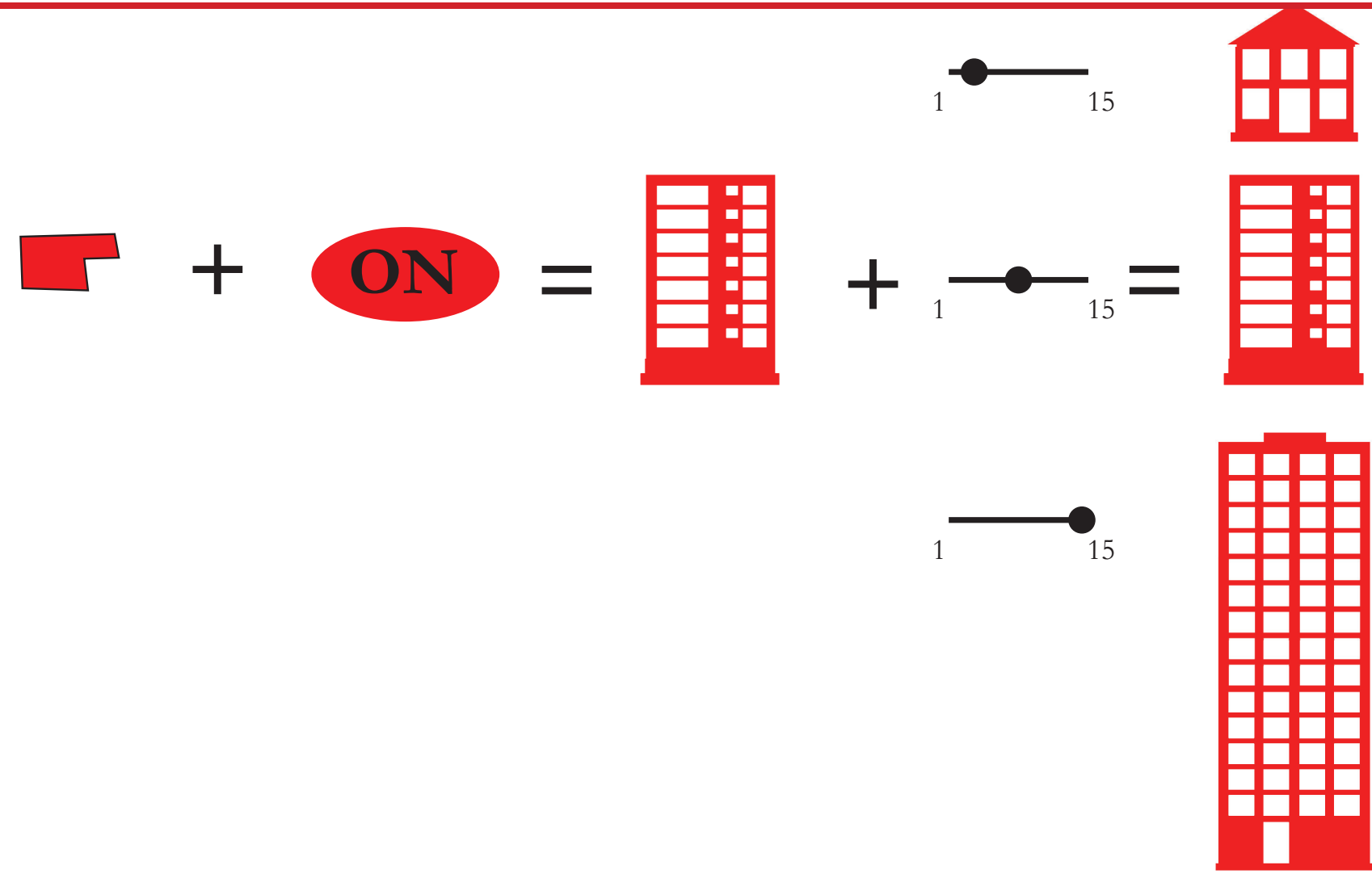


Figure 3.04 Still shot of Philadelphia being generated within a CityEngine demonstration. Taken From ESRI. *Example Urban Design 2015.*



Shape File

MetaData Switch

Three Dimensional Form based on real world existing data

Manipulation of a single Variable - as an example height

Parametric output. The change in the height also changed the roof and window type due to the associative nature of the parametric model

Figure 3.05

This exploration has uncovered the fact that most Canadian cities have incomplete Metadata sets. Winnipeg's building shape files are missing both the height and façade sections required to generate the existing city as shown in the promotional videos resulting in an error.

Figure 3.06

Preprogrammed Capabilities: Streets

The other aspect that was uncovered during the initial exploration of the program is that the pre-existing parametric variables are limited to streets, intersections and blocks and the simple alterations that can occur within them.

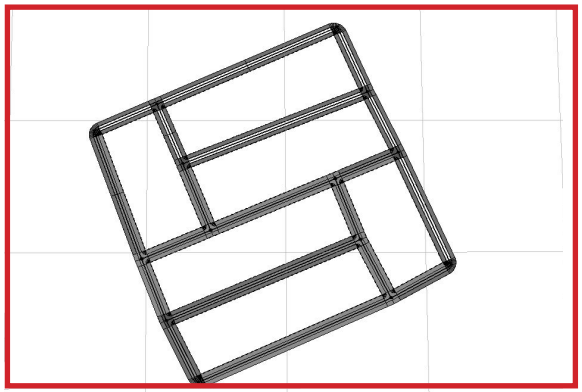


Figure 3.07 The Creation of streets.

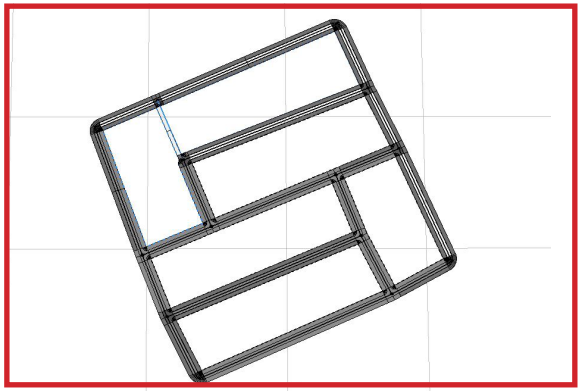


Figure 3.08 The manipulation of streets and sidewalks.

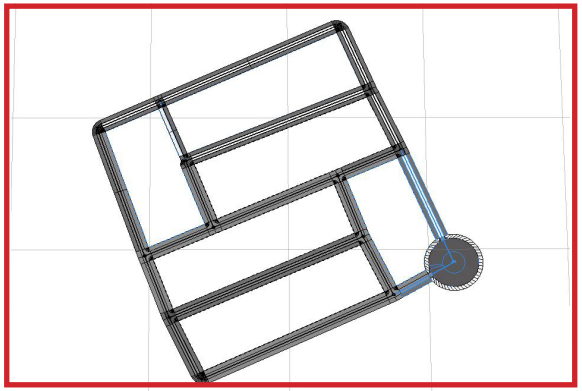


Figure 3.09 The creation of roundabouts and the manipulation of intersections.

Preprogrammed Capabilities:
Streets

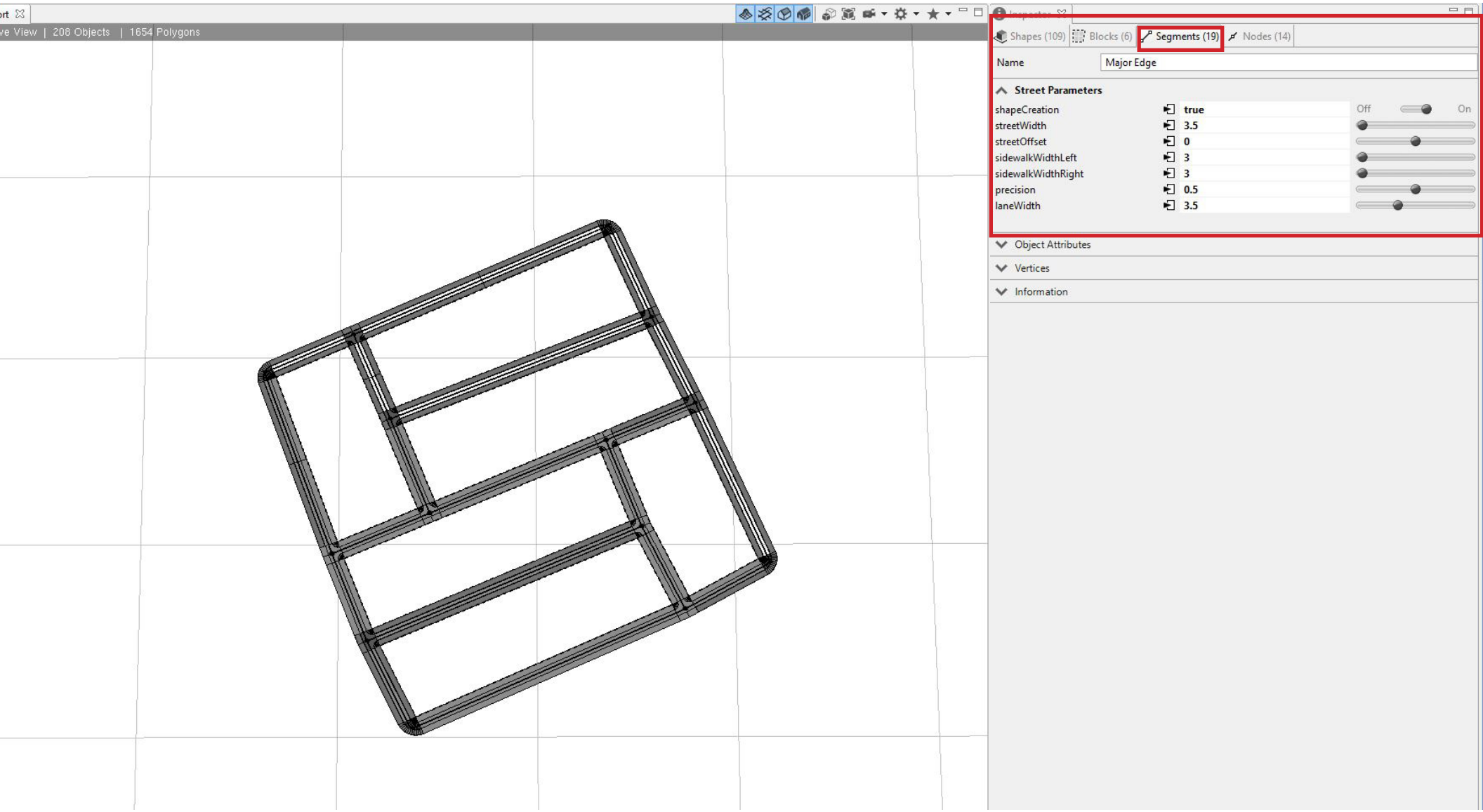


Figure 3.10 Streets are capable of being generated.

Preprogrammed Capabilities:
Streets

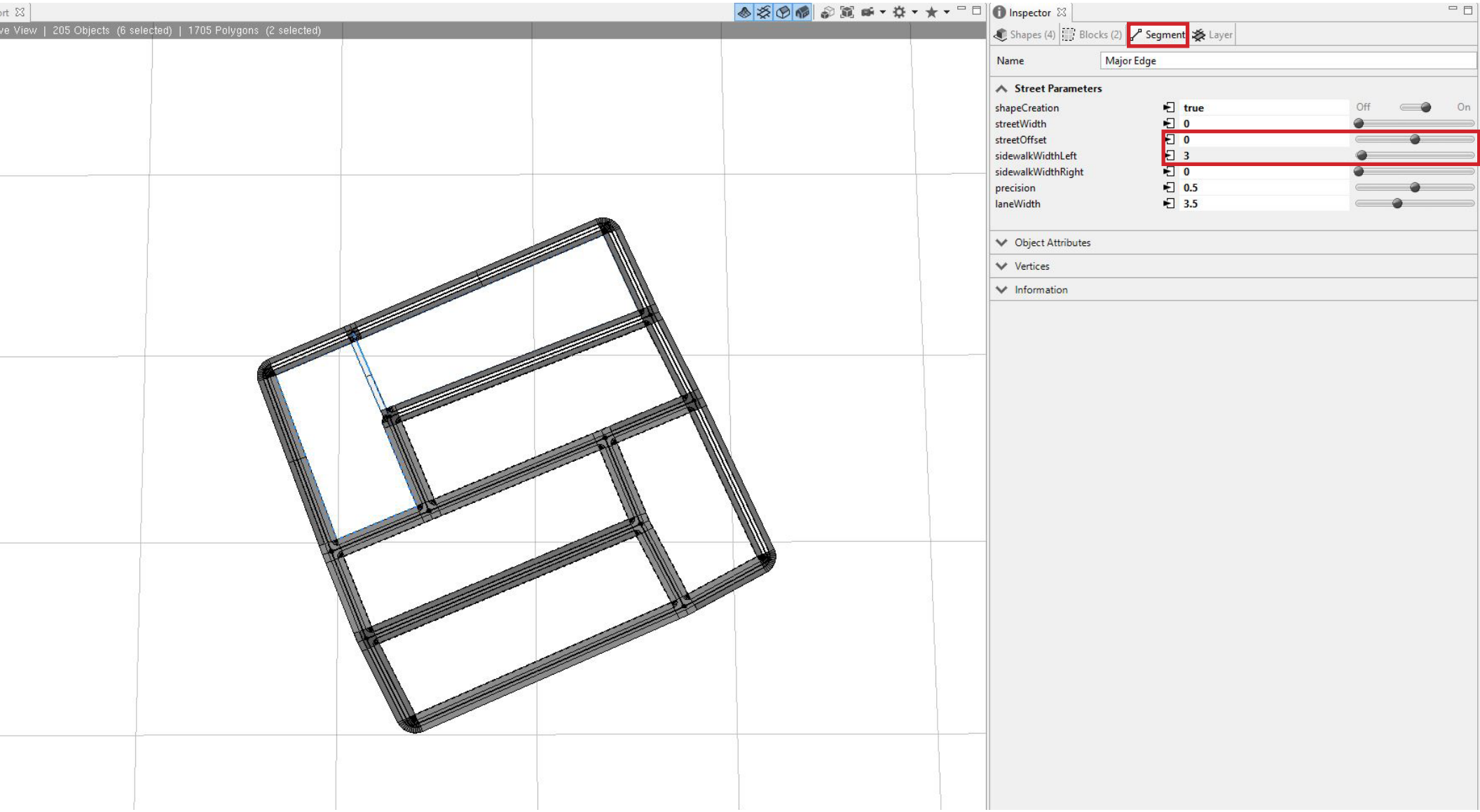


Figure 3.11 The street width and sidewalk widths are capable of being manipulated.

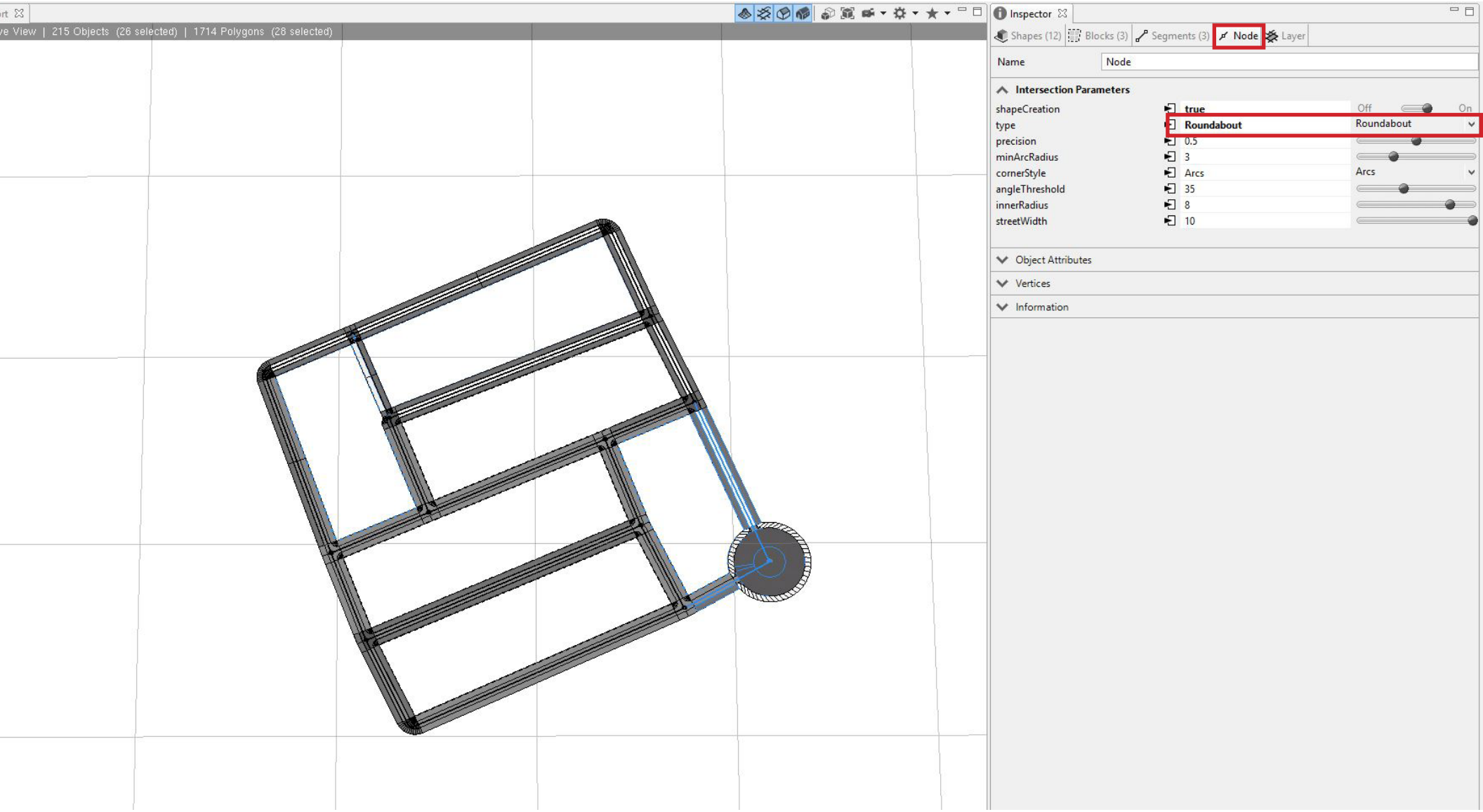


Figure 3.12 Intersections are capable of being manipulated. They can be changed into three-way or four-way stops as well as intersections.

Preprogrammed Capabilities:
Blocks

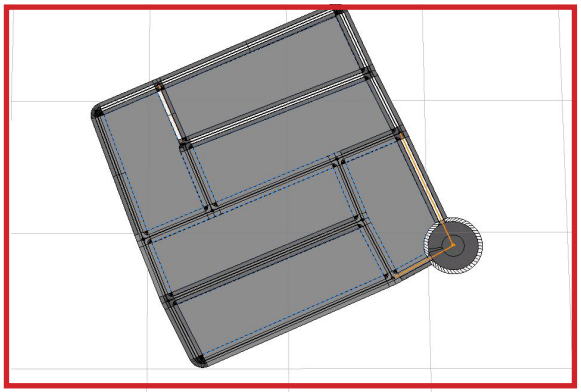


Figure 3.13 The Creation of blocks.

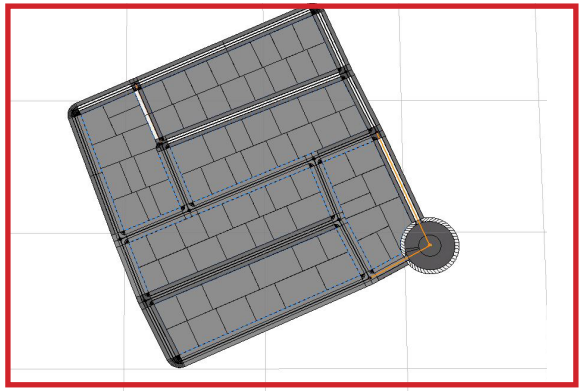


Figure 3.14 The creation of an offset subdivision.

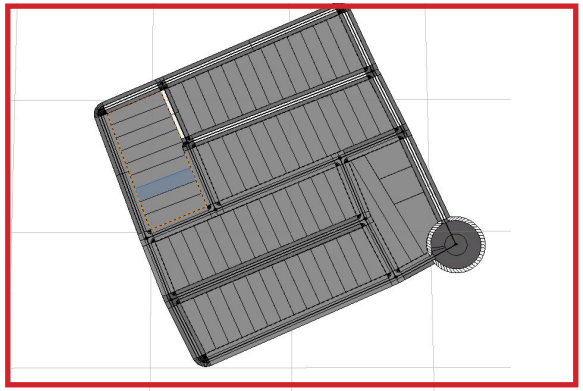


Figure 3.15 The creation of a straight lot subdivision.

Preprogrammed Capabilities:
Blocks: No Subdivision

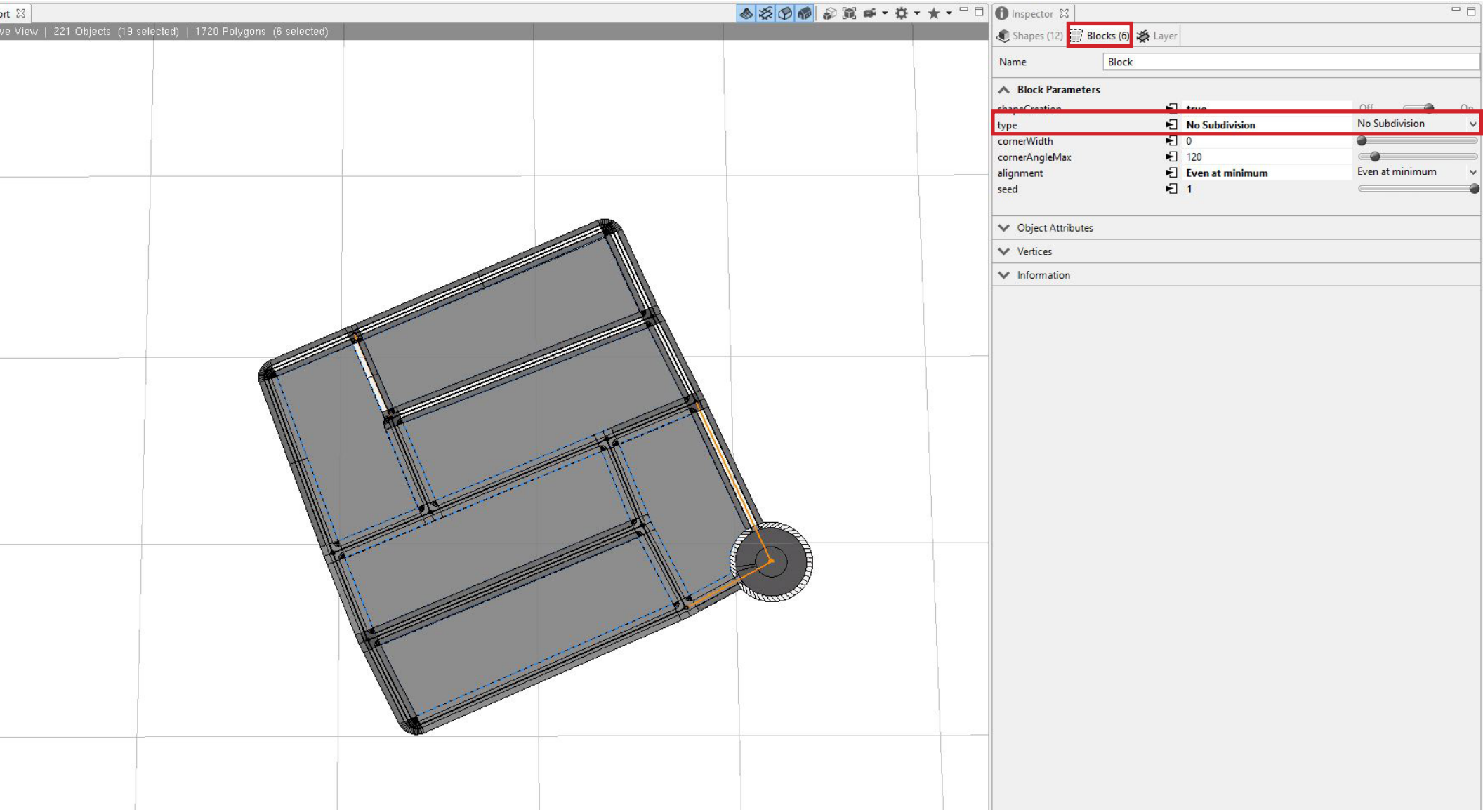


Figure 3.16 Blocks are capable of being generated.

Preprogrammed Capabilities:
Blocks: Offset subdivision (or Medieval subdivision as per Schenk)

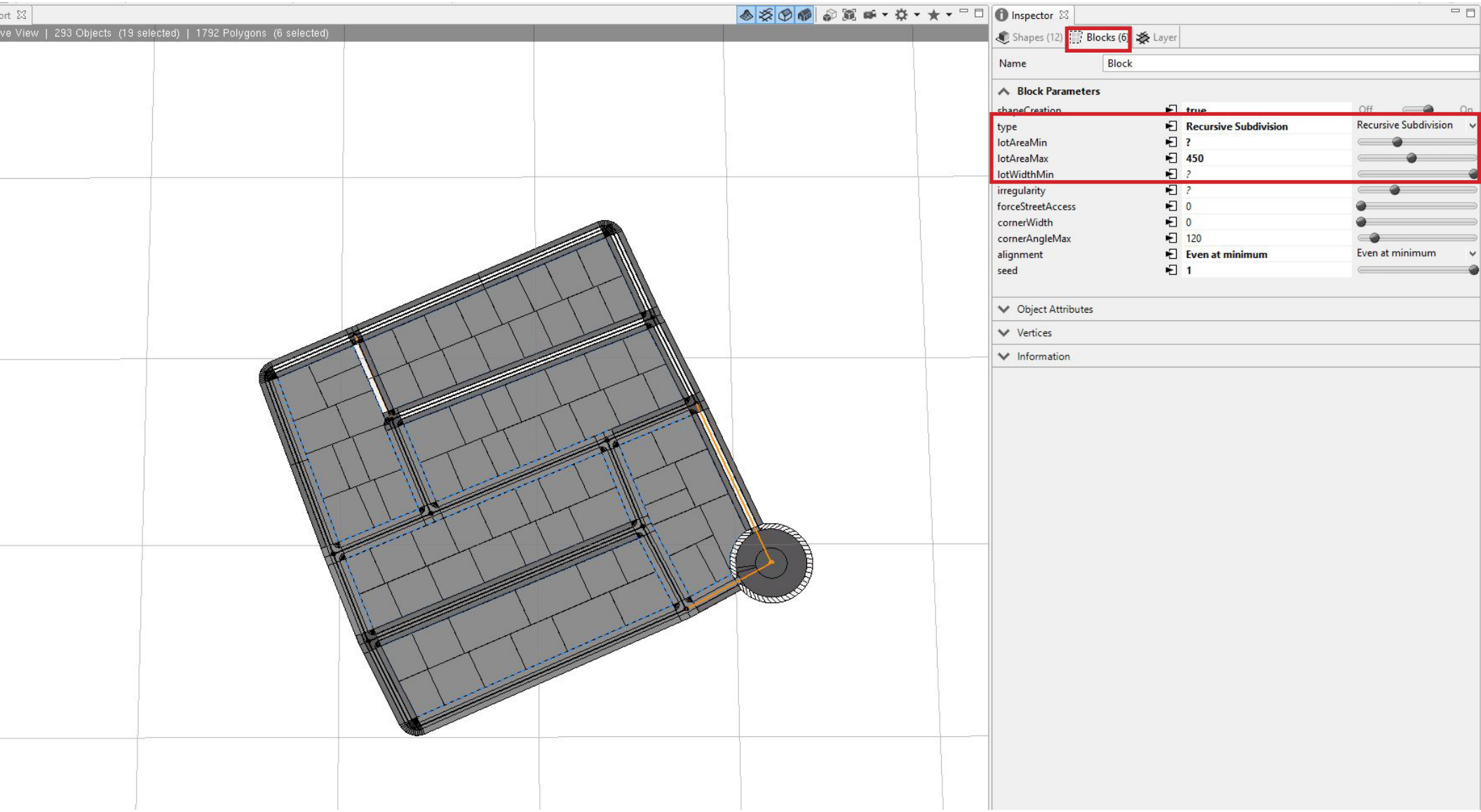


Figure 3.17 Blocks can be further subdivided and manipulated through the lot widths and lot areas.

Preprogrammed Capabilities:
Blocks: Straight Lot Subdivision

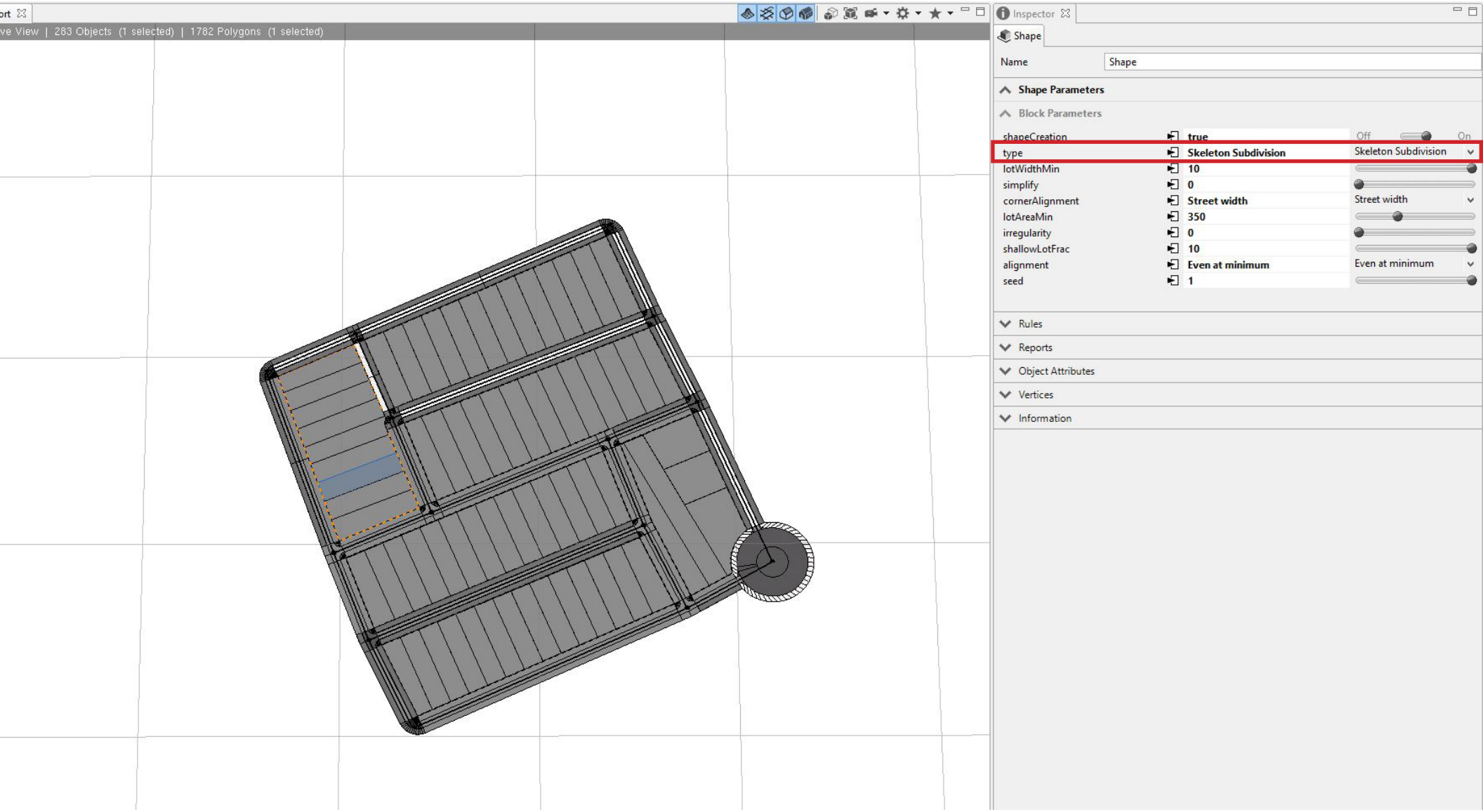


Figure 3.18 The blocks can be subdivided into straight lots as well.

4.0 Creation of the Rules

Once I understood the limited nature of the preinstalled parametric variables, it became evident that I would have to learn the programs computer code in order to generate serviceable parametric variables to create the preconceived urban frameworks.

Developing the Base concepts for Urban Design Tools through the reading of *Designing Cities*.

Hours of reading and writing computer scripts.

Three Dimensional Form.

Manipulation of a single Variable which have been redefined through LEED Neighbourhood.

Parametric output. The change in the height also changed the roof and window type due to the associative nature of the parametric model.

Figure 4.01

The exploration of the parametric software continued through the reading and manipulation of codes written by ESRI. Going through each line of the code and manipulating it by editing, removing and adding different lines has enabled the manipulation of the parametric representation, variable capabilities, visual output and reports. The initial understanding of the computer code has become crucial to the understanding of the framework of the software.

Several resources helped influence the creation and manipulation of several rule sets. Leonhard Schenks Designing Cities was a critical source that assisted in designing the base level ideas for the urban design tools. LEED Neighbourhood Design has been used to further refine these tools by providing the parameters through their three tiered rating systems.

1. Smart Location and Linkage
2. Neighborhood Pattern and Design
3. Green Infrastructure and Building.

The City of Winnipeg's zoning bylaw has further refined the parameters to a Winnipeg context.

LEED Neighbourhood Design is a standard best practice rating system for planned neighbourhoods and development based on the combined principles of smart growth. These parameters have been incorporated as default numbers associated with several of the rules in order to bring a sense of reality to their foundation. They prove to be more important as the rules become more complex.

Smart Linkage and Location proved to be important in the selection of sites. It was decided that two sites would be selected to determine whether the rules created are transferable to different topographic conditions. It was important that a site I was working on with my work at Qualico Communities Land Development was used in this practicum so that I could continue to be involved with the site as my work obligations increased without losing focus on the practicum. With multiple sites available to choose from, Smart Linkage and Location helped determine the two sites which became the focus of the practicum. The first site which most of the work has been done with is a 1.5 acre site in St. Boniface at the corner of Tache and Darveau. The second site which has been incorporated to determine the transferability of the rules is an 8 acre site in between Kenora and Keewatin on the banks of the Lake of the Woods.

Neighbourhood Pattern and Design has been used to provide the default numbers associated with the several of the rules and prove to be especially influential in the advanced building rule. It may be a better practice to set the neighbourhood pattern and design parameters up as a range, so that any scenario that not meeting the range specified is flagged as being non-compliant in the visual output and corresponding notes reflected in the reporting tool. The Reporting tool could inform the user of which variable in the scenario is not meeting the LEED parameters and its cost to the project, whether monetary or LEED status.

As an example, one of the LEED ND parameters is that 15% of new buildings have to meet a minimum of 1:3 height to street width minimum. If the built simulation does not meet this parameter and only has a height of 1:4, the reporting tool should inform the user of the resulting impacts. Does this reduce the possibility of LEED Gold and reduce it to LEED Silver? Is LEED status still possible? What are the cost implications, both initial and potential revenues? This may help the user decide whether LEED certification is worth the cost or not. At the same time the visual output simulation provides an idea of the look that could be expected.

4.1 Site Selection Alpha
St, Boniface 1.5 Acre Site at the Corner of Tache and Darveau

Points which this site would receive from LEED ND

1. It is located on a site which is currently served by existing water and wastewater infrastructure.
2. It is an infill site which has previously been developed.
3. It is adjacent to existing neighbourhoods with excellent connectivity opportunities.
4. It is adjacent to a transit corridor, with a potential Rapid Bus Transit Station being implemented 20 metres to the South.
5. It is nearby neighbourhood assets including parks and restaurants and within a 20 minute walk to the nearest Hospital.
6. It is located within a high priority location.
7. It is located within an existing bicycle network.
8. It has the potential to include 30% affordable housing based on what is currently built around and the mandates of the local government.
9. It possess opportunities for a 30% nonresidential built component, and will have more potential if the RBT proposal goes through.
10. It takes into consideration the slope of the site as it has no slope over 15%
11. It is within 15 degrees of the East West Axis.

Figure 4.10

4.2 Site Selection Beta
Kenora 8 Acre Site on the Banks of Lake of The Woods.

Points which this site would receive from LEED ND

1. It is located on a site which is currently served by existing water and wastewater infrastructure.
2. It is an infill site which has previously been developed.
3. It is adjacent to existing neighbourhoods with excellent connectivity opportunities.
4. It is adjacent to the Number 1 Highway.
5. It is nearby neighbourhood assets including parks and restaurants and within a 20 minute walk to the nearest Hospital.
6. It is located within a high priority location.
7. It is located within an existing bicycle network.
8. It has the potential to include 30% affordable housing based on what is currently built around and the mandates of the local government.
9. It possess opportunities for a 30% nonresidential built component, as it is adjacent to the Trans-Canada Highway and bus routes as well as the Lake of the Woods.
10. It has already been built upon but will also try to avoid building on any slope over 15% through the implementation of no build zones.
11. It is within 15 degrees of the East West Axis

Figure 4.20

4.3 LEED ND Neighbourhood Pattern and Design

Several of the Neighbourhood Pattern and Design rules have been incorporated into the visual massing of the program.

1. At least 90% of new buildings must include an entrance on the front façade
2. At least 15% of new street frontage has a minimum height to street width of 1:3
3. At least 90% of new roads include continuous sidewalks.
4. At least 50% of the new buildings cannot be setback further than 5.5 metres
5. At least 50% of the non-residential facades should be within .3 metres of a sidewalk
6. Building entries need to be included at minimum every
    i. 23 metres along residential properties and
    ii. 30 metres for non residential properties
7. Ground level retail uses should have clear glass facades between 1 and 2.4 metres from grade.
8. At least 60% of street facades must have windows and/or doors
9. At least 70% of each side of the street must provide for street parking.
10. For residential properties, the density must provide for at least 12 dwelling units per acre
11. For non residential properties, the density must provide for a Floor Area Ratio of 0.8
12. The neighbourhood must include or a minimum of 670 square metre park
13. Trees on the street must be included every 12 metres.

4.4 LEED ND Green Infrastructure and Buildings

Several of the Green Infrastructure and Building rules have been incorporated into the reporting section of the program.

1. Include sections of the certified green building through reduction percentages.
2. Include sections of the minimum building energy efficiency through reduction percentages.
3. Include sections of the minimum water efficiency through reduction percentages.
4. Include sections of storm-water management through reduction percentages.
5. Include sections of the heat island reduction through the site location, orientation of the buildings and material choices.
6. Include reflective material on the roofs
7. Include green roofs
8. Include photo-voltaic systems.

5.0 Development of the Rule

Throughout the practicum, over 20 different rules that begin to pattern urban frameworks were written, or modified as a way to understand the computer coding language. As I worked through understanding the program and the writing of the rules, the simple tools of setbacks, building heights and roof types helped with understanding the basics of the computer coding language through providing a simple visual and reporting output that made sense to the development of the streetscape. These three simple alterations go a long in the development and alteration of the massing variety seen on the streetscape. I will discuss 6 of the rules which ended being the most complete.

5.1 Simple Building Rule (Roofs)

The simple building rule was developed to understand the basics of how the computer coding worked in a way that would influence the streetscape. It was created to have a simple mass that had the options of changing the overall height, the heights of the different floors and the types/ heights of the roofs. LEED Neighbourhood Design does not have any impact on this specific rule as this rule was created more as a test to begin to understand how the computer coding worked.

Going forward, it could be further developed to be influenced by the LEED parameters.

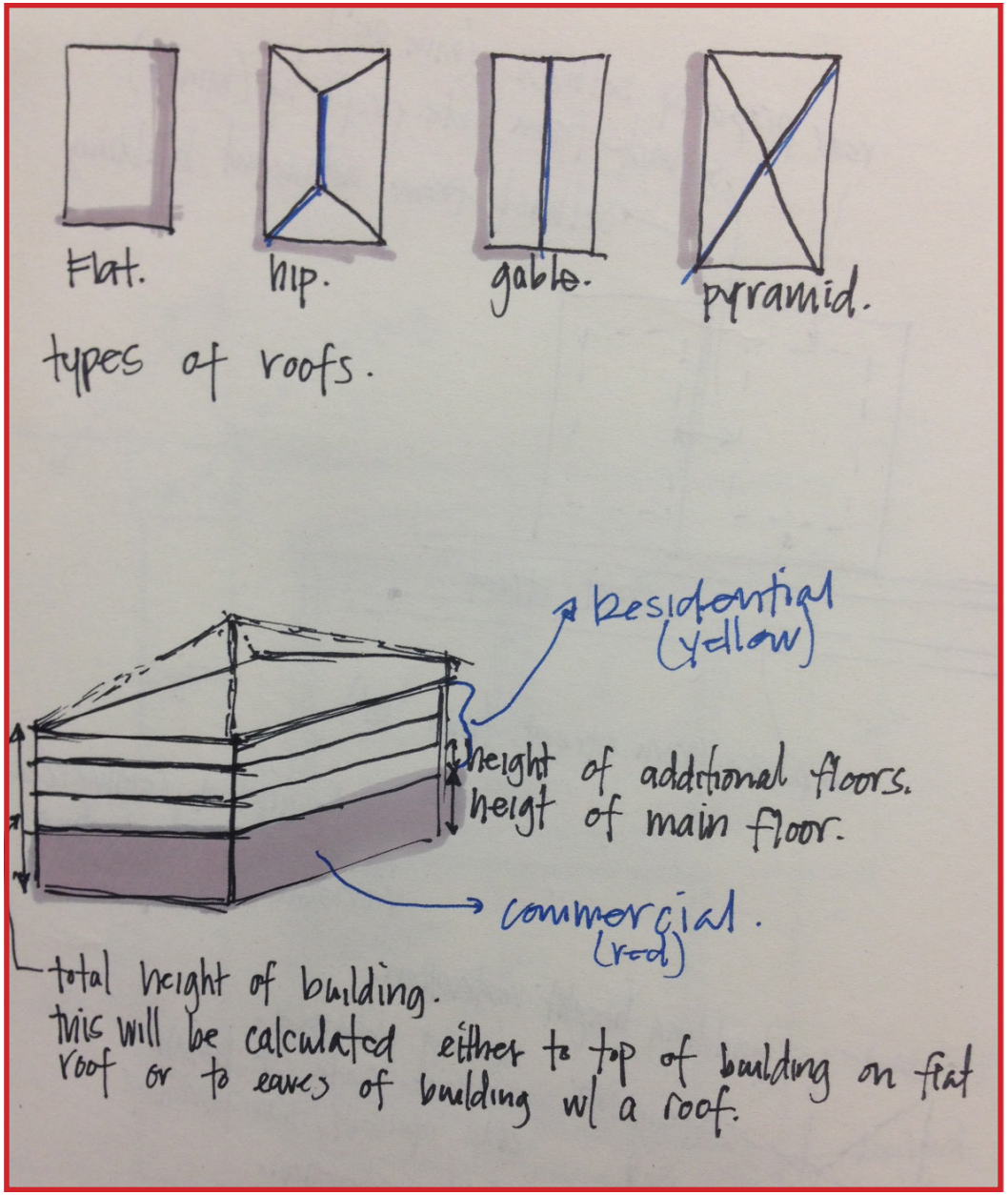


Figure 5.10

5.1 Roof
(Simple Building Rule)

CGA Script

```
/**
 * File:    roof.cga
 * Created: 1 Oct 2015 01:10:23 GMT
 * Author:  Grafton
 */

version "2015.0"

1   @Group ("Building", 0)
1.1 attr builtHeight = rand (3,24)
    @Group ("Building")
1.2 attr groundFloorHeight = rand(3.0, 5.0)
    @Group ("Building")
1.3 attr otherFloorHeight = 3.0

2   @Group ("Roof Pitch", 1)
2.1 attr Overhang = rand (.1, .5)

    @Group ("Roof Pitch")
2.2 attr roofHeight =
     case function_roofType == "flat" : 0
     else : rand (2,5)

    @Group ("Roof Pitch")
2.3 @Range ("random", "cornice", "hip",
    "gable", "contemporary", "pyramid")
    attr roofType = "random"
    const function_roofType =
     case roofType == "random" :
      30% : "cornice"
      10% : "hip"
      10% : "gable"
      15% : "pyramid"
      else : "contemporary"
     else : roofType


    @StartRule
    Lot -->
     case function_roofType == "cornice":
      extrude(world.y, builtHeight +
    flatRoofEdge)
      Mass
     else :
      extrude(world.y, builtHeight -
    roofHeight)
      Mass

    Mass --> split(y) {groundFloorHeight
    : floorVolume("groundFloor") |
    ~1 : split(y) {~ otherFloorHeight :
    floorVolume ("otherfloor")}}
     comp(f) {top : Roof  | all : NIL}


    floorVolume(type) -->
     continueHere.

    flatRoofEdge = 0.2

    Roof -->
     case function_roofType == "cornice" :
     offset(-.3)
     comp(f){border : extrude(world.y,
    flatRoofEdge) roofColoring | inside :
    t(0,0,.02) roofColoring}
     case function_roofType == "hip" :
     roofHip(45)
     s('1, roofHeight, '1)
     roofColoring
     case function_roofType == "gable" :
     roofGable(30,1,1)
     s('1, roofHeight, '1)
     roofColoring
     case function_roofType ==
    "contemporary" :
     roofShed(40,3)
     s('1, roofHeight, '1)
     roofColoring
     else:
      roofPyramid(45)
      s('1, roofHeight, '1)
      roofColoring

    roofColoring -->
     color(.5,7,35)
```

Associated English Explanation

Create a rule and call it roof.cga. (or simple building)
The system automatically inputs the time that the rule was created, the author of the rule and the version of the system that the rule was created in.

Each Parametric variable has to be created in a hierarchal fashion prior to starting the rule.

The first section of variables that are created in this rule have to do with the 1 Building mass.

The individual variables within the building mass controls are as follows:
1.1 the overall building height is suggested to be between 3 and 24 metres.
1.2 the ground floor height is suggested to be between 3 and 5 metres.
1.3 and the other floor heights are suggested to be 3 metres.

The second section of variables that are created in this rule have to do with the ability to control are the 2 Roof Pitch
The individual variables within the roof pitch variables are as follows:
2.1 the Overhang is suggested to be between 0.1 and 0.5 metres.
2.2 the Roof Height is suggested to be between 2 and 5 metres high.
2.3 and the Type of the Roof is suggested to have a range between cornice, hip, gable, contemporary and pyramid styles.

The rule begins with the lot (which is generated from the preexisting road and block tools)
From the lot, the rule begins with an if-than statement that requests what type of roof is being discussed. If the roof type is a cornince style roof, the lot should be extruded along the y axis by the associated overall building height with the addition of the flat roof edge of 0.2 metres.
If the roof is not a cornice style roof, it should be extruded by the associated overall building height minus the associated roof height.
A resulting mass should be generated.

This mass should be split between the ground floor and the other floors.
It should be further split between the other floors and the roof.

The floor volume should be created.

The generation of each type of roof is then laid out.
The flat portion of the cornince style roof should be 0.3 metres lower than the top of the cornice wall. The cornice wall and the interior of the flat cornice roof should be coloured differently.

For hip style roofs, the roof should be situated at a 45 degree angle to the X-axis and should be coloured.

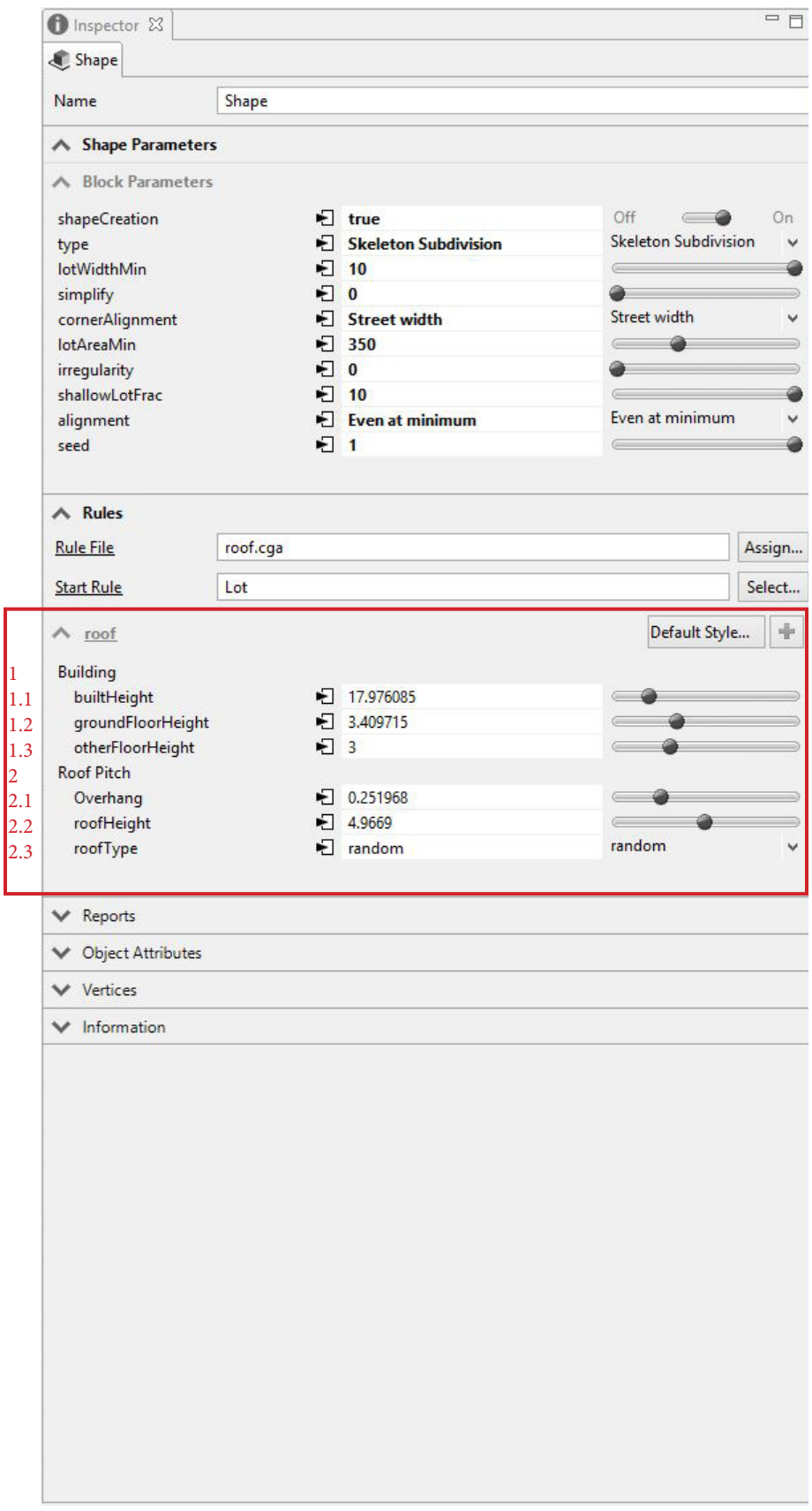
For gable style roofs, the roof should situated at a 30 degree angle to the X-axis should be coloured.

The contemporaty shed style roof should be situated at a 40 degree angle to the X-axis and should be coloured.

The pyramid style roof should be situated at a 45 degree angle to the X-axis and should be coloured.

The roofs should be coloured a light blue to differentiate between the building mass.

Parametric Variable Result



5.1 Simple Building Rule (Roofs)

The overall height of the buildings are being altered through the use of a single variable.

Table 5.1.1

Shape Parameters			
Block Parameters			
shapeCreation	true	Off	On
type	Skeleton Subdiv...	Skeleton Subdivision	
lotWidthMin	10		
simplify	0.25		
cornerAlignment	Street width	Street width	
lotAreaMin	325		
irregularity	0		
shallowLotFrac	2.5		
alignment	Uneven	Uneven	
seed	388219		
Rules			
Rule File	roof.cga	Assign...	
Start Rule	Lot	Select...	
roof		Default Style...	
Building			
builtHeight	3.292725		
groundFloorHe...	4.011302		
otherFloorHeight	3		
Roof Pitch			
Overhang	0.372286		
roofHeight	2.277915		
roofType	random	random	

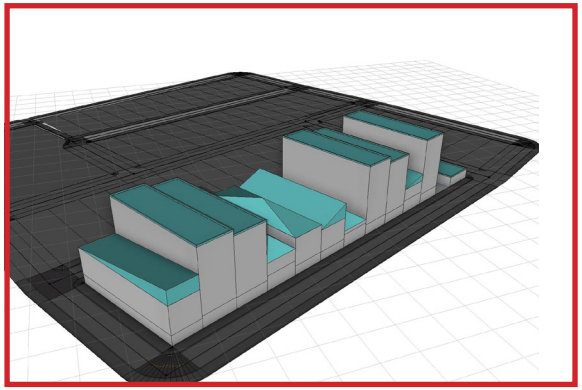


Figure 5.11.1 Building at default.

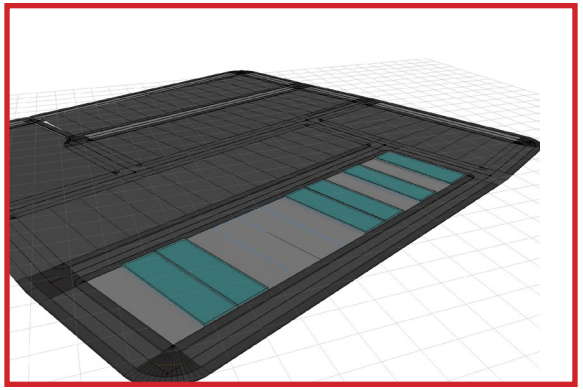


Figure 5.11.2 Building with an overall height of 0 metres.

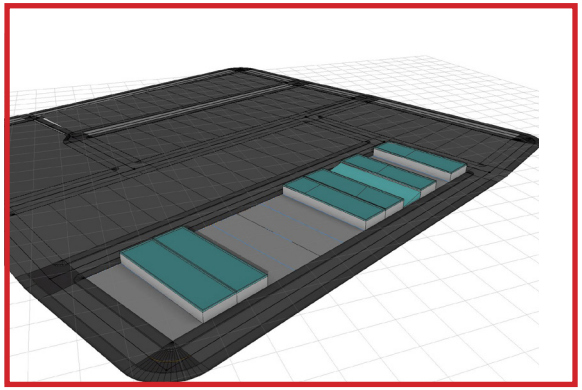


Figure 5.11.3 Building with an overall height of 3 metres.

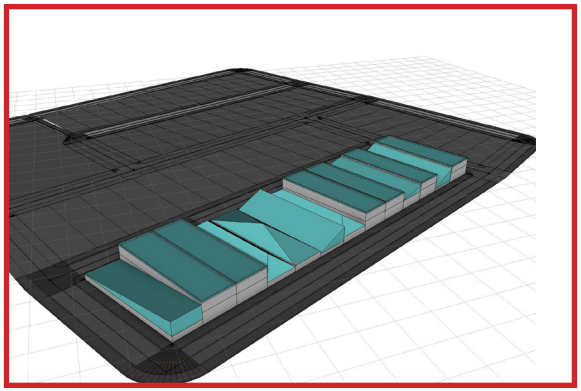


Figure 5.11.4 Building with an overall height of 6 metres.

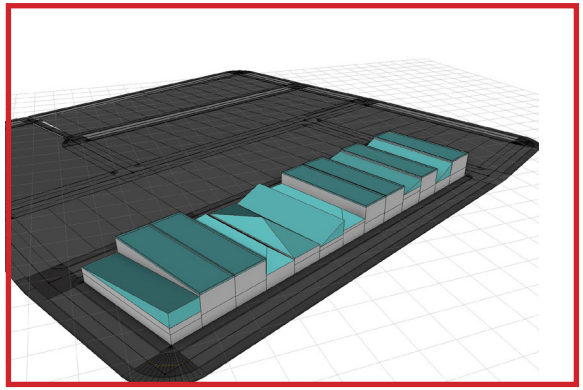


Figure 5.11.5 Building with an overall height of 9 metres.

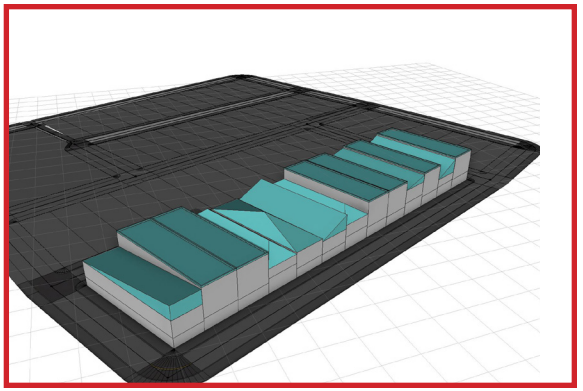


Figure 5.11.6 Building with an overall height of 12 metres.

5.1 Simple Building Rule (Roofs)

The ground floor height of the buildings are being altered through the use of a single variable.

Table 5.1.1

Shape Parameters			
Block Parameters			
shapeCreation	true	Off	On
type	Skeleton Subdiv...	Skeleton Subdivision	
lotWidthMin	10		
simplify	0.25		
cornerAlignment	Street width	Street width	
lotAreaMin	325		
irregularity	0		
shallowLotFrac	2.5		
alignment	Uneven	Uneven	
seed	388219		
Rules			
Rule File	roof.cga	Assign...	
Start Rule	Lot	Select...	
roof		Default Style...	
Building			
builtHeight	3.292725		
groundFloorHe...	4.011302		
otherFloorHeight	3		
Roof Pitch			
Overhang	0.372286		
roofHeight	2.277915		
roofType	random	random	

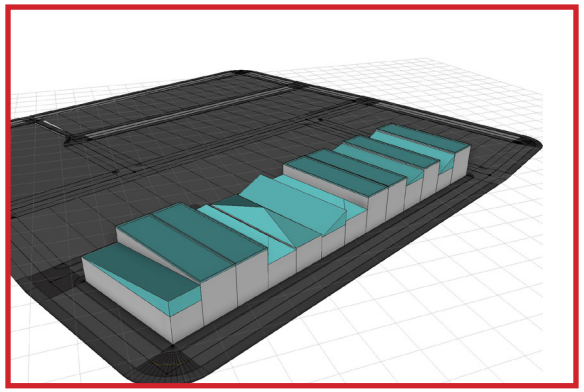


Figure 5.12.1 Building with a ground floor height of 0 metres.

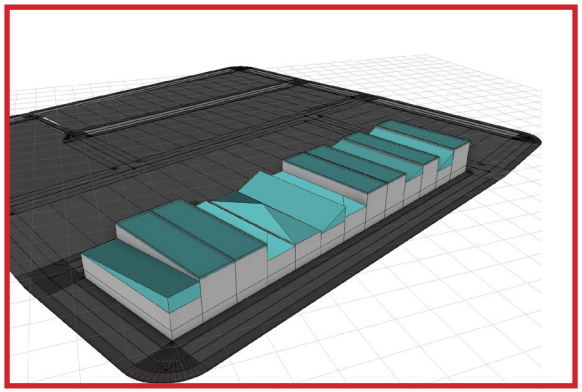


Figure 5.12.2 Building with a ground floor height of 3 metres.

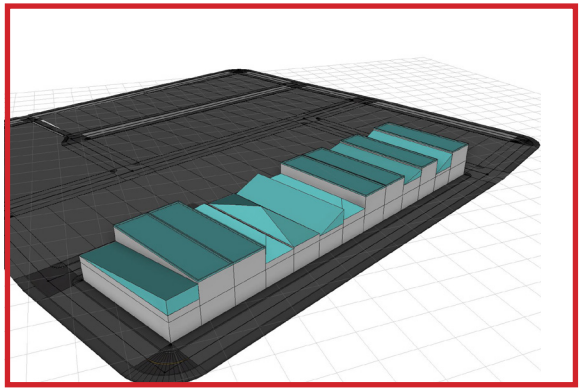


Figure 5.12.3 Building with a ground floor height of 6 metres.

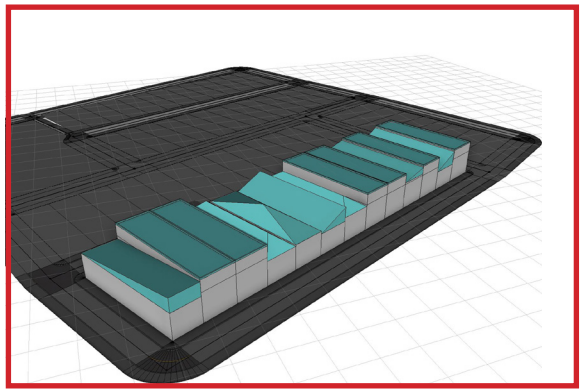


Figure 5.12.4 Building a ground floor height of 9 metres.

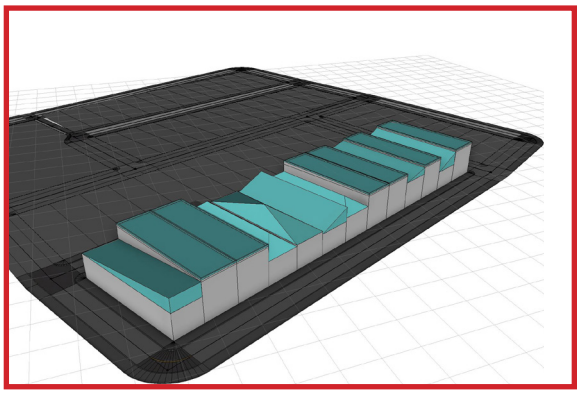
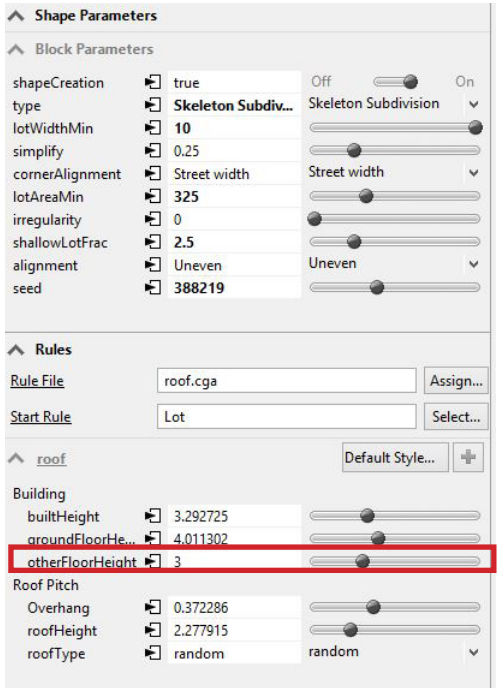


Figure 5.12.5 Building with a ground floor height of 12 metres.

5.1 Simple Building Rule (Roofs)

The upper floor heights of the buildings are being altered through the use of a single variable.

Table 5.1.1



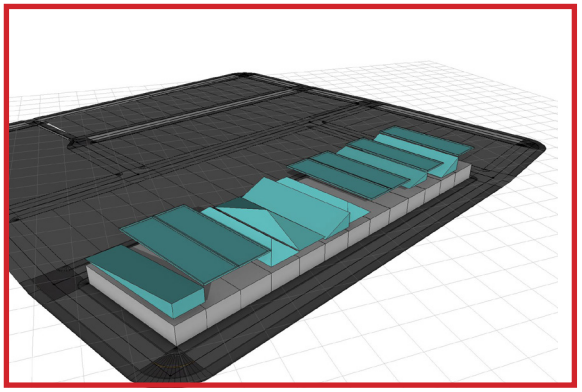


Figure 5.13.1 Building with an upper floor height of 0 metres.

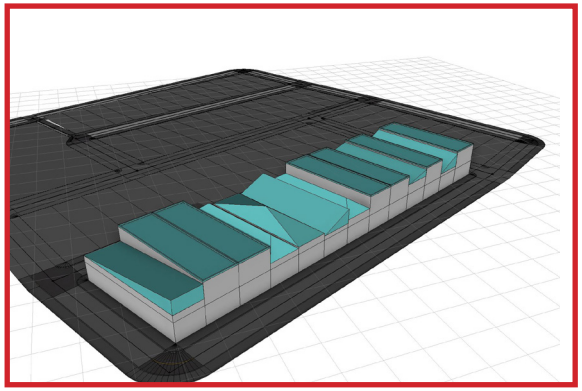


Figure 5.13.2 Building with an upper floor height of 3 metres.

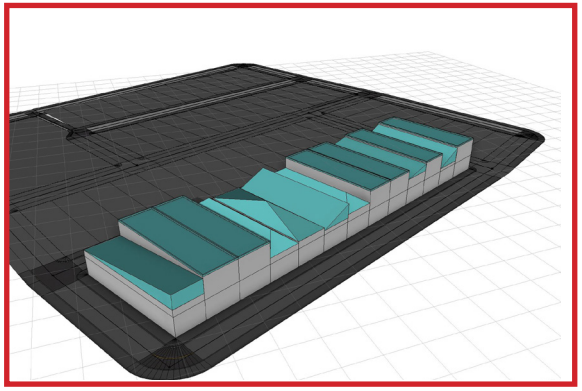
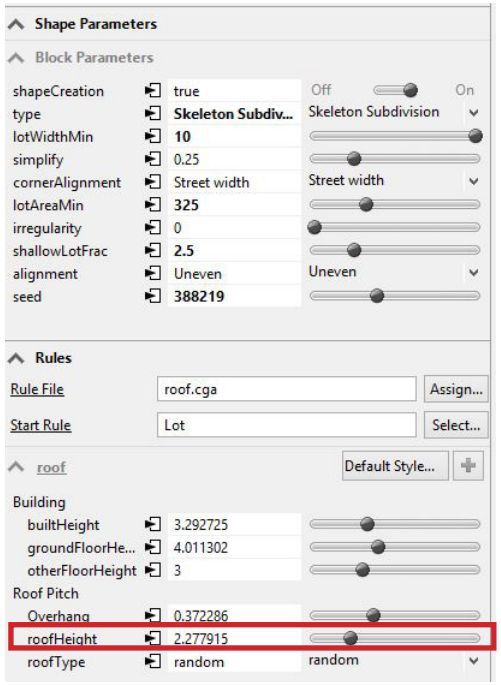


Figure 5.13.3 Building with an upper floor height of 6 metres.

5.1 Simple Building Rule (Roofs)

The roof heights of the buildings are being altered through the use of a single variable.

Table 5.1.1



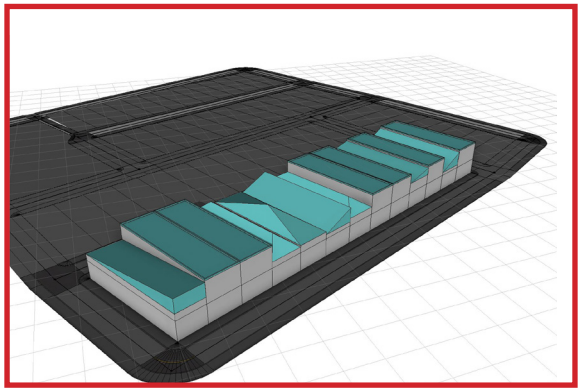


Figure 5.14.1 Building with default roof heights generated through parametrics.

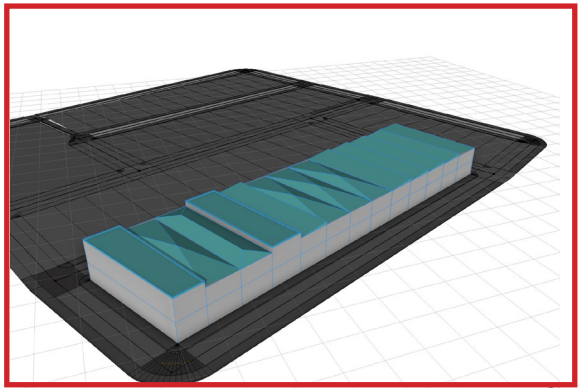


Figure 5.14.2 Buildings with the roof height standardized to 1 metre.

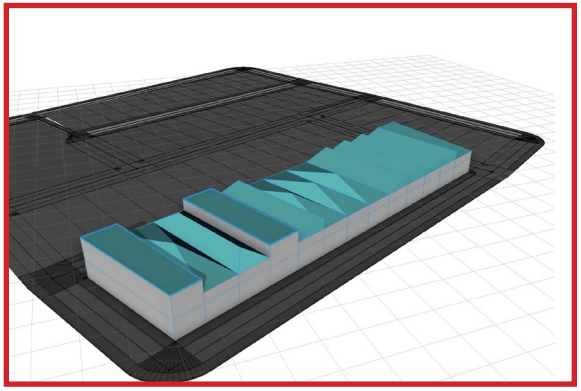
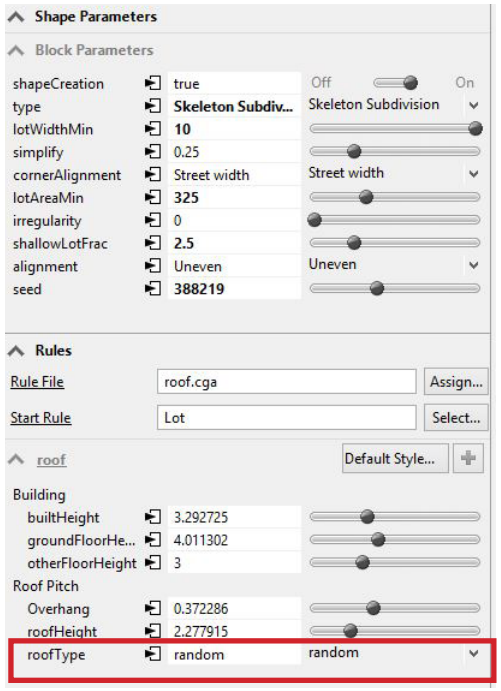


Figure 5.14.3 Buildings with the roof height standardized to 3 metres

5.1 Simple Building Rule (Roofs)

The roof styles of the buildings are being altered through the use of a single variable.

Table 5.1.1



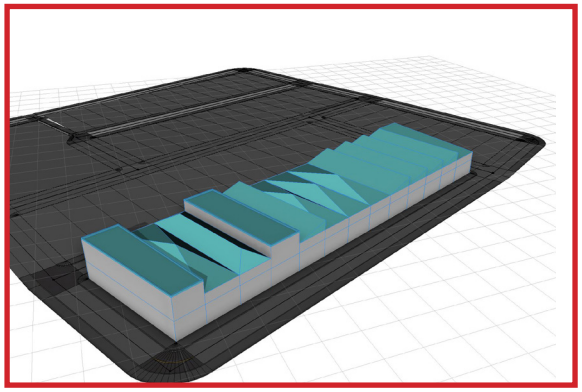


Figure 5.15.1 Buildings with default random roofs.

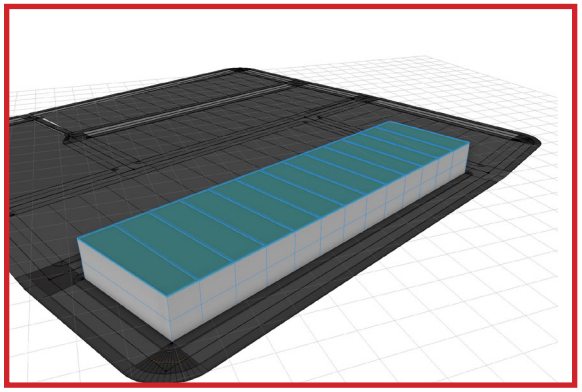


Figure 5.15.2 Buildings with cornice style roofs.

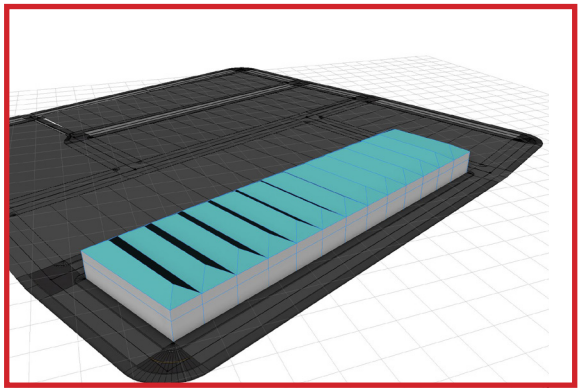


Figure 5.15.3 Buildings with hip style roofs

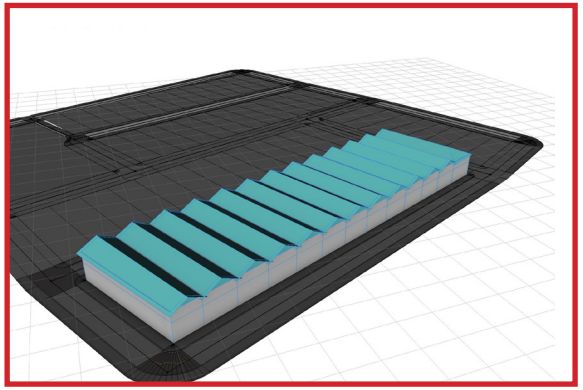


Figure 5.15.4 Buildings with gable style roofs.

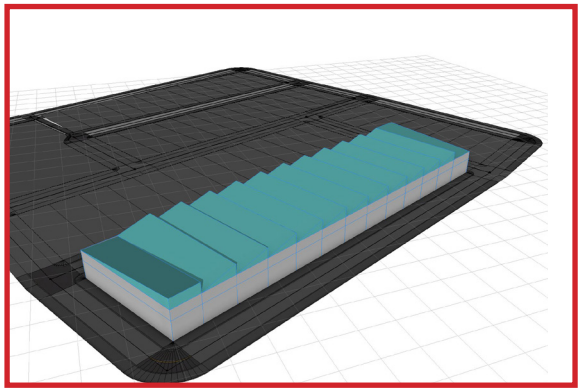


Figure 5.15.5 Buildings with contemporary shed style roofs

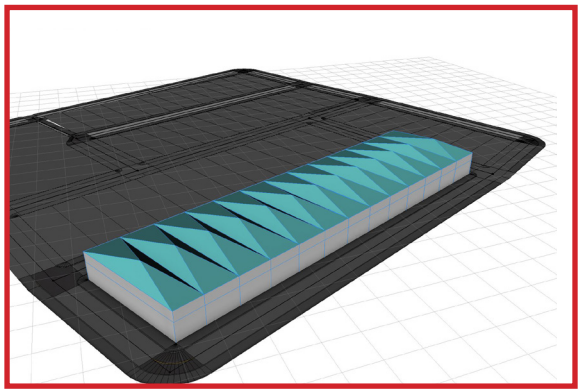


Figure 5.15.6 Buildings with pyramid style roof type.

5.2 Simple Setback Rule (Roofs + Zoning)

The setback rule was developed in conjunction with the simple building rule to demonstrate how the Winnipeg Zoning Bylaw influences a simple mass. It creates building volumes within the build-able area of each lot. Due to the associative nature of the program, the building mass adjusts in accordance with the setbacks attributed to the lot.

Going forward, this rule could be further influenced through the creation of a range of numbers instead of a single number within each variable. Additional portions of the Winnipeg Zoning Bylaw should be added into the rule. LEED Neighbourhood Design does not impact this rule as it is but it could also be incorporated to influence the range available to the user.

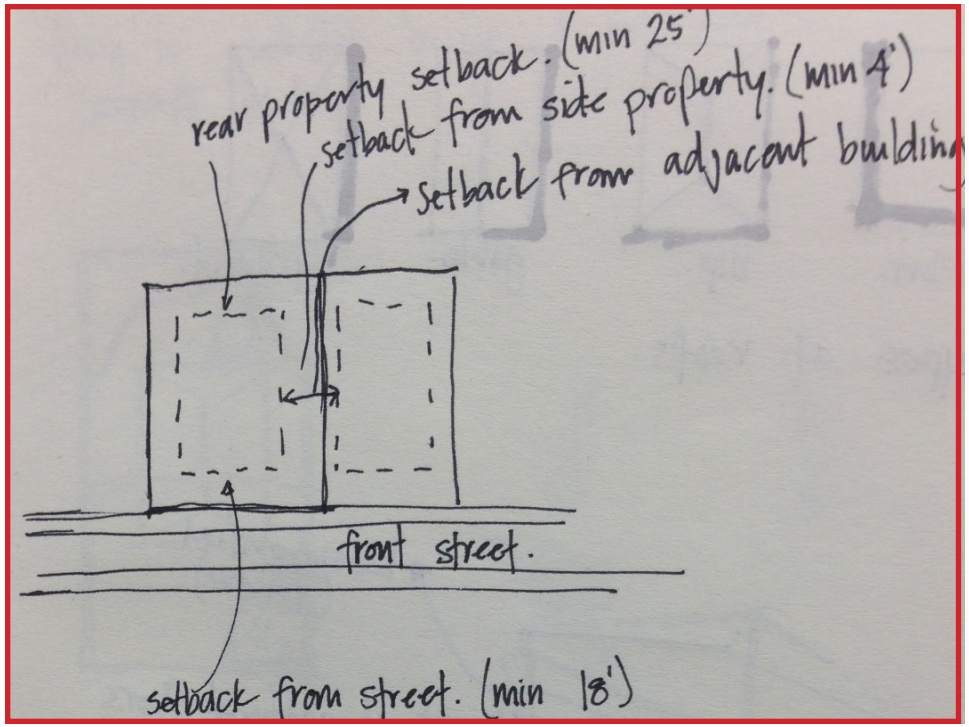


Figure 5.20

5.2 Roofs And Zoning (Simple Setback Rule)

CGA Script

```
/**
 * File:    roofs+zoning.cga
 * Created: 30 Sep 2015 02:45:46 GMT
 * Author:  Grafton
 */

version "2015"

1     @Group ("Zoning",0)
      @Order(0)
      @Range("Residential", "Commercial")
1.1   attr ZoningCode   = "Residential"
      @Group ("Zoning")
      @Order(1)
1.2   attr Show_Buildable_Area  = true

2     @Group ("Residential Zoning", 1)
      @Order(0)
2.1   attr Residential_Street_Setback
      = 3.048
      @Group ("Residential Zoning")
      @Order(1)
2.2   attr Residential_Sideyard_Setback
      = 1.210
      @Group ("Residential Zoning")
      @Order(2)
2.3   attr Residential_Rear_Setback
      =5

3     @Group ("Commercial Zoning", 2)
      @Order(0)
3.1   attr Commercial_Street_Setback
      = 0.3
      @Group ("Commercial Zoning")
      @Order(1)
3.2   attr Commercial_Sideyard_Setback
      = 0
      @Group ("Commercial Zoning")
      @Order(2)
3.3   attr Commercial_Rear_Setback
      =0

4     @Group ("Building", 3)
4.1   attr builtHeight = rand (3,24)
      @Group ("Building")
4.2   attr groundFloorHeight = rand(3, 5.0)
      @Group ("Building")
4.3   attr otherFloorHeight = 3

5     @Group ("Roof Pitch", 4)
5.3   @Range ("random", "cornice", "hip",
      "gable", "contemporary")
      attr roofType = "random"
      const function_roofType =
        case roofType == "random" :
         30% : "cornice"
         10% : "hip"
         10% : "gable"
         20% : "pyramid"
        else : "contemporary"
      else : roofType


      @Group ("Roof Pitch", 4)
5.1   attr Overhang = rand (.1, .5)

      @Group ("Roof Pitch")
5.2   attr roofHeight =
        case function_roofType == "flat" : 0
        else : rand (2,5)

      @Group ("Roof Pitch")
5.3   @Range ("random", "cornice", "hip",
      "gable", "contemporary")
      attr roofType = "random"
      const function_roofType =
        case roofType == "random" :
         30% : "cornice"
         10% : "hip"
         10% : "gable"
         20% : "pyramid"
        else : "contemporary"
      else : roofType


      @Hidden
      attr ParcelArea = 0

      precisionDelta = 0.1

      roundValue(value)
      = (int(value * 100)) / 100
      Street_Setback   =
      case ZoningCode == "Residential"
      :Residential_Street_Setback
      else :Commercial_Street_Setback
      Sideyard_Setback =
      case ZoningCode == "Residential"
      :Residential_Sideyard_Setback
      else :Commercial_Sideyard_Setback
      Rear_Setback   =
      case ZoningCode == "Residential"
      :Residential_Rear_Setback
      else :Commercial_Rear_Setback


      @StartRule
      Parcel-->
              report ("Parcel Area",
      roundValue(geometry.area) )
              setback(Street_Setback)
      {street.front: NIL | remainder:
              setback(Sideyard_Setback)
      {street.side: NIL | remainder:
              setback(Rear_Setback){street.
      back: NIL | remainder:
              BuildableArea}}}
              color (.5,.5,.5)
              Parcel.

      BuildableArea -->
       case function_roofType == "cornice":
        extrude(world.y, builtHeight +
      flatRoofEdge)
        Mass
       else :
        extrude(world.y, builtHeight -
       roofHeight)
        Mass

      Mass --> split(y) {groundFloorHeight
      : floorVolume("groundFloor") |
      ~1 : split(y) {~ otherFloorHeight :
      floorVolume ("otherfloor")}}
       comp(f) {top : Roof | all : NIL}

      floorVolume(type) -->
       continueHere.

      flatRoofEdge = 0.2

      Roof -->
       case function_roofType == "cornice"
      :
        offset(-.3)
       comp(f){border : extrude(world.y,
      flatRoofEdge) roofColoring | inside :
      t(0,0,.02) roofColoring}
       case function_roofType == "hip" :
       roofHip(45)
       s(1, roofHeight, 1)
       roofColoring
       case function_roofType == "gable" :
       roofGable(90,1,1)
       s(1, roofHeight, 1)
       roofColoring
       case function_roofType ==
      "contemporary" :
       roofShed(40,3)
       s(1, roofHeight, 1)
       roofColoring
       else:
        roofPyramid(45)
        s(1, roofHeight, 1)
        roofColoring

      roofColoring -->
      color(.5,7,.55)
```

Associated English Explanation

Create a rule and call it roofs+zoning.cga
The system automatically inputs the time that the rule was created, the author of the rule and the version of the system that the rule was created in.

Each Parametric variable has to be created in a hierarchal fashion prior to starting the rule.

In this case the first section of variables that are created in this rule have to do with the 1 Zoning Variables The individual variables within the zoning control are as follows:
1.1 the decision between residential and commercial zoning.
1.2 the decision to show the buildable area or not.

The second section of variables that are created in this rule have to do with the 2 Residential Zoning Variables. The individual variables within the residential zoning control are as follows:
2.1 the residential street setback is set to Winnipeg's zoning bylaw standard of 3.048 metres.
2.2 the residential sideyard setback is set to Winnipeg's zoning bylaw standard of 1.219 metres.
2.3 the residential rear yard setback is set to Winnipeg's zoning bylaw standard of 7.62 metres

The third section of variables that are created in this rule have to do with the 3 Commercial Zoning Variables. The individual variables within the commercial zoning control are as follows:
3.1 the commercial street setback is set to Winnipeg's zoning bylaw standard of 0.3 metres.
3.2 the commercial sideyard setback is set to Winnipeg's zoning bylaw standard of 0 metres.
3.3 the commercial rear yard setback is set to Winnipeg's zoning bylaw standard of 0 metres.

The fourth section of variables that are created in this rule have to do with the 4 Building variables.
The idividual variables within the building control are as follows:
4.1 the overall building height is suggested to be between 3 and 24 metres.
4.2 the ground floor height is suggested to be between 3 and 5 metres.
4.3 and the other floor heights are suggested to be 3 metres.

The fifth section of variables that are created in this rule have to do with the 5 Roof Pitch Variables
The individual variables with control wanted are as follows:
5.1 the Overhang is suggested to be between 0.1 and 0.5 metres.
5.2 the Roof Height is suggested to be between 2 and 5 metres high.
5.3 and the Type of the Roof is suggested to have a range between cornice, hip, gable, contemporary and pyramid styles.

The original parcel area which is generated in the report is 0. The report is generating a discussion of the total amount of the buildable area.

Since CityEngine is based on ArcGIS projections, the precision delta rule is telling the system to ensure that the visual representation of the model is within a centimeter of the correct location so there is limited room for error.

The rule begins with the parcel (which is again generated from the preexisting road and block tools)
From the parcel, a report is generated that discusses the overall area.
A buildable area is generated from the associated parcel minus the setbacks. The buildable area is coloured with a grey outline.

From the lot, the rule begins with an if-than statement that requests what type of roof is being discussed. If the roof type is a cornince style roof, the lot should be extruded along the y axis by the associated overall building height with the addition of the flat roof edge of 0.2 metres.
If the roof is not a cornice style roof, it should be extruded by the associated overall building height minus the associated roof height.
A resulting mass should be generated.

This mass should be split between the ground floor and the other floors.
It should be further split between the other floors and the roof.

The floor volume should be created.

The generation of each type of roof is then laid out.
The flat portion of the cornince style roof should be 0.3 metres lower than the top of the cornice wall. The cornice wall and the interior of the flat cornice roof should be coloured differently.

For hip style roofs, the roof should be situated at a 45 degree angle to the X-axis and should be coloured.

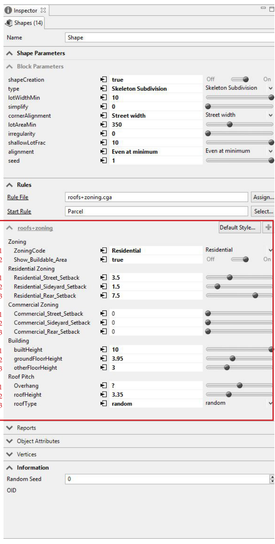
For gable style roofs, the roof should situated at a 30 degree angle to the X-axis should be coloured.

The contemporary shed style roof should be situated at a 40 degree angle to the X-axis and should be coloured.

The pyramid style roof should be situated at a 45 degree angle to the X-axis and should be coloured.

The roofs should be coloured a light blue to differentiate between the building mass.

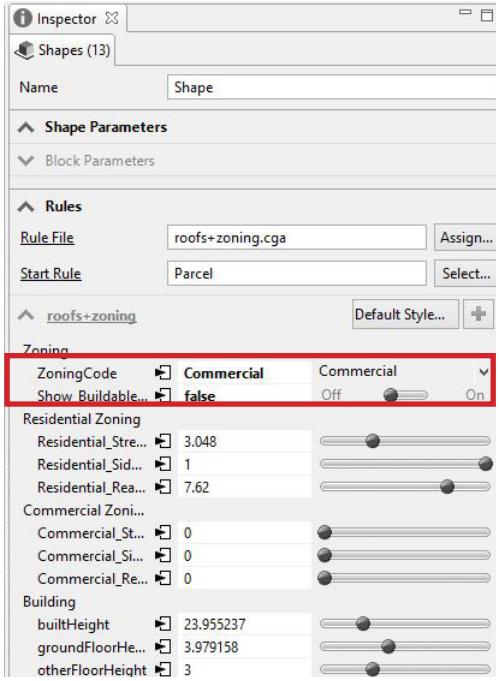
Parametric Variable Result



5.2 Simple Setback Rule (Roofs + Zoning)

The type of zoning is being decided through the use of two variables.

Table 5.2.1



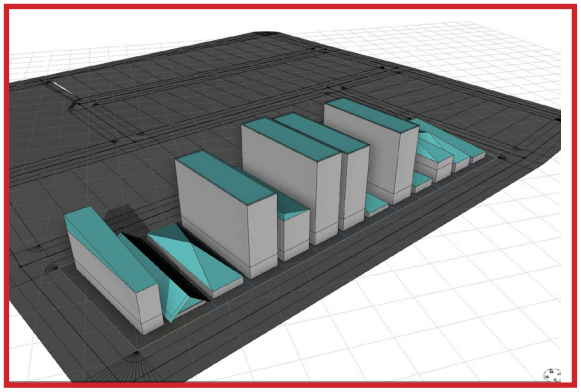


Figure 5.21.1 Buildings set to residential setback standards.

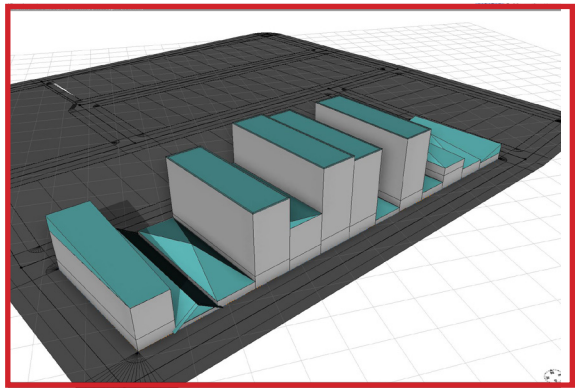


Figure 5.21.12 Buildings set to commercial setback standards.

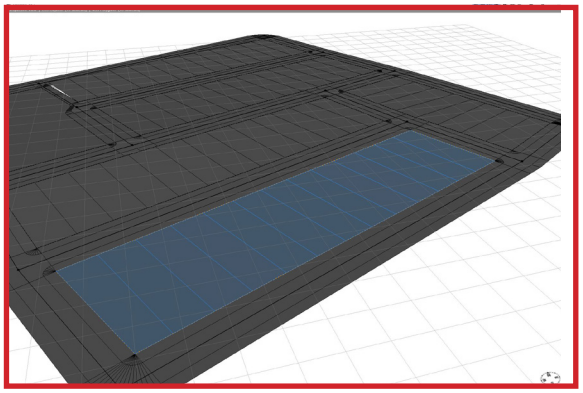
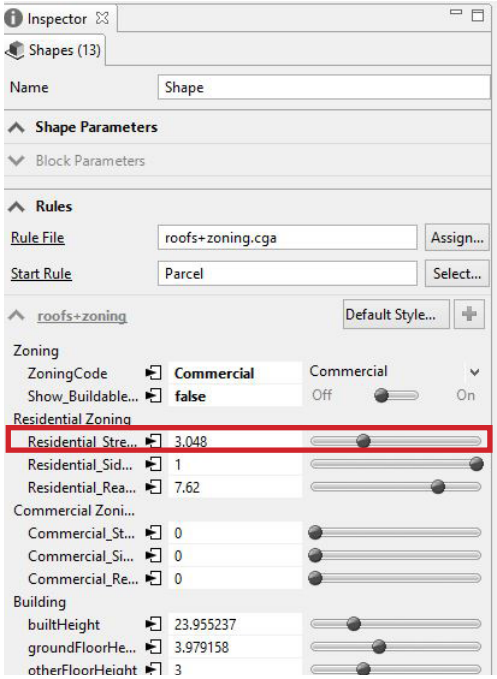


Figure 5.21.3 Buildings will either be shown or they wont be. This is to alleviate some of the visual data

5.2 Simple Setback Rule (Roofs + Zoning)

The buildings are being shifted back from the front street through the use of a single variable

Table 5.2.1



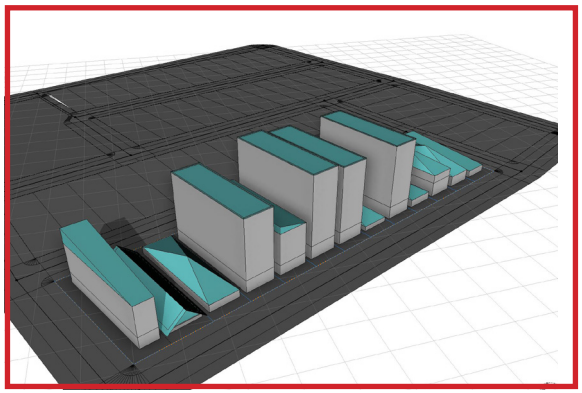


Figure 5.22.1 Buildings set to residential setbacks.

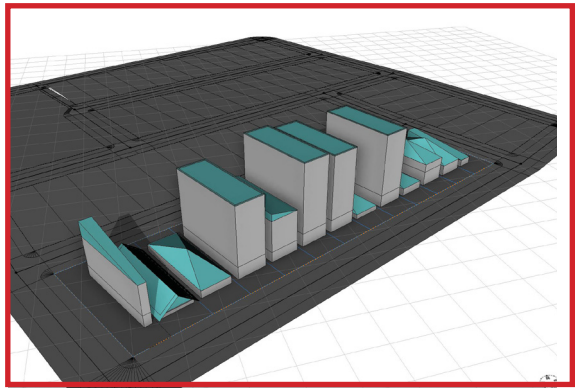


Figure 5.22.2 The front street setback is doubled.

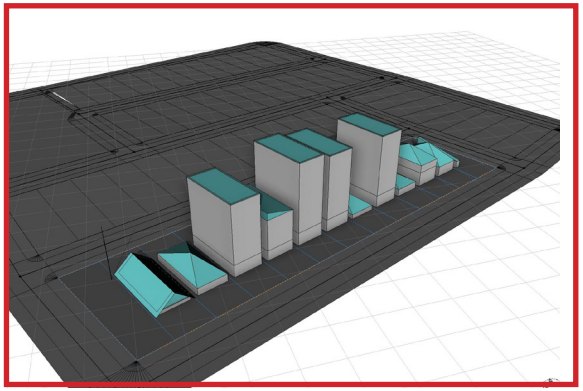
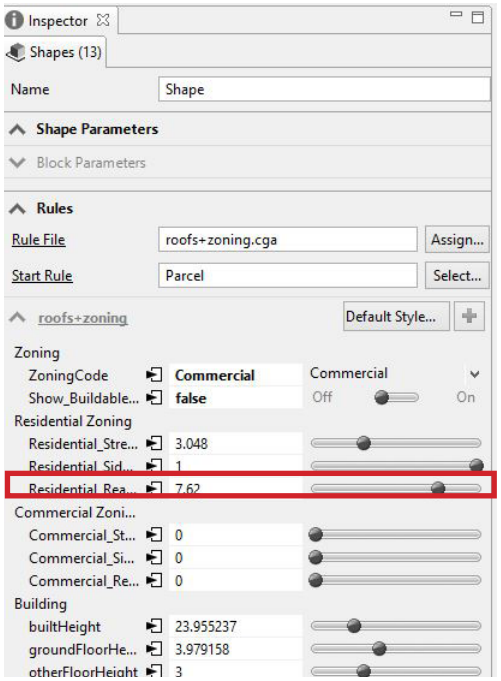


Figure 5.22.3 The front street setback is tripled.

5.2 Simple Setback Rule (Roofs + Zoning)

The buildings are being shifted back from the rear property line through the use of a single variable

Table 5.2.1



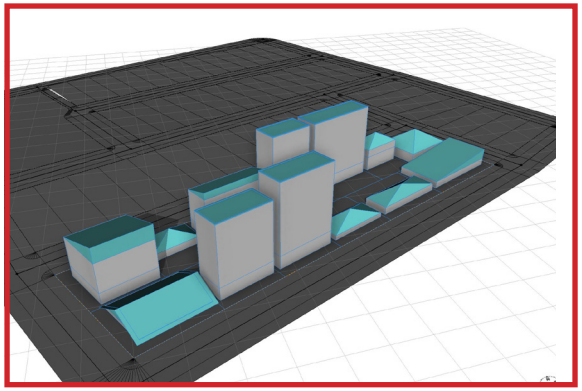


Figure 5.23.1 The block has been shifted to an offset subdivision to allow for rear setbacks to occur.

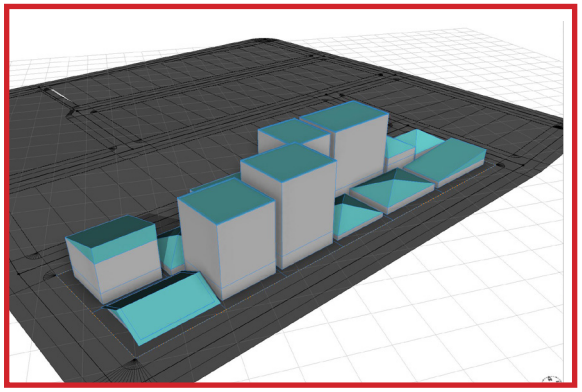


Figure 5.23.2 The rear setback is set to 0 metres.

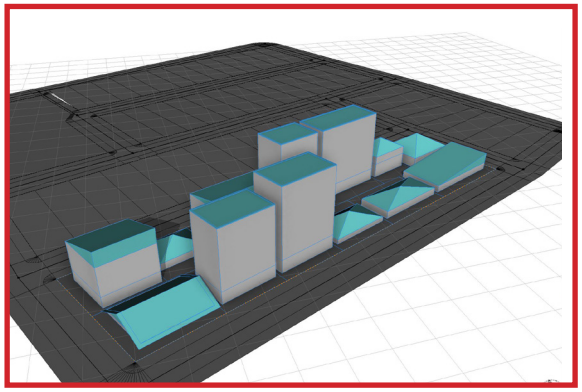


Figure 5.23.3 The rear setback is set to 5 metres.

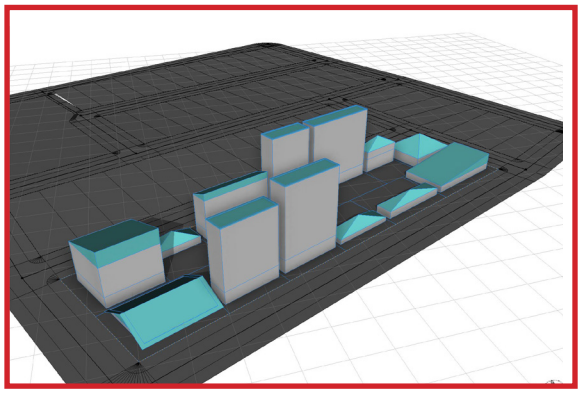
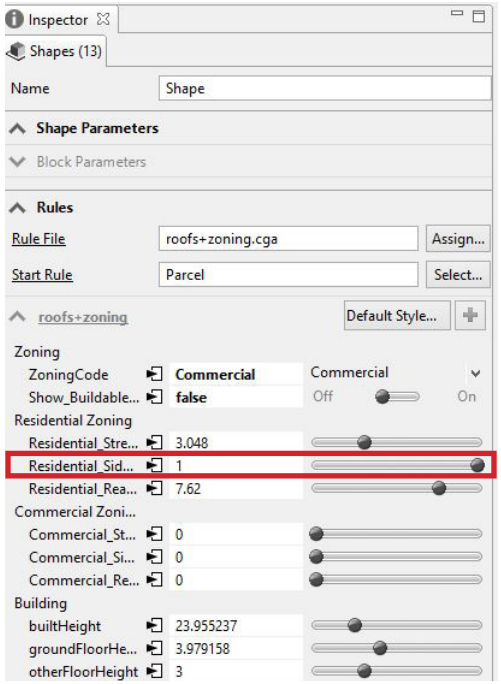


Figure 5.23.4 The rear setback is set to 10 metres.

5.2 Simple Setback Rule (Roofs + Zoning)

The buildings are being shifted back from the side property line through the use of a single variable.

Table 5.2.1



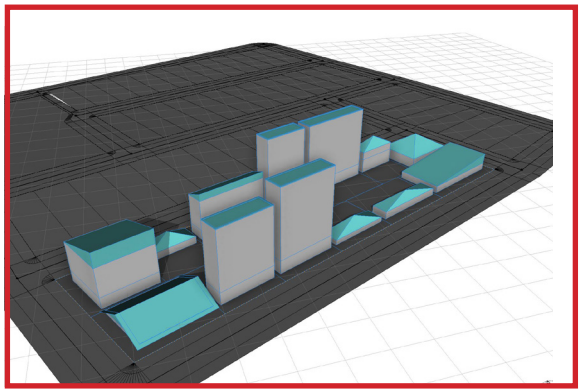


Figure 5.24.1 This default side yard image is taken from the resultant of the rear yard changes.

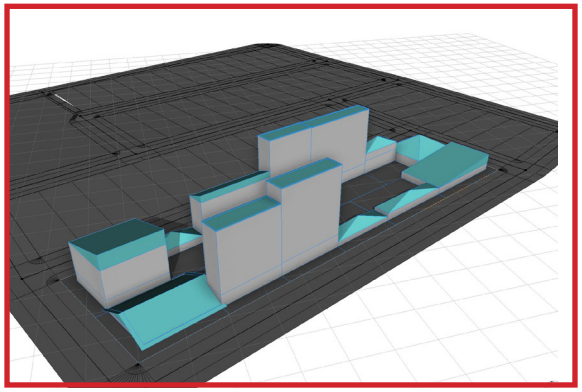


Figure 5.24.2 The side yard setback is set to 0 metres.

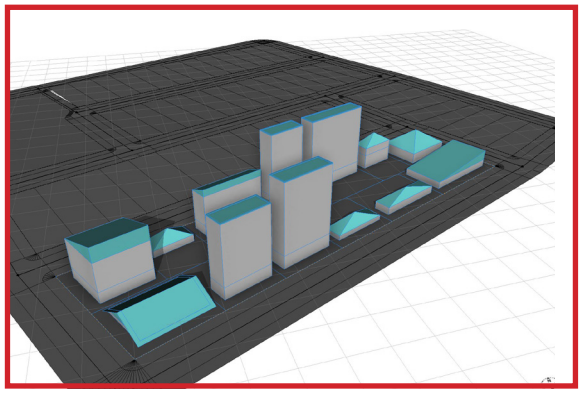


Figure 5.24.3 The side yard setback is set to 2 metres.

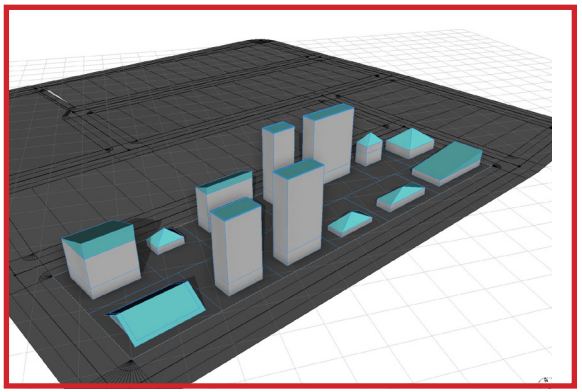


Figure 5.24.4 The side yard setback is set to 4 metres.

5.3 Floor Area Ratio Rule

The floor area ratio rule was developed to create a building mass based on the City's Bylaw of lot coverage, Floor Area Ratio and building height.

Going forward it should be incorporated with other rules from the Winnipeg Zoning Bylaw to influence a more accurate building mass on each site. It needs to be developed further to become an associative tool as currently it does not play an impact into the actual buildings being generated in the following tools.

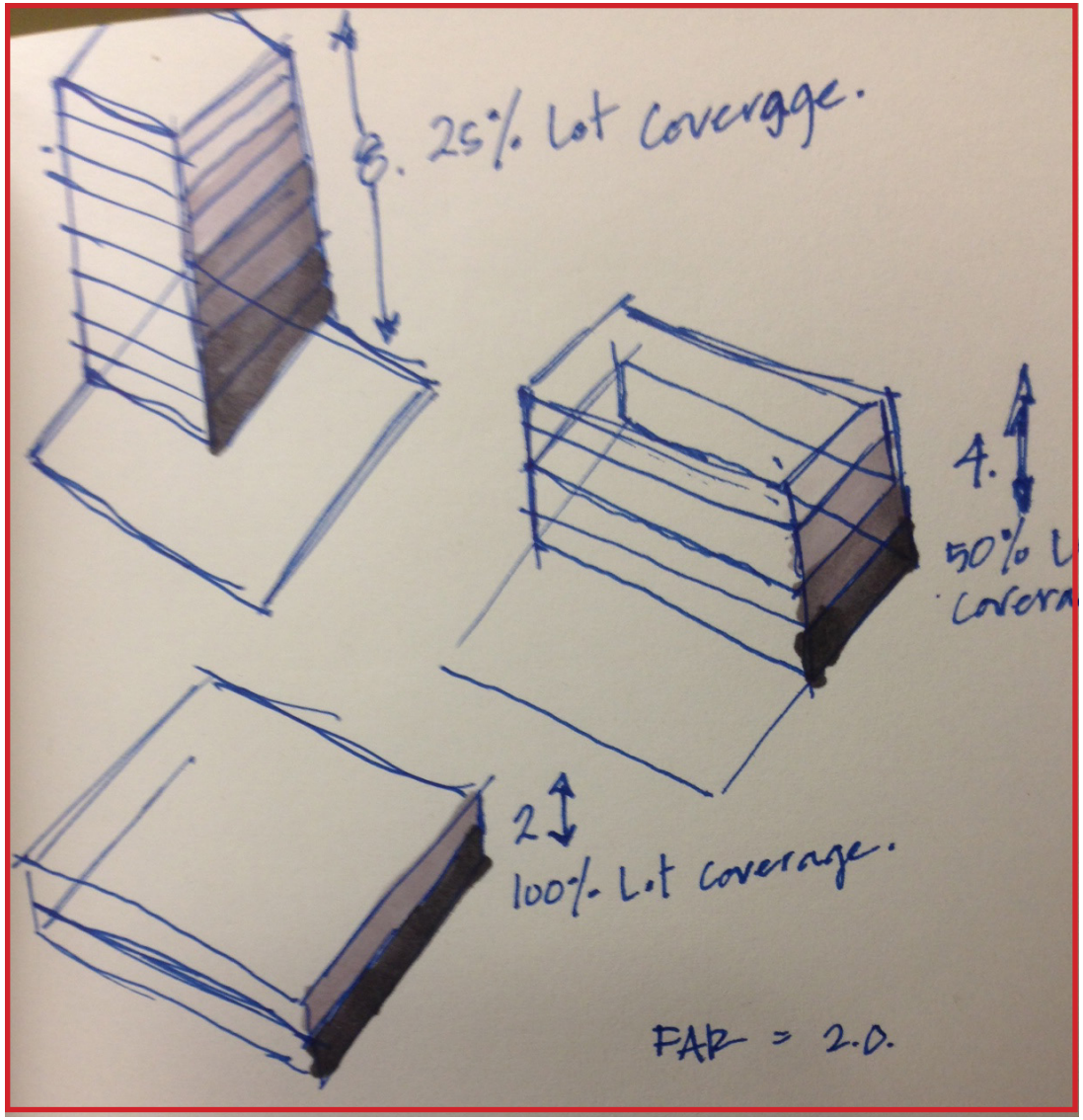


Figure 5.30

5.3 Floor Area Ratio Rule

CGA Script

```
/**
 * File:    FAR.cga
 * Created: 2 Oct 2015 11:18:04 GMT
 * Author:  Grafton
 */

version "2015.0"

#GFA = Gross Floor Area
#FAR = Floor Area Ratio

@Range(1,10)
1  attr FAR = 2

@Range(0,1)
2  attr coverage = 0.45

@Range(3,6)
3  attr floorHeight = 3

#functions
const GFA = FAR * geometry.area
const footprintArea = geometry.area * coverage
const height = (GFA / footprintArea) * floorHeight


@StartRule
Parcel -->
        report
        s('relativeScale(footprintArea, geometry.area), 0,
          'relativeScale(footprintArea, geometry.area))
        center(xz)
        extrude(height)
        split(y){{floorHeight: X.}* | ~1: NIL}

relativeScale(targetArea, originalArea) = sqrt(targetArea / originalArea)

report -->
        print("Gross Floor Area generated from Floor Area Ratio and
Lot Coverage: " + GFA)
        print("Buildable Area generated from percentage of Lot
Coverage: " + footprintArea)
        print("Height generated from Buildable Area and Floor Area
Ratio: " + height)
        NIL
```

Associated English Explanation

Create a rule and call it roof.cga. (or simple building)
The system automatically inputs the time that the rule was created, the author of the rule and the version of the system that the rule was created in.

Each Parametric variable has to be created in a hierarchal fashion prior to starting the rule.

The first variable in this rule has to do with the 1. Floor Area Ratio which is set to a standard of 2.

The second variable in this rule has to do with the 2. total lot coverage percentage which is set to a Winnipeg Zoning Bylaw standard for residential use of 45%.

The third variable in this rule has to do with the 3. floor height which is set to a standard 3 metres.

The gross floor area is equal to the floor area ration multiplied by the overall area of either the lot or the parcel.

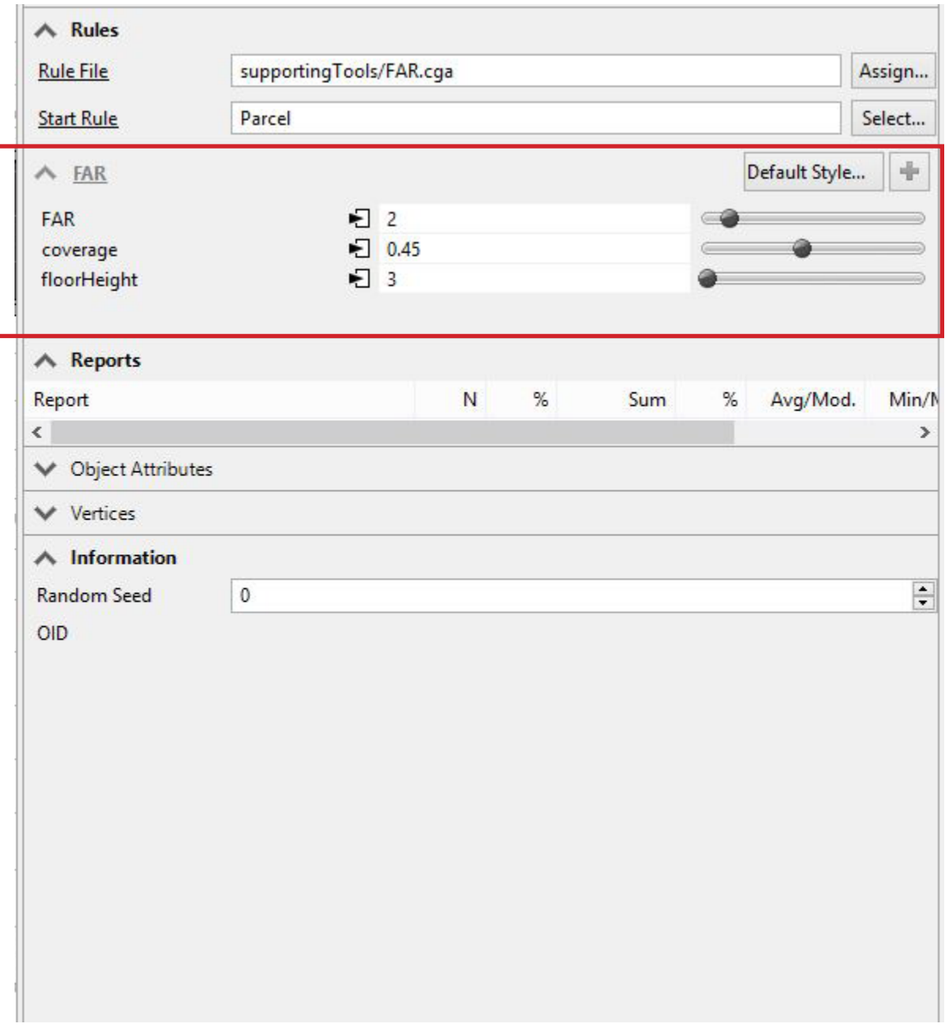
The overall building footprint area is equal to the lot or parcel area multiplied by the associative lot coverage variable.

The overall height of the building is equal to the gross floor area divided by the associative building footprint area and the resultant multiplied by the associative floor height.

The rule begins with the parcel generated from the preexisting road and block tools.
From the parcel, a report is generated that discusses the footprint area as it relates to the overall area of the parcel.
The building mass is centred on the parcel and then extruded by the overall height of the building. The overall building mass is then split by an associative number of floors depending on the height of those floors.

The report should also discuss the gross floor area, buildable area, and height of the associative buildings.

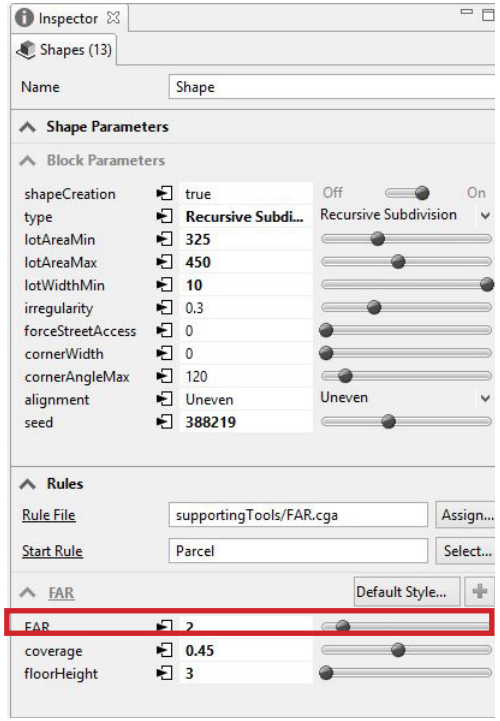
Parametric Variable Result



5.3 Floor Area Ratio Rule

The mass is being shifted based on the single variable of the Floor Area Ratio.

Table 5.3.1



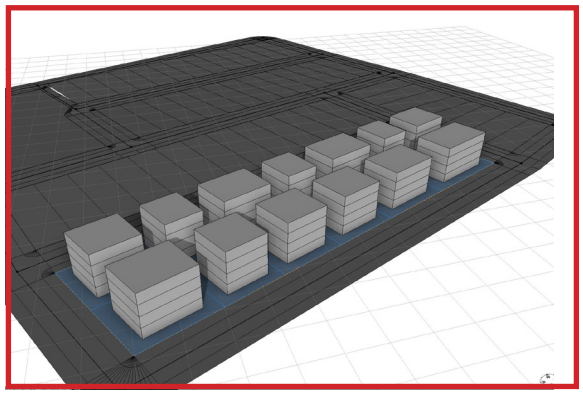


Figure 5.31.1 The default floor area ratio (FAR) is 2.

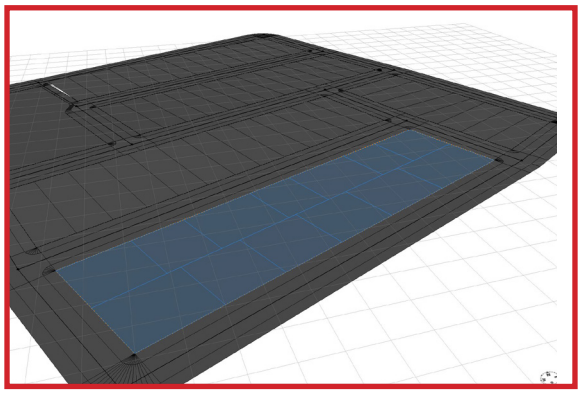


Figure 5.31.2 The FAR is reduced to 0.

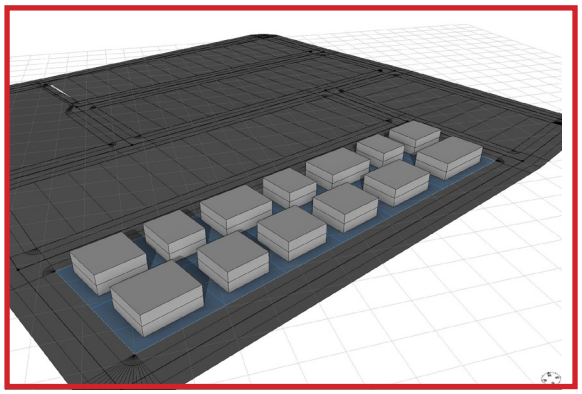


Figure 5.31.3 The FAR is increased to 1.

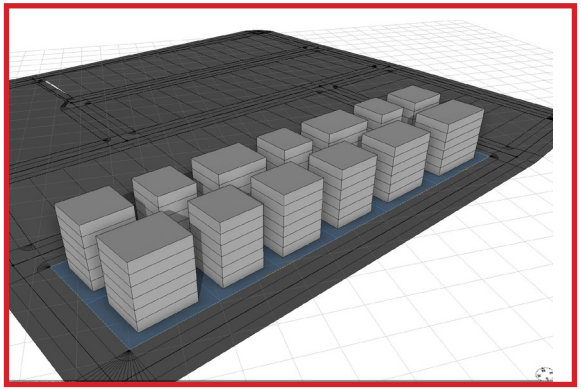


Figure 5.31.4 The FAR is increased to 3.

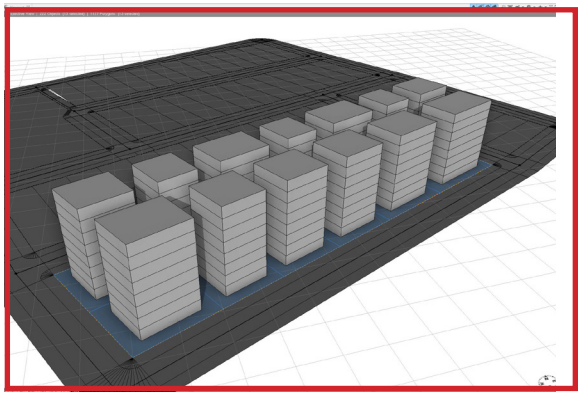
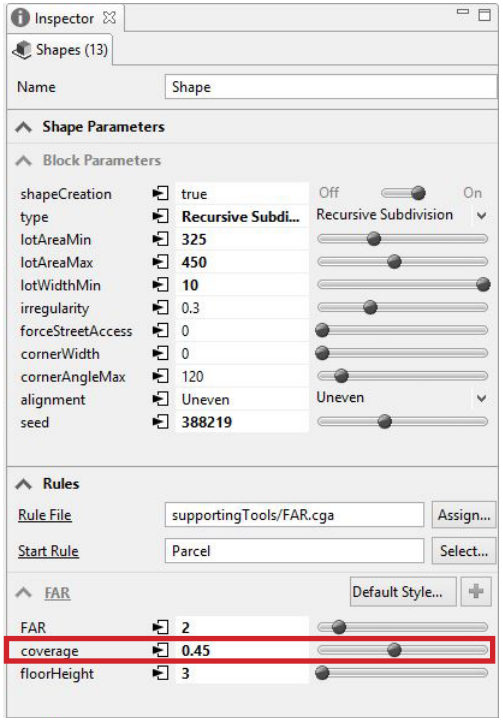


Figure 5.31.5 The FAR is increased to 4.

5.3 Floor Area Ratio Rule

The building mass is being shifted based on the single variable of the Lot coverage

Table 5.3.1



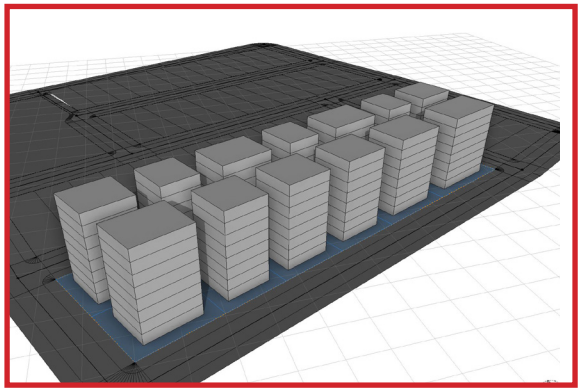


Figure 5.32.1 The default lot coverage is 45%.

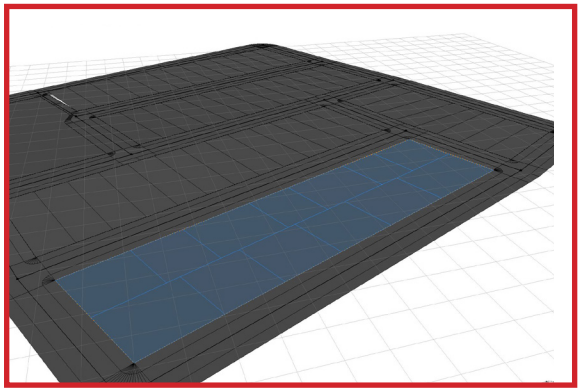


Figure 5.32.2 The lot coverage is reduced to 0%.

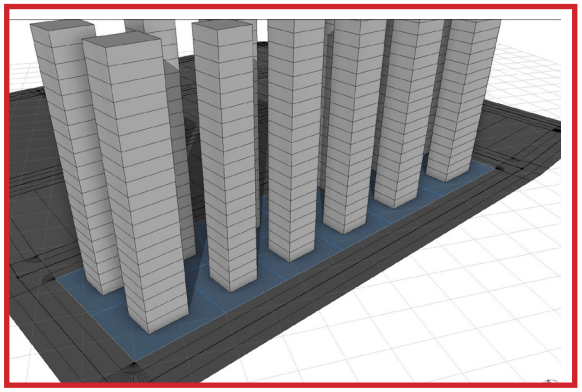


Figure 5.32.3 The lot coverage is increased to 20%.

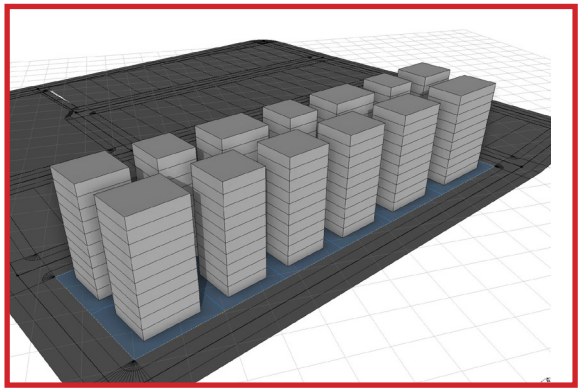


Figure 5.32.4 The lot coverage is increased to 40%.

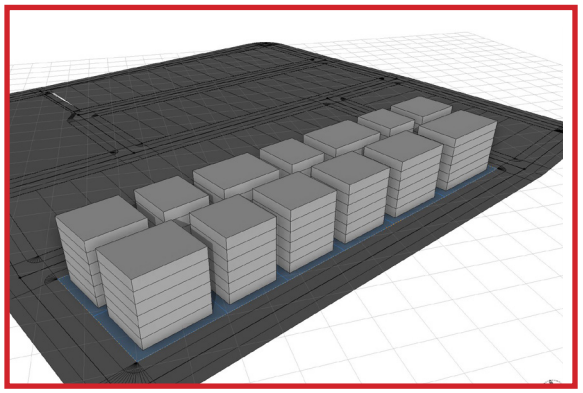
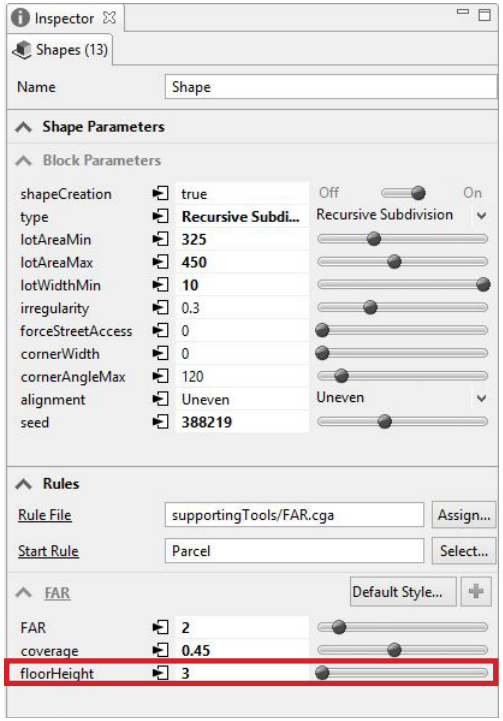


Figure 5.32.5 The lot coverage is increased to 60%.

5.3 Floor Area Ratio Rule

The mass is being shifted based on the single variable of the floor heights.

Table 5.3.1



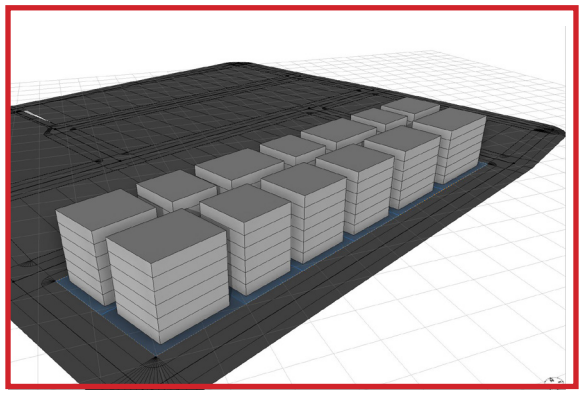


Figure 5.33.1 The default floor height is set at 3 metres.

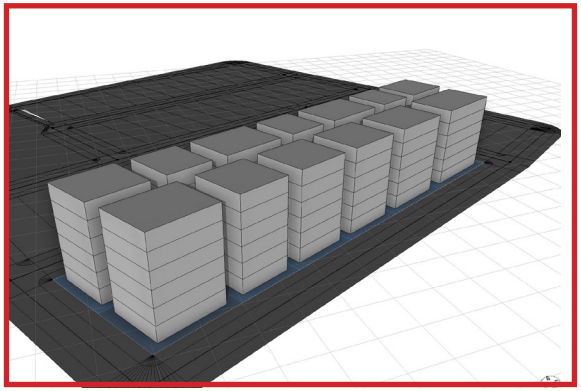


Figure 5.33.2 The floor height is increased to 4 metres.

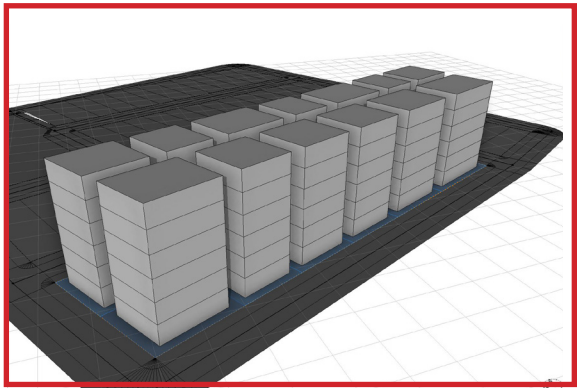


Figure 5.33.3 The floor height is increased to 5 metres.

5.4 Zoning Rule

The advanced zoning rule was developed to be a more comprehensive and inclusive zoning rule which includes the previous zoning rules, but adds an opacity layer, a usage layer and a facade height layer. The default is different based on residential or commercial zoning. This rule is important as it sets up the parameters for how the buildings can be built on each lot.

Going forward it would need to be further developed to be more associative and more inclusive of LEED neighbourhood design parameters.

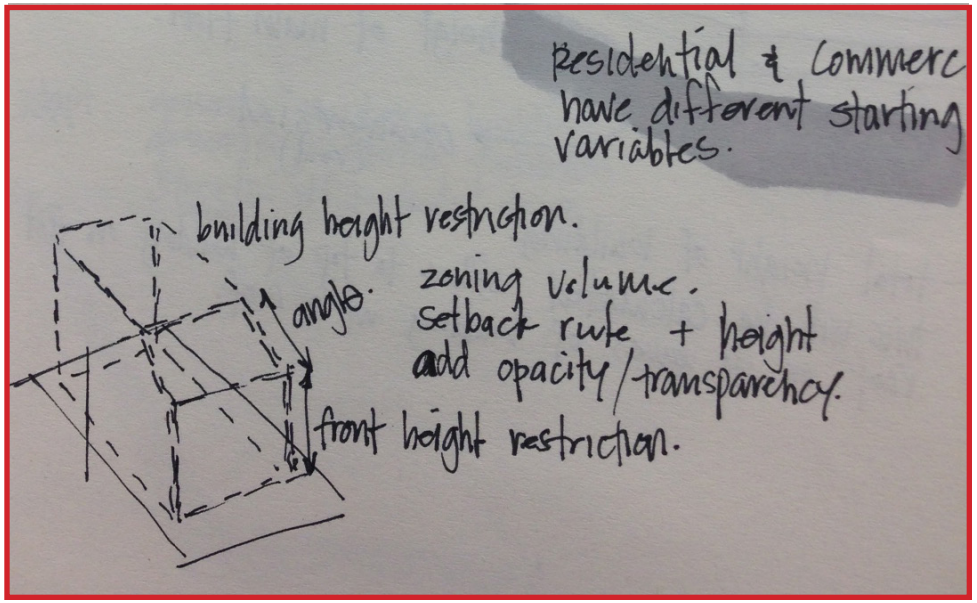


Figure 5.40

CGA Script

Associated English Explanation

```
/**
 * File:    Zoning.cga
 * Created: 2 October 2015, 18:15:17 GMT
 * Code modified from ESRI's "Zoning obtained from Example_05_
Urban_Design_2015/rules/Buildings_Advanced_Buildings/Support at
                    http://www.arcgis.com/home/item.
html?id=18baa6129da342a388f7c1b6bae69df3 on September 30 2015.
 * Author:  Grafton
 */

6   version "2015.0"
    import FAR:"Grafton_Files/rules/supportingTools/FAR.cga"
    import zoningSettings : "Grafton_Files/rules/supportingTools/Zoning
    Settings.cga"

    ##Still need to imput the FAR data so that it is being incorporated into
    the code and becomes a useable variable.
```

Create a rule and call it Zoning.cga
The system automatically inputs the time that the rule was created, the author of the rule and the version of the system that the rule was created in.
This particular rule has been modified from an original Zoning rule that was created by ESRI in thier Urban Design Rules tutorial.

Each Parametric variable has to be created in a hierarchal fashion prior to starting the rule.
Other rules can be imported into the rule which is being created. In this case, the previous floor area ratio rule and another zoning settings rule have been imported. The zoning settings rule disccusses performance specifications written by ESRI, which should be altered to reflect LEED standards. It does not impact this rule, but impacts the future rules that this Zoning rule is imported into such as ParkSpace.cga and Advanced Building Construction.cga.

```
1   @Group("Display",0) @Order(0) @Range("Building",
    "Envelope","Building & Envelope")
1.1 attr zoningDisplay = "Building & Envelope"

    @Group("Display") @Order(1) @Range(0.2,1)
1.2 attr envelopeTransparency = 0.4

    @Group("Display") @Order(2)
1.3 attr storyEdgeDisplay = false

    @Group("Display") @Order(3)
1.4 attr floorEdgeSize = 0.1

    @Group("Display") @Order(4)
1.5 attr floorEdgeColor = "#ffffff"
```

In this case the first section of variables that are created in this rule have to do with the 1 Display Variables.
The individual variables within the display control are as follows:
1.1 The decision between displaying the building, the building envelope or both is made.
1.2 The decision of how transparent the building envelope should be is made. Typically it is left at 40%.
1.3 The decision to display the edge between floors in order to differentiate the floors is made. Typically it is left off but allows to quickly see how many floors are within a building.
1.4 The decision of how prominant this differentiation is being displayed at. is set to a minimal amount of 0.15 metres.
1.5. The colour of the edge is usually left as black.

```
3   @Group ("Usage",2) @Order(10) @Range(0,5)
3.1 attr fistZoneFloorCount = 2

    @Group ("Usage") @Order(11)
    @Range("None", "Commercial", "Office", "Residential", "Parking",
    "Other")
3.2 attr firstZoneUsage = "Commercial"

    @Group ("Usage") @Order(12) @Range(0,5)
33  attr secondZoneFloorCount = 0

    @Group ("Usage") @Order(13)
    @Range("None", "Commercial", "Office", "Residential", "Parking",
    "Other")
3.4 attr secondZoneUsage = "None"

    @Group ("Usage") @Order(14) @Range(0,5)
3.5 attr thirdZoneFloorCount = 0

    @Group ("Usage") @Order(15)
    @Range("None", "Commercial", "Office", "Residential", "Parking",
    "Other")
3.6 attr thirdZoneUsage = "None"
```

The second section of varaibles that are created in this rule have to do with the 3 Usage Variables. It displays the usage type of each floor.
3.1 The decision of how many floors are a part of the first zone. The default is two floors.
3.2 The decision of what type of usage is on the bottom section of the building. The default is commercial.
3.3 The decision of how many floors are a part of the second zone. The default is zero.
3.4 The decision of what type of usage is on the second section of the building. The default is none.
3.5 The dicision of how many floors are a part of the third zone. The default is zero.
3.6 The decision of what type of usage is on the third section of the building. The default is none.

```
#Transects
#Part of the original code supplied by ESRI but, I have manipulated the
corresponding numbers to be associated more closely with Winnipeg's
Zoning Bylaw.
const transect1 = "T1 Natural"
const transect2 = "T2 Rural"
const transect3 = "T3 Sub-Urban"
const transect4 = "T4 General Urban"
const transect5 = "T5 Urban Center"
const transect6 = "T6 Urban Core"

floorCountMinPertransect(transect) =
        case transect == transect1: 1
        case transect == transect2: 1
        case transect == transect3: 1
        case transect == transect4: 2
        case transect == transect5: 3
        case transect == transect6: 4
        else: 1

floorCountMaxPertransect(transect) =
        case transect == transect1: 1
        case transect == transect2: 2
        case transect == transect3: 3
        case transect == transect4: 4
        case transect == transect5: 10
        case transect == transect6: 30
        else: 1

streetSetbackPertransect(transect) =
        case transect == transect1: 0
        case transect == transect2: 9.8
        case transect == transect3: 3.048
        case transect == transect4: 0.3
        case transect == transect5: 0.3
        case transect == transect6: 0.3
        else: 1

sideSetbackPertransect(transect) =
        case transect == transect1: 0
        case transect == transect2: 18
        case transect == transect3: 1.219
        case transect == transect4: 0
        case transect == transect5: 0
        case transect == transect6: 0
        else: 1

rearSetbackPertransect(transect) =
        case transect == transect1: 0
        case transect == transect2: 23.8
        case transect == transect3: 7.62
        case transect == transect4: 0.91
        case transect == transect5: 0.3
        case transect == transect6: 0.3
        else: 1
```

The third section of variables created in this rule have to do with the 2 transects created as a part of ESRI's initial code but altered to be more reflective of Winnipegs Zoning Bylaw. The transects are reflective of the Urban Transect discussed by Duany Plater Zyberk that guides the development intensity from nature to highly urban.

```
const defaultEnvelopeAngle = 60
const defaulttransect = transect4
```

The default envelope angle is standardized at 60 degrees.
The default is the genral urban section of the transect.

```
    @Description("The type of transect chosen populates the base data but
    may be overiden by manipulating the other variables")
    ##There is a bug here. It will need to be altered so that it can return to
    a transect default. Currently once another piece of date is altered, the
    Transect variable is rendered useless.
    @Group("3Dform: transect",1) @Order(0) @Range("T1 Natural", "T2
    Rural", "T3 Sub-Urban", "T4 General Urban", "T5 Urban Center", "T6
    Urban Core")
2.1 attr transect = "T4 General Urban"

    @Description("Determines height limit of zoning envelope.")
    @Group("3Dform: height",3) @Order(1) @Range("Limit Height by
    maxHeight", "Limit Height by maxNumberOfFloors")
4.1 attr heightMethod = "Limit Height to maxNumberOfFloors"

    @Description("Set the heightMethod in order to control to the
    maxHeight.")
    @Group("3Dform: height") @Order(2)
4.2 attr maxHeight = 19

    @Group ("3Dform: height") @Order(3)
4.3 attr groundFloorHeight = 4.6

    @Group("3Dform: height") @Order(4) @Range(2,20)
4.4 attr minFloorCount =
            case heightMethod == "Limit Height to maxNumberOfFloors":
    floorCountMinPertransect(transect)
            else: floorCountMinPerMaxHeight

    @Group("3Dform: height") @Order(5) @Range(2,20)
4.5 attr maxNumberOfFloors =
            case heightMethod == "Limit Height to maxNumberOfFloors":
    floorCountMaxPertransect(transect)
            else: floorCountMaxPerMaxHeight

    # How many floors will fit into the max height?
    availableToUpperFloors = maxHeight - roofHeight - groundFloorHeight
    # - Foundation?
    floorCountMaxPerMaxHeight =
            case maxHeight < groundFloorHeight: 0
            else: 1 + floor(availableToUpperFloors / upperFloorHeight)
    floorCountMinPerMaxHeight =
            case floorCountMaxPerMaxHeight <= 2: 1
            case floorCountMaxPerMaxHeight <= 4: 2
            case floorCountMaxPerMaxHeight <= 5: 3
            else: floor(floorCountMaxPerMaxHeight * 0.7)

    @Group ("3Dform: height") @Order(6)
4.6 attr upperFloorHeight = 3.6

    @Group ("3Dform: height") @Order(7)
4.7 attr roofHeight = 3
```

The fourth section of variables have to do with the 4. height of the zoning envelope.

4.1 The decision of how to limit the overall height of the building enveloper is determined either by the overall height of the building restraints enforced by the City Zoning Bylaw or by the total number of floors. The default is left at the number of floors.

4.2 The decision of the overall height restraint is associated with the transect and the City of Winnipeg Zoning bylaw and in this case the default is left at 19 metres.
4.3 The decision of the ground floor height is left at a default of 4.6 metres.

4.4 The decision of the minimum floor count is associated with the transect.

4.5 The decision of the maximum floor count is associated with the transect.

The total number of floors is determined by the overall height of the building minus the height of the roof, the height of the ground floor, the foundation height and the associated height of the upper floors.

4.6 The upper floors are set to a default of 3.6 metres high.

4.7 The roof height is set to a default of 3 metres high.

```
    @Group ("3Dform: setbacks",4) @Order(1) @Range(0,50)
5.1 attr streetSetback = streetSetbackPertransect(transect4)

    @Group ("3Dform: setbacks") @Order(2)
5.2 attr streetHeight = defaultFacadeHeight

    @Group ("3Dform: setbacks") @Order(3)
5.3 attr streetAngle = defaultEnvelopeAngle

    @Group ("3Dform: setbacks") @Order(4)
5.4 attr rearSetback = backSetbackPertransect(transect)

    @Group ("3Dform: setbacks") @Order(5)
5.5 attr rearHeight = defaultFacadeHeight

    @Group ("3Dform: setbacks") @Order(6)
5.6 attr rearAngle = defaultEnvelopeAngle

    @Group ("3Dform: setbacks") @Order(7)
5.7 attr sideSetback= sideSetbackPertransect(transect)

    @Group ("3Dform: setbacks") @Order(8)
5.8 attr sideHeight = defaultFacadeHeight

    @Group ("3Dform: setbacks") @Order(9)
5.9 attr sideAngle = defaultEnvelopeAngle
```

The fifth section of variables has to do with the 5. setback variables.
5.1 to 5.9 The standard setbacks are associated with the transect. They each deal with the setback distance, the allowed height at that setback and the angle at which the building envelop recedes back at. This helps determine at what point the building needs to be stepped back from the street or interior courtyard.

```
@Hidden
attr foundationHeight = 0
@Hidden
attr adjustFoundation = 0
```

The foundation height and adjustment is not a variable but it should allow for the building or envelope to ensure they are sitting above the sites topography.

```
usageColor(usage) =
        case usage == "Residential" : zoningSettings.
residentialZoningColour
        case usage == "Commercial" : zoningSettings.
commercialZoningColour
        case usage == "Office" : zoningSettings.officeZoningColour
        case usage == "Other" : zoningSettings.additionalZoningColour
        case usage == "Green Space" : zoningSettings.
parkZoningColour
        case usage == "None" : zoningSettings.noZoningColour
        else: zoningSettings.noZoningColour
```

The imported zoning settings rule determines the colours of each type of usage. Residential being yellow, commercial being red, office being grey, other being orange, greenspace being green. etc.

```
const thisMuchBiggerThanParcel = 0.1
```

Similar to the precision tool, this constant allows for the building facade to be proud of the parcel by 0.1 metres.

```
ZoningEnvelope -->
        s('1,0,'1)
        setback(streetSetback) { street.front: NIL | remainder:
                setback(rearSetback) { street.back: NIL | remainder:
                        setback(sideSetback) { street.left: NIL |
remainder:
                                setback(sideSetback) { street.right:
NIL | remainder:
                                        zoningShell
                                }
                        }
                }
        }
```

The zoning shell is created by taking the remainder of the zoning envelope after all of the setbacks are put to work. It will be further sub-divided by usage.

```
foundationHeightAdjusted = foundationHeight + adjustFoundation

maxEnvelopeHeight =
        case heightMethod == "Allow for maxHeight":
maxEnvelopeHeightFromMaxHeight
        else: maxEnvelopeHeightFromFloorCount
```

The foundation height can be adjusted to account for the topographic changes. This tool has not worked as intended.

The maximum enevelope height is determined either by the overall height, or the total number of floors, roof and foundation heights.

```
const maxEnvelopeHeightFromMaxHeight = foundationHeightAdjusted
+ maxHeight

const maxEnvelopeHeightFromFloorCount = foundationHeightAdjusted
+ groundFloorHeight
        + (upperFloorHeight * (maxNumberOfFloors - 1)) +
roofHeight

const defaultFacadeHeight = maxEnvelopeHeight - roofHeight


zoningShell -->
        case maxEnvelopeHeight > 0:
                alignScopeToAxes(y)
                s(scope.sx + thisMuchBiggerThanParcel, '1, scope.sz +
thisMuchBiggerThanParcel)
                center(xz)
                set(material.opacity, envelopeTransparency)
                envelope(maxEnvelopeHeight, streetHeight,
streetAngle, rearHeight, rearAngle, sideHeight, sideAngle)
                ColorByUsage
        else: NIL
```

The zoning shell is only created if the envelope height is greater than 0. It is aligned to the y axis and made larger than the zoning envelope so that the colours of the usage can be seen.

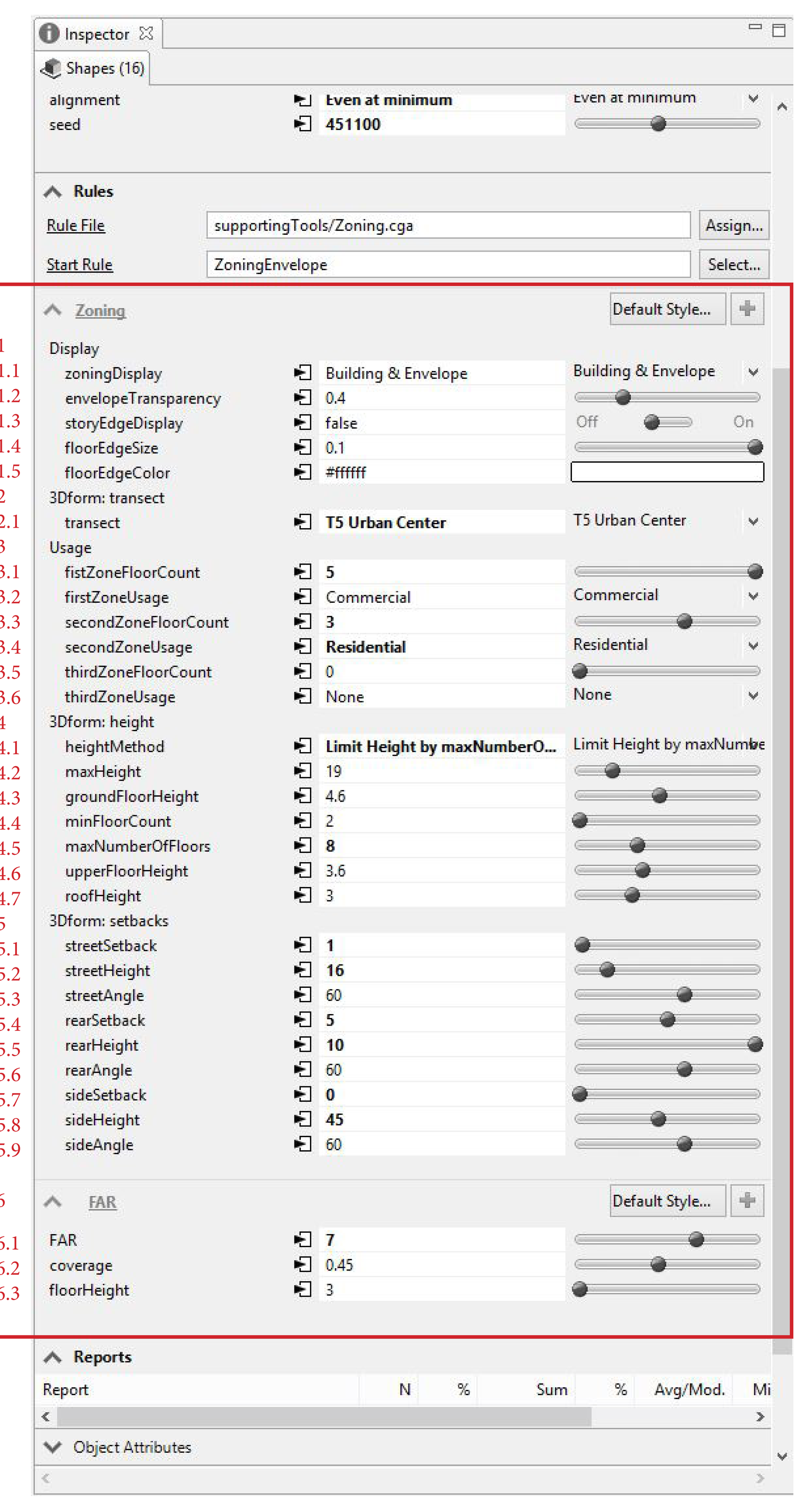
```
usagePerFloor(floorNumber) =
        case fistZoneFloorCount <= 0: firstZoneUsage
        case floorNumber >= fistZoneStartFloor && floorNumber <=
fistZoneEndFloor: firstZoneUsage
        case floorNumber >= secondZoneStartFloor && floorNumber
<= secondZoneEndFloor: secondZoneUsage
        case floorNumber >= thirdZoneStartFloor && floorNumber
<= thirdZoneEndFloor: thirdZoneUsage
        else: ""

# Incoming floorNumber is zero based (ground floor is zero).
fistZoneStartFloor = 0
fistZoneEndFloor = fistZoneStartFloor + (fistZoneFloorCount - 1)
secondZoneStartFloor = fistZoneEndFloor + 1
secondZoneEndFloor = secondZoneStartFloor +
(secondZoneFloorCount - 1)
thirdZoneStartFloor = secondZoneEndFloor + 1
thirdZoneEndFloor = thirdZoneStartFloor + (thirdZoneFloorCount - 1)
```

The usage is determined through floors and zones. There are three zones for each building which allow for mixed use buildings to be created. This is based off of LEED requirements to have mixed use neighbourhood.

```
#Performance Specifications
#These are a part of the original Code written by ESRI and only altered
to link with other files.
#Unfortunately, this does not do the best job of representing how LEED
ND as it is not a rating sytem based on points.
#The numbers being linked into these are based on data that I have
accumulated through my work experiences at Qualico
waterConsumptionPerUsage(usage) =
        case usage == "Residential": zoningSettings.
residentialWaterConsumption_L_m2
        case usage == "Commercial": zoningSettings.
commercialWaterConsumption_L_m2
        case usage == "Office": zoningSettings.
officeWaterConsumption_L_m2
        case usage == "Parking": zoningSettings.
parkingWaterConsumption_L_m2
        case usage == "Other": zoningSettings.
otherWaterConsumption_L_m2
        else: 0

percentGreywaterProducedPerUsage(usage) =
        case usage == "Residential": zoningSettings.
residentialWaterPercentGreywaterProduced_L_m2
        case usage == "Commercial": zoningSettings.
commercialWaterPercentGreywaterProduced_L_m2
        case usage == "Office": zoningSettings.
officeWaterPercentGreywaterProduced_L_m2
        case usage == "Parking": zoningSettings.
parkingWaterPercentGreywaterProduced_L_m2
        case usage == "Other": zoningSettings.
otherWaterPercentGreywaterProduced_L_m2
        else: 0

electricConsumptionPerUsage(usage) =
        case usage == "Residential": zoningSettings.
residentialElectricityConsumption__kWh_m2
        case usage == "Commercial": zoningSettings.
commercialElectricityConsumption__kWh_m2
        case usage == "Office": zoningSettings.
officeElectricityConsumption__kWh_m2
        case usage == "Parking": zoningSettings.
parkingElectricityConsumption__kWh_m2
        case usage == "Other": zoningSettings.
otherElectricityConsumption__kWh_m2
        else: 0

heatingConsumptionPerUsage(usage) =
        case usage == "Residential": zoningSettings.
residentialHeatingConsumption__kWh_m2
        case usage == "Commercial": zoningSettings.
commercialHeatingConsumption__kWh_m2
        case usage == "Office": zoningSettings.
officeHeatingConsumption__kWh_m2
        case usage == "Parking": zoningSettings.
parkingHeatingConsumption__kWh_m2
        case usage == "Other": zoningSettings.
otherHeatingConsumption__kWh_m2
        else: 0

domesticWastePerUsage(usage) =
        case usage == "Residential": zoningSettings.
residentialDomesticWaste__kg_m2
        case usage == "Commercial": zoningSettings.
commercialDomesticWaste__kg_m2
        case usage == "Office": zoningSettings.officeDomesticWaste__
kg_m2
        case usage == "Parking": zoningSettings.
parkingDomesticWaste__kg_m2
        case usage == "Other": zoningSettings.otherDomesticWaste__
kg_m2
        else: 0

constructionWastePerUsage(usage) =
        case usage == "Residential": zoningSettings.
residentialConstructionWaste__kg_m2
        case usage == "Commercial": zoningSettings.
commercialConstructionWaste__kg_m2
        case usage == "Office": zoningSettings.
officeConstructionWaste__kg_m2
        case usage == "Parking": zoningSettings.
parkingConstructionWaste__kg_m2
        case usage == "Other": zoningSettings.
parkingConstructionWaste__kg_m2
        else: 0
```

Performance specifications do not influence this rule but influence susbequent rules that the Zoning.cga rule is imported into. It is written as a part of ESRI's initial code but could be modified to meet LEED Neighbourhood Design's Green Infrastrure and Building section as it reports the performance of water consumption, waste produced, greywater produced, electricity consumption and heating consumption.

Parametric Variable Result



5.4 Zoning Rule

The transparency of the building envelope is being shifted based on the single variable.

Table 5.4.1

Rules			
Rule File	supportingTools/Zoning.cga	Assign...	
Start Rule	ZoningEnvelope	Select...	
Zoning		Default Style...	
Display			
zoningDisplay	**Building**	Building	
envelopeTrans...	0.4		
storyEdgeDisplay	**false**	Off	On
floorEdgeSize	0.1		
floorEdgeColor	#ffffff		
3Dform: transect			
transect	**T4 General Urban**	T4 General Urban	
Usage			
fistZoneFloorC...	0		
firstZoneUsage	**Commercial**	Commercial	
secondZoneFlo...	0		
secondZoneUs...	None	None	
thirdZoneFloor...	0		
thirdZoneUsage	None	None	
3Dform: height			
heightMethod	Limit Height to ...	Limit Height by maxHeight	
maxHeight	19		
groundFloorHe...	4.6		
minFloorCount	2		
maxNumberOf...	4		
upperFloorHeig...	3.6		
roofHeight	3		

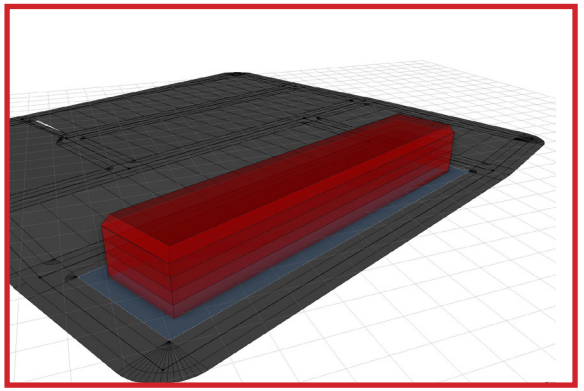


Figure 5.41.1 The default transparency is set to 40%.

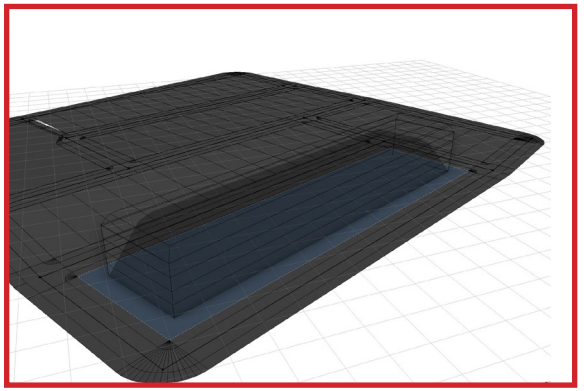


Figure 5.41.2 The transparency is changed to 0%.

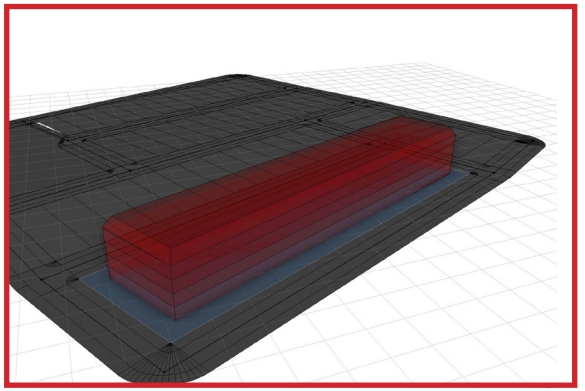


Figure 5.41.3 The transparency is changed to 20%.

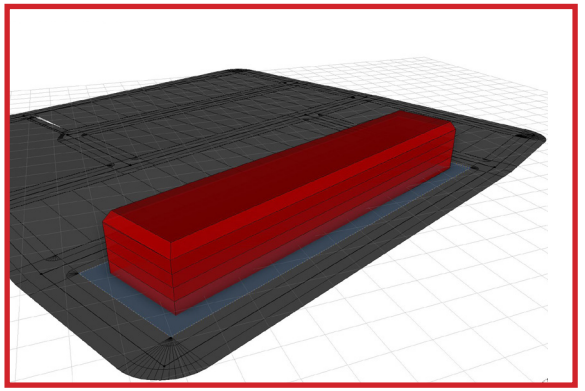


Figure 5.41.4 The transparency is changed to 60%.

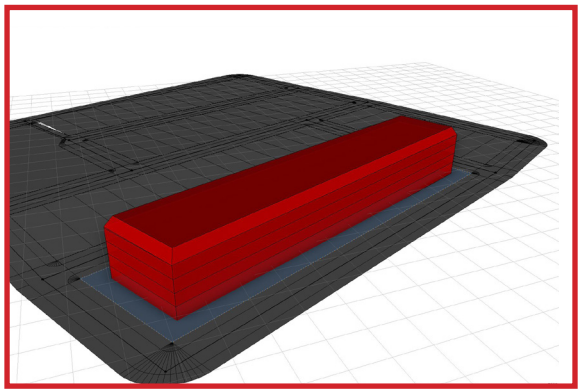


Figure 5.41.5 The transparency is changed to 80%.

5.4 Zoning Rule

The building envelope is altered based on preset zoning rules for each section of the Duany Urban Transect.

Table 5.4.1

Rules			
Rule File	supportingTools/Zoning.cga	Assign...	
Start Rule	ZoningEnvelope	Select...	
Zoning		Default Style...	
Display			
zoningDisplay	Building	Building	
envelopeTrans...	0.4		
storyEdgeDisplay	false	Off	On
floorEdgeSize	0.1		
floorEdgeColor	#ffffff		
3Dform: transect			
transect	T4 General Urban	T4 General Urban	
Usage			
fistZoneFloorC...	0		
firstZoneUsage	Commercial	Commercial	
secondZoneFlo...	0		
secondZoneUs...	None	None	
thirdZoneFloor...	0		
thirdZoneUsage	None	None	
3Dform: height			
heightMethod	Limit Height to ...	Limit Height by maxHeight	
maxHeight	19		
groundFloorHe...	4.6		
minFloorCount	2		
maxNumberOf...	4		
upperFloorHeig...	3.6		
roofHeight	3		

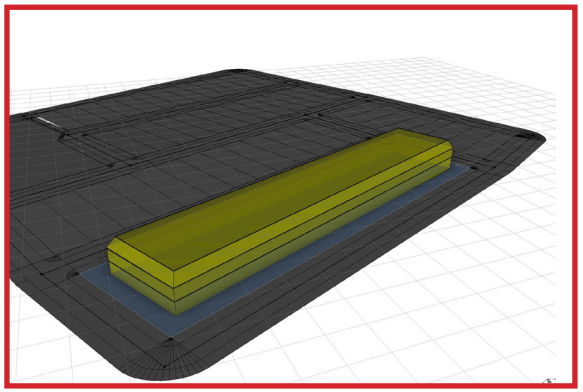


Figure 5.42.1 The building envelope is depicted with the zoning code related to the Rural section within Duany's Urban Transect.

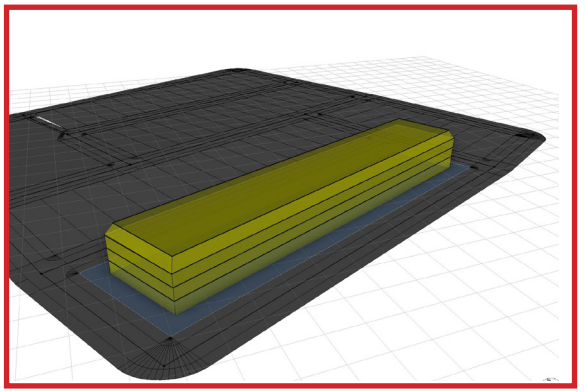


Figure 5.42.2 The building envelope is depicted with the zoning code related to the Suburban section within Duany's Urban Transect.

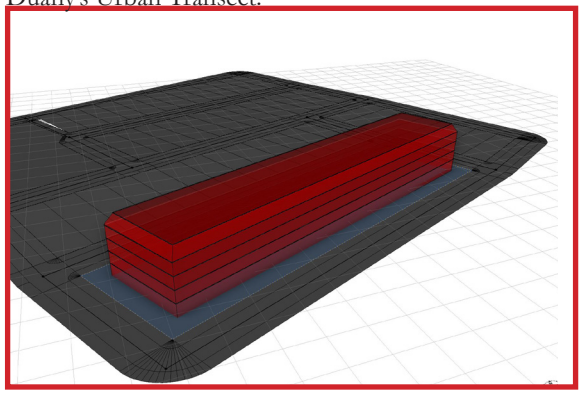


Figure 5.42.3 The building envelope is depicted with the zoning code related to the General Urban section within Duany's Urban Transect.

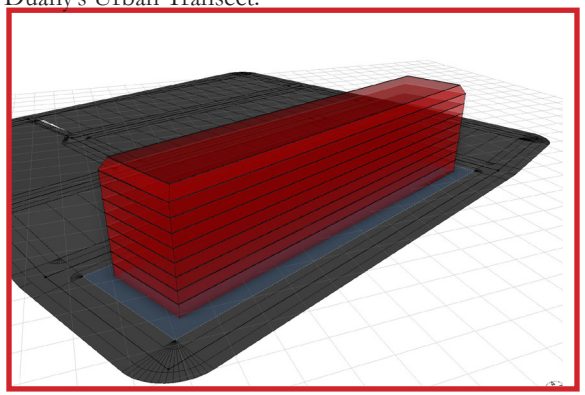


Figure 5.42.4 The building envelope is depicted with the zoning code related to the Urban Centre Transect section within Duany's Urban Transect.

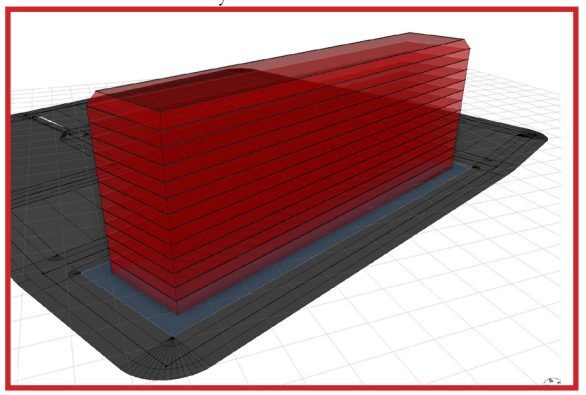


Figure 5.42.5 The building envelope is depicted with the zoning code related to the Urban Core section within Duany's Urban Transect.

5.4 Zoning Rule

The Usage is being shifted based type and number variables.

Table 5.4.1

3Dform: transect		
transect	T6 Urban Core	T6 Urban Core
Usage		
fistZoneFloorC...	5	
firstZoneUsage	Commercial	Commercial
secondZoneFlo...	4	
secondZoneUs...	Office	Office
thirdZoneFloor...	0	
thirdZoneUsage	None	None
3Dform: height		
heightMethod	Limit Height to ...	Limit Height by maxHeight
maxHeight	19	
groundFloorHe...	4.6	
minFloorCount	4	
maxNumberOf...	12	
upperFloorHeig...	3.6	
roofHeight	3	
3Dform: setbacks		
streetSetback	5.5	
streetHeight	44.2	
streetAngle	60	
rearSetback	0	
rearHeight	44.2	
rearAngle	60	
sideSetback	0	
sideHeight	44.2	
sideAngle	60	

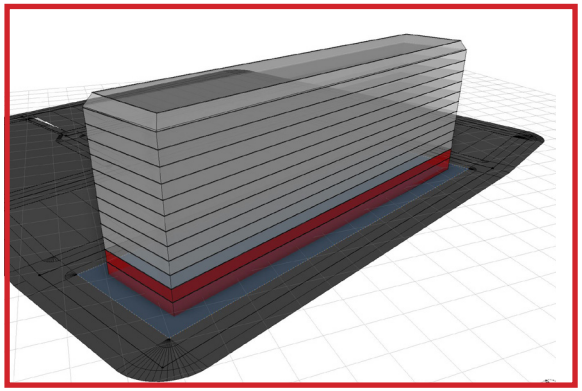


Figure 5.43.1 The building envelope depicts 2 floors of commercial use.

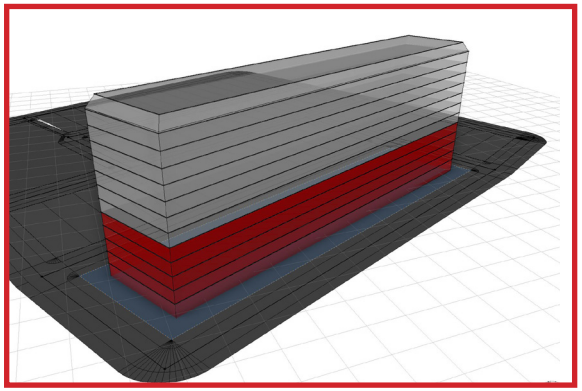


Figure 5.43.2 The building envelope depicts 5 floors of commercial use.

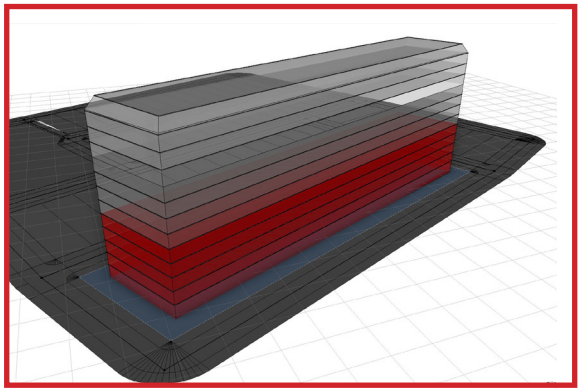


Figure 5.43.3 The building envelope depicts 5 floors of commercial use and 4 floors of office use.

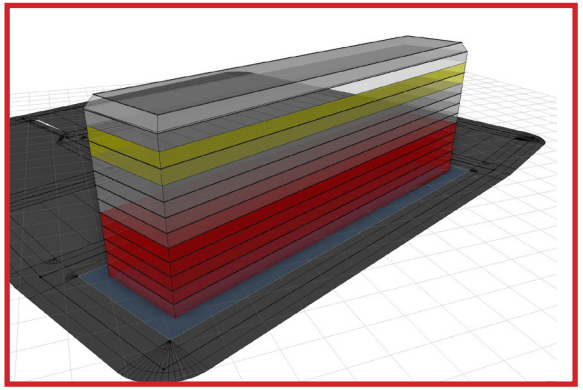


Figure 5.43.4 The building envelope depicts 5 floors of commercial use, 4 floors of office use, and 2 floors of residential use

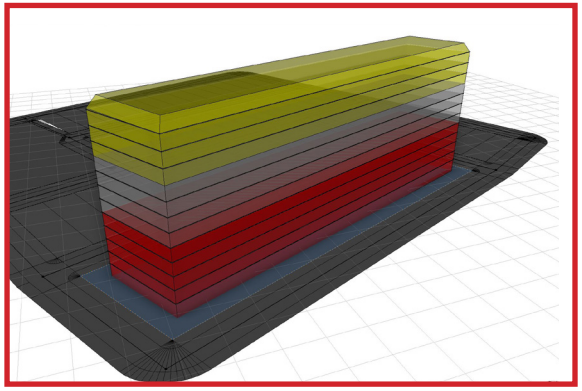


Figure 5.43.5 The building envelope depicts 5 floors of commercial use, 4 floors of office use, and 4 floors of residential use

5.4 Zoning Rule

The height restrictions on different sections of the build-able envelope are being set through the use of a couple of variables

Table 5.4.1

3Dform: transect		
transect	**T6 Urban Core**	T6 Urban Core
Usage		
fistZoneFloorC...	**5**	
firstZoneUsage	**Commercial**	Commercial
secondZoneFlo...	**4**	
secondZoneUs...	**Office**	Office
thirdZoneFloor...	0	
thirdZoneUsage	None	None
3Dform: height		
heightMethod	Limit Height to ...	Limit Height by maxHeight
maxHeight	19	
groundFloorHe...	4.6	
minFloorCount	4	
maxNumberOf...	12	
upperFloorHeig...	3.6	
roofHeight	3	
3Dform: setbacks		
streetSetback	**5.5**	
streetHeight	44.2	
streetAngle	60	
rearSetback	0	
rearHeight	44.2	
rearAngle	60	
sideSetback	**0**	
sideHeight	44.2	
sideAngle	60	

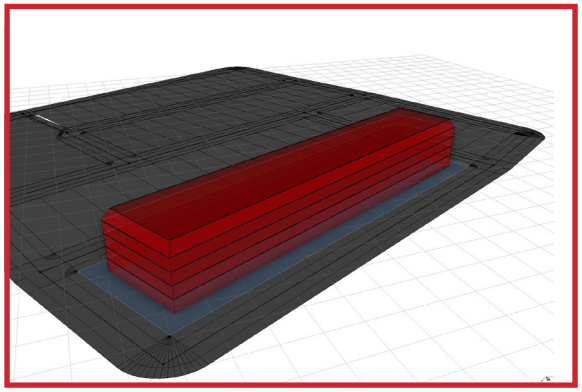


Figure 5.44.1 The default building envelope is set.

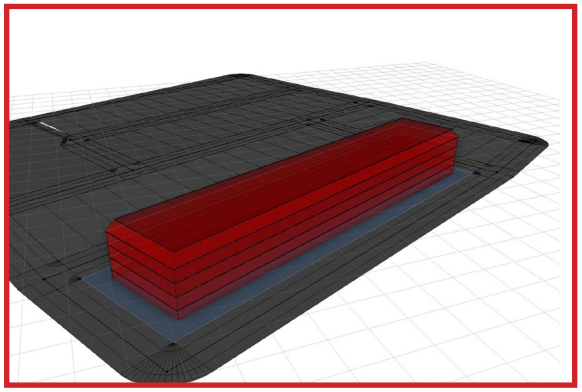


Figure 5.44.2 The ground floor height is reduced to 3 metres.

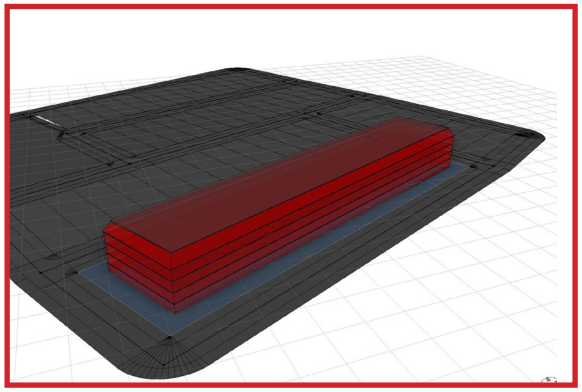


Figure 5.44.3 The upper floors height are reduced to 3 metres.

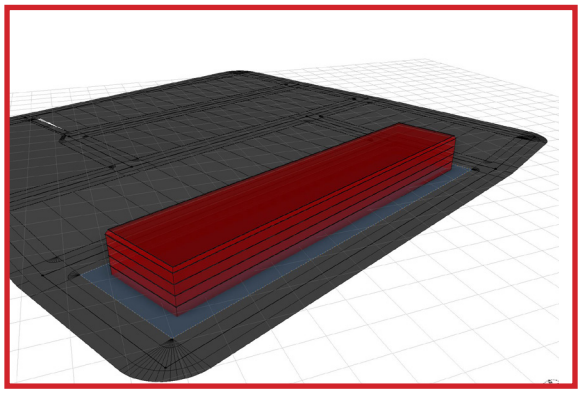


Figure 5.44.4 The roof height is reduced to 1 metre.

5.4 Zoning Rule

The height of the building envelope at the street side is altered based on a single variable.

Table 5.4.1

3Dform: transect			
transect		**T6 Urban Core**	T6 Urban Core
Usage			
fistZoneFloorC...		**5**	
firstZoneUsage		**Commercial**	Commercial
secondZoneFlo...		**4**	
secondZoneUs...		**Office**	Office
thirdZoneFloor...		**4**	
thirdZoneUsage		**Residential**	Residential
3Dform: height			
heightMethod		**Limit Height by ...**	Limit Height by maxNumbe
maxHeight		**19**	
groundFloorHe...		**3.5**	
minFloorCount		**2**	
maxNumberOf...		**4**	
upperFloorHeig...		**3**	
roofHeight		**1**	
3Dform: setbacks			
streetSetback		**0**	
streetHeight		**10**	
streetAngle		60	
rearSetback		0	
rearHeight		12.5	
rearAngle		60	
sideSetback		**0**	
sideHeight		12.5	
sideAngle		60	

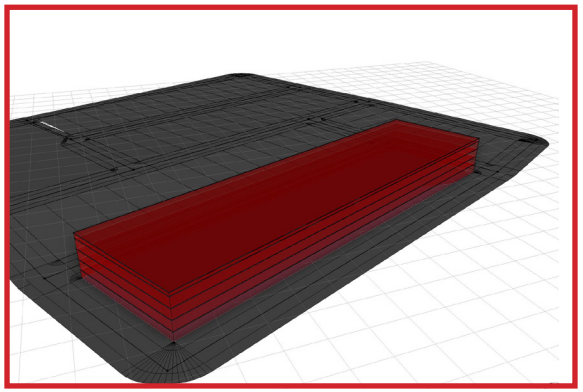


Figure 5.45.1 The at street building height is set to 15 metres.

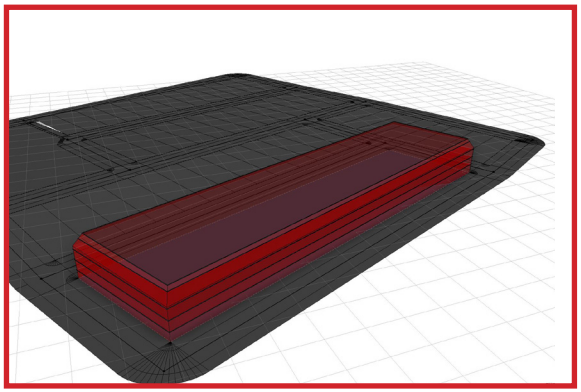


Figure 5.45.2 The at street building height is reduced to 10 metres

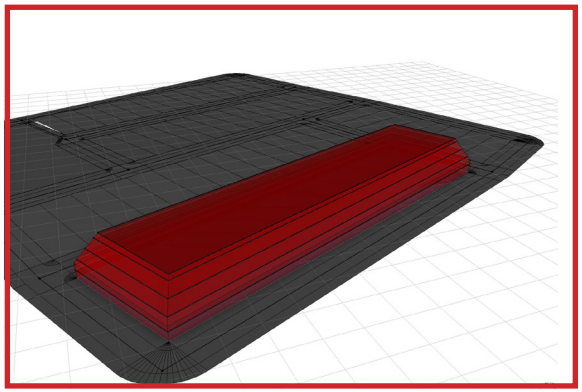


Figure 5.45.3 The at street building height is set to 5 metres.

5.4 Zoning Rule

The angle of the building envelope at the street side is altered based on a single variable.

Table 5.4.1

3Dform: transect			
transect		**T6 Urban Core**	T6 Urban Core
Usage			
fistZoneFloorC...		**5**	
firstZoneUsage		**Commercial**	Commercial
secondZoneFlo...		**4**	
secondZoneUs...		**Office**	Office
thirdZoneFloor...		**4**	
thirdZoneUsage		**Residential**	Residential
3Dform: height			
heightMethod		**Limit Height by ...**	Limit Height by maxNumb
maxHeight		**19**	
groundFloorHe...		**3.5**	
minFloorCount		**2**	
maxNumberOf...		**4**	
upperFloorHeig...		**3**	
roofHeight		**1**	
3Dform: setbacks			
streetSetback		**0**	
streetHeight		**10**	
streetAngle		60	
rearSetback		0	
rearHeight		12.5	
rearAngle		60	
sideSetback		**0**	
sideHeight		12.5	
sideAngle		60	

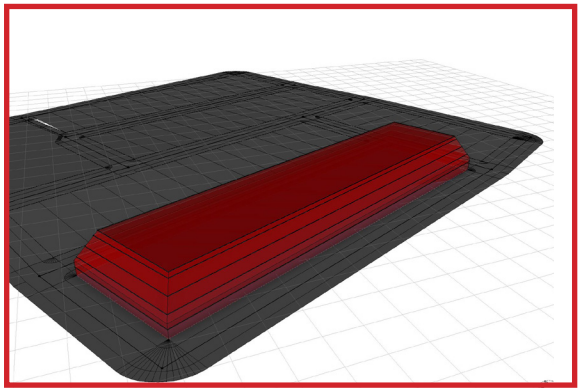


Figure 5.45.4 The building envelope returns from the set building height at the street at an angle of 60%.

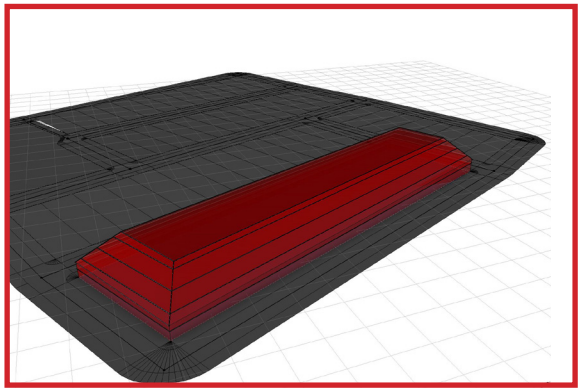


Figure 5.45.5 The building envelope returns from the set building height at the street at an angle of 45%.

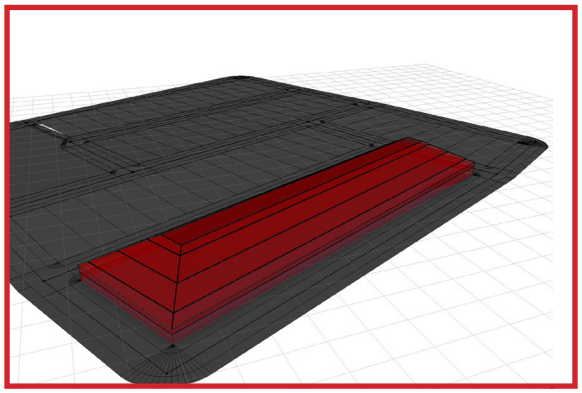


Figure 5.45.6 The building envelope returns from the set building height at the street at an angle of 30%.

5.4 Zoning Rule

The height of the building envelope at the rear yard is altered based on a single variable.

Table 5.4.1

3Dform: transect		
transect	T6 Urban Core	T6 Urban Core
Usage		
fistZoneFloor...	5	
firstZoneUsage	Commercial	Commercial
secondZoneFl...	4	
secondZoneU...	Office	Office
thirdZoneFlo...	4	
thirdZoneUsa...	Residential	Residential
3Dform: height		
heightMethod	Limit Height b...	Limit Height by maxNumb
maxHeight	19	
groundFloor...	3.5	
minFloorCount	2	
maxNumber...	4	
upperFloorHe...	3	
roofHeight	1	
3Dform: setbacks		
streetSetback	0	
streetHeight	5	
streetAngle	30	
rearSetback	7.62	
rearHeight	12.5	
rearAngle	60	
sideSetback	0	
sideHeight	12.5	
sideAngle	60	

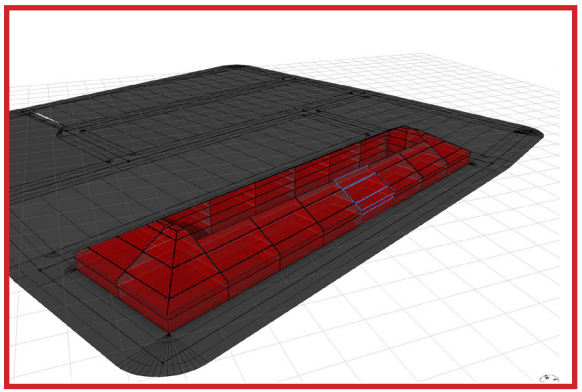


Figure 5.46.1 The height is set at 12.5 metres

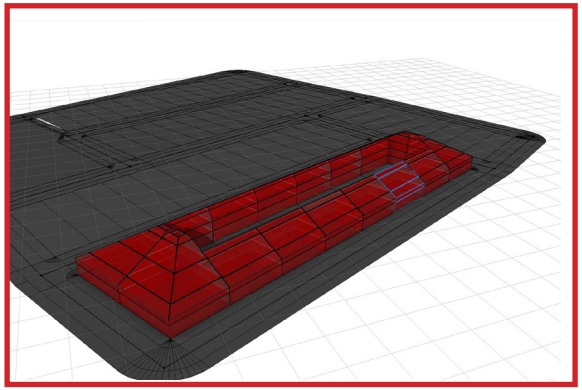


Figure 5.46.2 The height is reduced to 7.5 metres

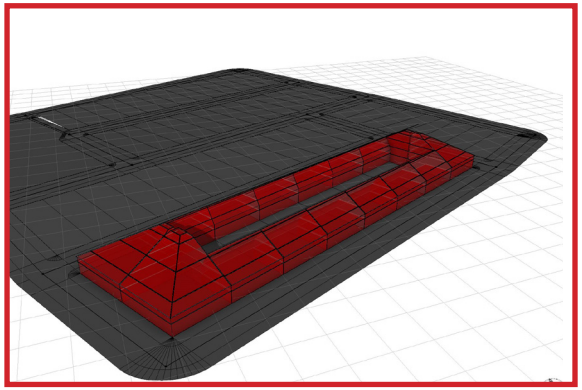


Figure 5.46.3 The height is reduced to 5 metres.

5.4 Zoning Rule

The side yard setback is altered based on a single variable.

Table 5.4.1

3Dform: transect		
transect	T6 Urban Core	T6 Urban Core
Usage		
fistZoneFloor...	5	
firstZoneUsage	Commercial	Commercial
secondZoneFl...	4	
secondZoneU...	Office	Office
thirdZoneFlo...	4	
thirdZoneUsa...	Residential	Residential
3Dform: height		
heightMethod	Limit Height b...	Limit Height by maxNumb
maxHeight	19	
groundFloor...	3.5	
minFloorCount	2	
maxNumber...	4	
upperFloorHe...	3	
roofHeight	1	
3Dform: setbacks		
streetSetback	0	
streetHeight	5	
streetAngle	30	
rearSetback	7.62	
rearHeight	12.5	
rearAngle	60	
sideSetback	0	
sideHeight	12.5	
sideAngle	60	

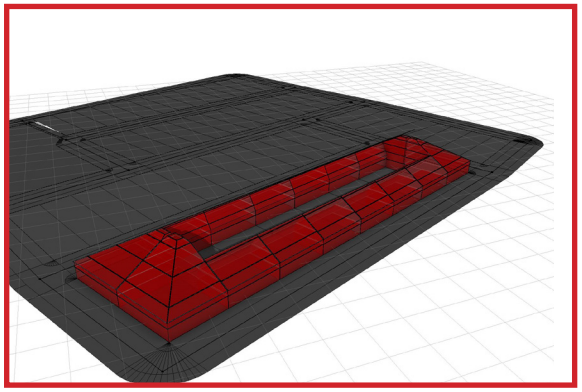


Figure 5.47.1 The side yard setback is set to 0.

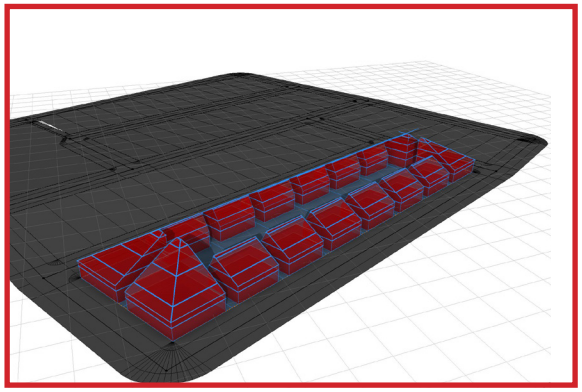


Figure 5.47.2 The side yard setback is increased to 2 metres.

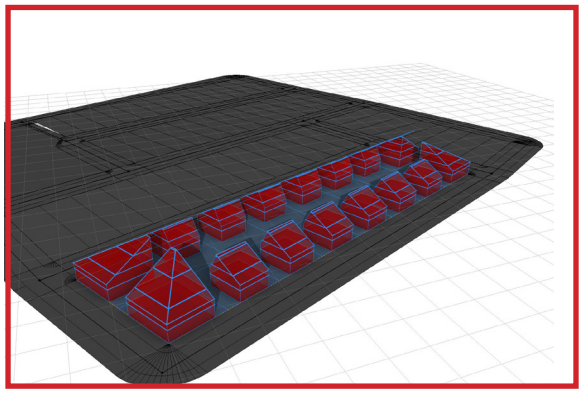


Figure 5.47.3 The side yard setback is increased to 4 metres.

5.5 ParkSpace Rule

The parks rule was conceived to decide which trees currently on site should be retained during a site development. As the program was explored, it became apparent that the existing trees could not be imported as the data did not exist in the shape file format required. The rule has subsequently been developed to import trees spontaneously based on an algorithm. It also generates pathways and imports textures.

Going forward this tool would need to be further developed through the use of an extensive data collection and import of landscape features.

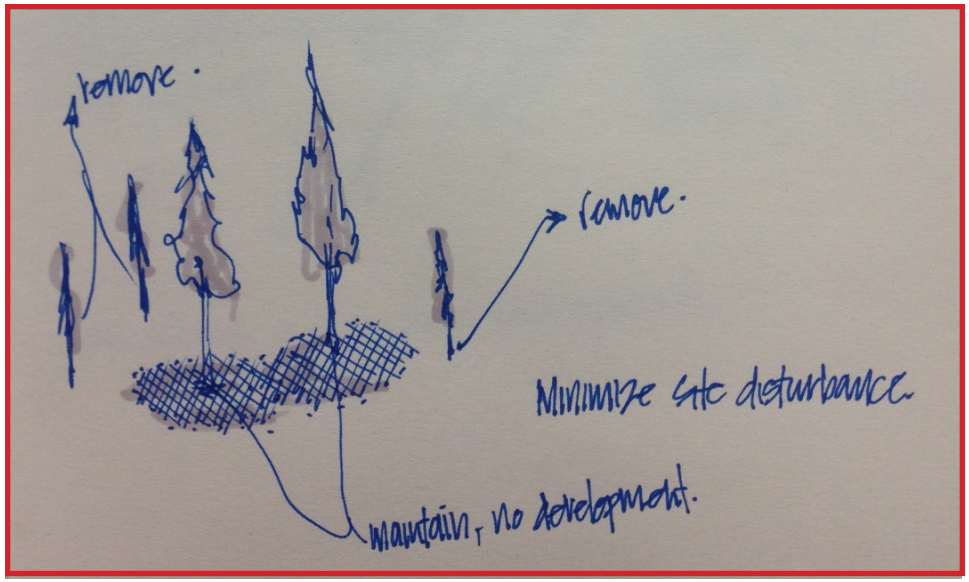


Figure 5.50

CGA Script / Associated English Explanation

```
/**
 * File:    Parkspace.cga
 * Code modified from ESRI's Greenspace Construcion obtained from
Example_05_Urban_Design_2015/rules/Buildings_Advanced_Buildings/
Support at
                    http://www.arcgis.com/home/item.
html?id=18baa6129da342a388f7c1b6bae69df3 on October 01 2015.
 * Created: 7 Oct 2015
 * Author:  Grafton
 */

version "2015.0"

const assetDirectory = "Grafton_Files/assets/Landscape_Design_
Greenspace"
peopleAsset = fileRandom("Grafton_Files/assets/3DModels_from_
LowPolygon3D.com/LowPolygon3D.com_People/*.obj")

import zoningSettings:"Grafton_Files/rules/supportingTools/Zoning
Settings.cga"
7   import greenspaceRules:"Grafton_Files/rules/supportingTools/
greenspaceRules.cga"
```

Create a rule and call it ParkSpace.cga
The system automatically inputs the time that the rule was created, the author of the rule and the version of the system that the rule was created in.
This particular rule has been modified from an original Greenspace Construction rule that was created by ESRI in thier Urban Design Rules tutorial.

Each Parametric variable has to be created in a hierarchal fashion prior to starting the rule.
Other rules can be imported into the rule which is being created. In this case, The zoning settings rule and a similar greenspace rule are imported. Neither have a visual output but discuss sections of the report.

3d visual aspects such as trees and people are also imported from external rules creted by ESRi and LowPolygon3D.com

```
# Display

1   @Group("Display",0) @Order(1)
1.1 attr textureDisplay = true

    @Group("Display") @Order(2)
    @Range("Thematics Off", "Solid Color", "Usage", "Peak Runoff/
    Permeability")
1.2 attr thematicDisplay = "Thematics Off"

    @Group("Display") @Order(3)
1.3 attr colour = "#FFFFFF"

    @Group("Display") @Order(4) @Range(0,1)
1.4 attr transparency = 1
```

In this case the first section of variables that are created in this rule have to do with the 1 Display Variables.
The individual variables within the display control are as follows:
1.1 The decision whether the texture is being shown or not is determined.
1.2 The decision of which thematic layer is turned on is discussed. The default is that the thematics are turned off, but the usage and permeability tool can be insightful.
1.3 The decision of the colour display is carried over from the zoning tool.
1.4 The decision of the transparency is typically left at 1.

```
texturingOn = textureDisplay          # Shorthand.
thematicsOn = thematicDisplay != "Thematics Off"
coloringOn = !thematicsOn             # Shorthand.

thematicColor =
        case thematicDisplay == "Peak Runoff/Permeability":
                # Specific materials will be colored downstream, but
everything else will use white.
                "FFFFFF"
        case thematicDisplay == "Solid Color":
                colour
        case thematicDisplay == "Usage":
                zoningSettings.parkZoningColour
        else:
                ""
```

The more permeable sections are darker in colour

```
TextureSwitch -->
        case textureDisplay: X.
        else: deleteUV(0) X.

@StartRule
greenspace -->
        t(0,sidewalkHeight,0)
        report("Site Conditions, Slope (%)", geometry.angle(maxSlope)/90)
# Fix: Need way to get average slope, not max.
        set(greenspaceRules.textureDisplay, textureDisplay)
        set(greenspaceRules.thematicDisplay, thematicDisplay)
        set(greenspaceRules.colour, colour)
        set(greenspaceRules.transparency, transparency)
        set(greenspaceRules.landscapeType, landscapeType)
        #set(greenspaceRules.frontyardType, frontyardType)
        #set(greenspaceRules.hardscapeTexture, hardscapeTexture)
        #set(greenspaceRules.hardscapeScale, hardscapeScale)
        #set(greenspaceRules.hardscapeRotation, hardscapeRotation)
        set(greenspaceRules.unitWidth, unitWidth)
        set(greenspaceRules.rotation, rotation)
        set(greenspaceRules.perviousHardscape, perviousHardscape)
        set(greenspaceRules.pathType, pathType)
        set(greenspaceRules.pathScale, pathScale)
        set(greenspaceRules.peoplePercentage, peoplePercentage)
        set(greenspaceRules.sodType, sodType)
        set(greenspaceRules.sodScale, sodScale)
        set(greenspaceRules.hedgePercentage, hedgePercentage)
        set(greenspaceRules.hedgeType, hedgeType)
        set(greenspaceRules.treePercentage, treePercentage)
        set(greenspaceRules.maxTreesAnAcre, maxTreesAnAcre)
        #set(greenspaceRules.treeHeight, treeHeight)
        set(greenspaceRules.treeType, treeType)
        set(greenspaceRules.cutVolume, cutVolume)
        set(greenspaceRules.fillVolume, fillVolume)
        greenspaceRules.greenspace("main", colour)
```

The rule is started with greenspace. Greenspace is generated from the lot or the zoning shell discussed in the greenspace rule which has been imported.

Each of these "set(greenspace...) have been included in the rule through the importation of the greenspace rules. They discuss the capabilities of:
the texture display,
thematic display,
colours,
transparency,
landscape type, f
ront yard type,
hardscape texture, scale, rotation and perviousity
the overall unit width, rotation,
the path type, scale,
the percentage of people
the sod type, scale,
the hedge percentage, type and scale,
the tree percentage, height, type, and how many per acre,
and the cut and fill volumes

```
#Landscape Attributes

2   @Group("Model Options",0)          @Order(1)
    @Range("Formal","Natural")
2.1 attr landscapeType = "Formal"

    @Group("Model Options")            @Order(2) @Range(0, 0.2)
2.2 attr sidewalkHeight = 0.2
```

In this case the second section of variables that are created in this rule have to do with the 2 Model option Variables
The individual variables within the model option control are as follows:
2.1 The decision on whether the landscape should be formal or natural. The default is formal
2.2 The decision of the sidewalk height is typically left at 0.2 metres high

```
#Paths

3   @Group("Paths",1) @Order(1) @Range(10,50)
3.1 attr unitWidth = 23

    @Group("Paths") @Order(2) @Range(0,180)
3.2 attr rotation = 0

    @Group("Paths") @Order(3)
33  attr perviousHardscape = false
```

In this case the third section of variables that are created in this rule have to do with the 3 Overall landscape unit
3.1 The decision of the overall landscape unit width is typically set at 23 metres which is the distance that LEED determines should be between front entrances.
3.2 The decision of rotation of the overall landscape unit is typically set at 0.
3.3 The decision of the permeability of the hardscape is typically set as false.

```
    @Group("Paths") @Order(4)
    #Part of the Original Code imported from the ESRI Rule.
    #I will have to cull some of these out to allow for the program to run
    smoother.
    @Range ("Concrete Bright", "Concrete Bright White", "Concrete Aggregate",
    "Concrete Clean Dark", "Concrete Clean Light", "Concrete Composite",
    "Concrete Horizontal Lines", "Concrete Old", "Concrete Rough Dark",
    "Concrete Rough Light", "Concrete Rough Scratched", "Concrete Square
    Tiles", "Brick Brown No Mortar Rough Running Bond", "Brick Brown No
    Mortar Running Bond", "Brick Brown Running Bond", "Brick Brown Stack
    Bond", "Brick Grey Running Bond", "Brick Red High Contrast Running
    Bond", "Brick Red No Mortar Running Bond", "Brick Red Recessed Mortar
    Running Bond", "Brick Red Running Bond", "Brick Red Stack Bond", "Brick
    Red Purple Running Bond", "Brick Varied Brown Running Bond", "Brick
    White Dirty Running Bond", "Brick White Painted Running Bond", "Brick
    White Rough Running Bond", "Cement Block Dark Grey Running Bond",
    "Cement Block Grey Running Bond", "Cement Block Grey Specks Running
    Bond", "Cement Block Light Running Bond", "Cement Block Square Grey
    Stack Bond", "Paver Grey Ashlar")
3.4 attr pathType = "Paver Grey Ashlar"
```

3.4 The decision of the type of masonry used for the pathway is left as a grey paver.

```
    @Group("Paths") @Order(5)
    @Range (.5, 10)
3.5 attr pathScale = 2.4
```

3.5 The decision of the path width is left at 2.4 metres as discussed in the Winnipeg Zoning Bylaw

```
    @Group("Paths") @Order(6) @Range(0,100)
3.6 attr peoplePercentage = 20
```

3.6 The decision of the amount of people populating the site is set to 20% of the siewalks being populated.

```
## Vegetation

4   @Group("Vegetation", 2) @Order(1)
    @Range ("Random", "Standard Grass", "Park", "Bermuda 1", "Bermuda 2",
    "Bermuda Dark", "Bluegrass 1", "Bluegrass 2", "Grass Short", "Grass Thick",
    "St Augustine 1", "St Augustine 2", "Light Rye") @Order(2)
4.1 attr sodType = "Random"
```

In this case the fourth section of variables that are created in this rule have to do with the 4 Vegetation Variables.

4.1 The decision of the type of sod to lay down is set to a default of a random distribution of four types as written in the imported greenspace rules.

```
    @Group("Vegetation") @Order(2)
    @Range (0.5, 20)
4.2 attr sodScale = 1
```

4.2 The decision of the scale at which the sod's image is displayed is left at a deafult of 1 to 1

```
    @Group("Vegetation") @Order(3)
    @Range ("Hedge Standard", "Hedge Standard Dense", "Hedge Boxwood",
    "Hedge Cyprus", "Hedge Pine") @Order(2)
4.3 attr hedgeType = "Hedge Standard"
```

4.3 The decision of the type of hedge to include is set to a default of a the standard hedge.

```
    @Group("Vegetation") @Order(4)
    @Range(0,100)
4.4 attr hedgePercentage = 70
```

4.4 The decision of the number of hedges to include is set to a default of 70% of the total number of landscape units

```
    @Group("Vegetation",3) @Order(5) @Range(0,100)
4.5 attr treePercentage = 45
```

4.5 The decision of the number of trees to include is set to a default of 45% of the total number of landscape units

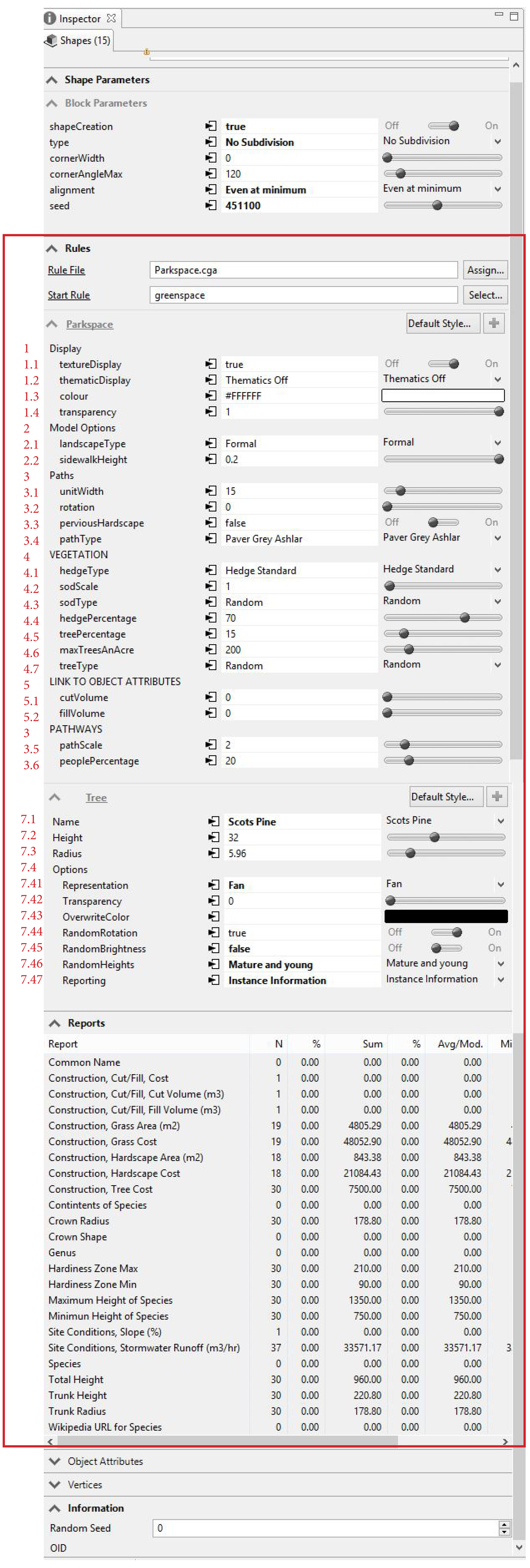
```
    @Group("Vegetation",3) @Order(6) @Range(1,1000)
4.6 attr maxTreesAnAcre = 300
```

4.6 The decision of the number of trees to include is set to a default of 300 trees an acre by taking the overall size of the landscape unit and dividing it by 300/acre.

```
    @Group("Vegetation") @Order(9)
    ##Part of the Original code which inserts a number of plants which are being
    imported.
    ##I will have to cull some of these out so that it is more reflective of
    Winnipeg and Kenoras plant species list.
    #@Range("Random", "Conifer", "Desert", "Eudicot", "Monocot")
    @Range("Random", "Alder Buckthorn","Amazon Sword
    Plant","American Chestnut","American Sycamore","Apricot","Australian
    Pine","Baldcypress","Balsam Fir","Bamboo","Banana Tree","Basswood","Bay
    Laurel","Black Locust","Blue Gum Eucalyptus","Boxwood","Cabbage
    Palm Fern","California Bay","California Incense Cedar","California
    Palm","California Redwood","California Walnut","Coconut
    Palm","Common Hawthorn","Common Whitebeam","Conker Tree","Date
    Palm","Desert Willow","Douglas Fir","European Beech","European
    Larch","Ficus","Field Elm","Flannelbush","Flowering Dogwood","Giant
    Sequoia","Hedgehog Agave","Japanese Angelica Tree","Lacy Tree
    Philodendron","Leyland Cypress","Lily of the Valley","Lodgepole
    Pine","Mediterranean Buckthorn","Mexican Palmetto","Mountain
    Mahogany","Northern Red Oak","Norway Maple","Norway Spruce","Orange
    Tree","Orchid","Oval-leaved Privet","Palm Lily","Palo Verde","Paper
    Birch","Parlour Palm","Prickly Pear Cactus","Red Alder","Red
    Hickory","Rhododendron Azaleas","Rose","Ruffle Palm","Saguaro
    Cactus","Sassafras","Scots Pine","Sea Islands Yucca","Shadbush","Snake
    Plant","Southern Magnolia","Spanish Broom","Strawberry Tree","Sugar
    Maple","Sunflower","Sweetgum","Umbrella Acacia","Western
    Juniper","White Ash","White Oak","White Poplar","White Willow","Witch
    Hazel","","______________________________","GENERICS","","Generic
    Dead Tree","Generic Stump","Generic
    __________________________","PROXIES","","Algarrobo","American
    Elderberry","American Pepper","American Silverberry","Athel
    Tamarisk","Avocado","Black Tupelo","Buttonbush","Canada
    Buffaloberry","Chinaberry Tree","Chinese Tallow Tree","Common
    Hackberry","Common Holly","Common Persimmon","Desert
    Bitterbrush","European Hornbeam","Giant Chinquapin","Honey
    Locust","Hophornbeam","Huckleberry Shrub","Japanese
    Hemlock","Japanese Nutmeg","Judas Tree","Lawson Cypress","Loblolly
    Bay","Mexican Buckeye","Necklacepod","Northern Bilberry","Northern
    White Cedar","Octopus Tree","Osage Orange","Paper Bark
    Tree","Pawpaw","Persian Silk Tree","Princess Tree","Smooth
    Sumac","Sourwood","Southern Wax Myrtle","Tanoak","Tree of
    Heaven","Turkish Hazel","Western Soapberry","White Mulberry","Yellow
    Poplar","Yew","","______________________________","LATIN
    NAME","","Abies balsamea","Acacia tortilis","Acer platanoides","Acer
    saccharum","Aesculus hippocastanum","Agave stricta","Ailanthus
    altissima","Aiphanes horrida","Albizia julibrissin","Alnus rubra","Amelanchier
    canadensis","Aralia elata","Arbutus unedo","Asimina triloba","Betula
    papyrifera","Bulbophyllum phalaenopsis","Buxus sempervirens","Calocedrus
    decurrens","Carnegiea saguaro","Carpinus betulus","Carya ovalis","Castanea
    dentata","Casuarina equisetifolia","Celtis occidentalis","Cephalanthus
    occidentalis","Cercis siliquastrum","Cercocarpus montanus","Chamaecyparis
    lawsoniana","Chamaedorea elegans","Chilopsis linearis","Chrysolepis
    chrysophylla","Citrus sinensis","Cocos nucifera","Convallaria
    majalis","Cordyline petiolaris","Cornus florida","Corylus colurna","Crataegus
    monogyna","Cupressus leylandii","Cyrilla racemiflora","Diospyros
    virginiana","Echinodorus bleheri","Elaeagnus commutata","Eucalyptus
    globulus","Fagus sylvatica","Ficus benjamina","Frangula alnus","Fraxinus
    americana","Fremontodendron californicum","Generic deadtree","Generic
    stump","Generic unknown","Gleditsia triacanthos","Gordonia
    lasianthus","Hamamelis virginiana","Helianthus annuus","Ilex
    aquifolium","Juglans regia","Juniperus occidentalis","Larix decidua","Laurus
    nobilis","Ligustrum ovalifolium","Liquidambar styraciflua","Liriodendron
    tulipifera","Lithocarpus densiflorus","Maclura pomifera","Magnolia
    grandiflora","Melaleuca quinquenervia","Melia azedarach","Morus
    alba","Musa acuminata","Myrica cerifera","Nyssa sylvatica","Opuntia
    aciculata","Ostrya virginiana","Oxydendrum arboreum","Parkinsonia
    aculeata","Paulownia tomentosa","Persea americana","Philodendron
    selloum","Phlebodium aureum","Phoenix dactylifera","Phyllostachys
    aurea","Picea abies","Pinus contorta","Pinus sylvestris","Platanus
    occidentalis","Populus tremuloides","Prosopis nigra","Prunus
    armeniaca","Pseudotsuga menziesii","Purshia glandulosa","Quercus
    alba","Quercus rubra","Rhamnus alaternus","Rhododendron tsutsuji","Rhus
    glabra","Robinia pseudoacacia","Rosa grandiflora","Sabal mexicana","Salix
    alba","Sambucus canadensis","Sansevieria trifasciata","Sapindus
    saponaria","Sassafras albidum","Schefflera actinophylla","Schinus
    molle","Sequoia sempervirens","Sequoiadendron giganteum","Shepherdia
    canadensis","Sophora tomentosa","Sorbus aria","Spartium junceum","Tamarix
    aphylla","Taxodium distichum","Taxus baccata","Thuja occidentalis","Tilia
    americana","Torreya nucifera","Triadica sebifera","Tsuga diversifolia","Ulmus
    minor","Umbellularia californica","Ungnadia speciosa","Vaccinium
    uliginosum","Washingtonia filifera","Yucca gloriosa")
4.7 attr treeType = "Random"
```

4.7 The decision of the type of trees to incorporate is set to a default of a random distribution of four types as written in the imported greenspace rules.

Parametric Variable Result



5.5 ParkSpace Rule

The type of park is determined with a single variable switch.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**false**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Natural**	Natural
sidewalkHeight	0.2	
Paths		
unitWidth	15	
rotation	0	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**500**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	20	

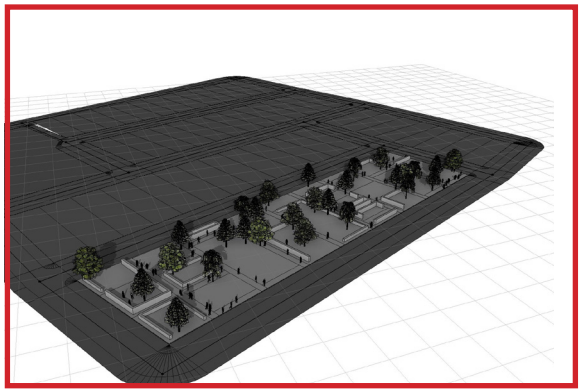


Figure 5.51.1 The default park space is set up in a formal fashion.

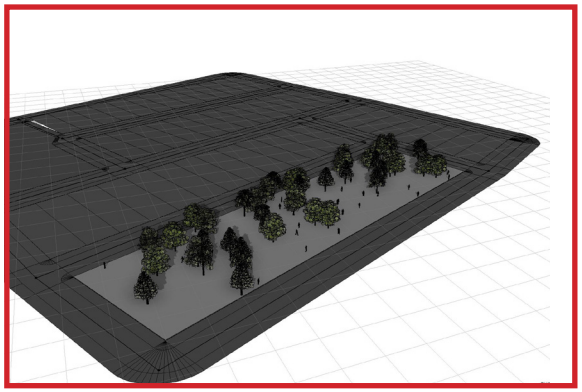


Figure 5.51.2 The park space can be changed to a more natural look.

5.5 ParkSpace Rule

The texture or the permeability can be displayed through the use of the thematic display variable and the texture display variable.

Table 5.5.1

Parkspace		Default Style...	
Display			
textureDisplay	**false**	Off	On
thematicDisplay	Thematics Off	Thematics Off	
colour	#FFFFFF		
transparency	1		
Model Options			
landscapeType	**Natural**	Natural	
sidewalkHeight	0.2		
Paths			
unitWidth	15		
rotation	0		
perviousHardscape	false	Off	On
pathType	Paver Grey Ashlar	Paver Grey Ashlar	
VEGETATION			
hedgeType	Hedge Standard	Hedge Standard	
sodScale	1		
sodType	Random	Random	
hedgePercentage	70		
treePercentage	15		
maxTreesAnAcre	**500**		
treeType	Random	Random	
LINK TO OBJECT ATTRIBUTES			
cutVolume	0		
fillVolume	0		
PATHWAYS			
pathScale	2		
peoplePercentage	20		

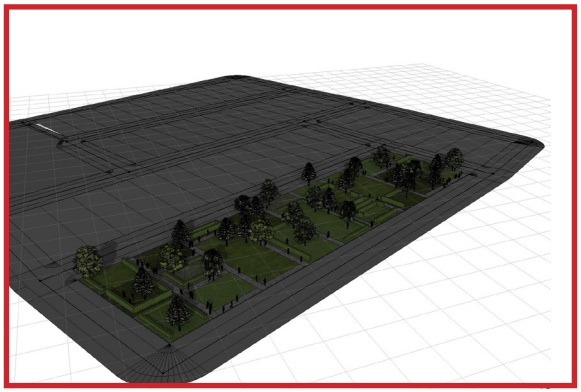


Figure 5.51.3 The texture can be displayed.

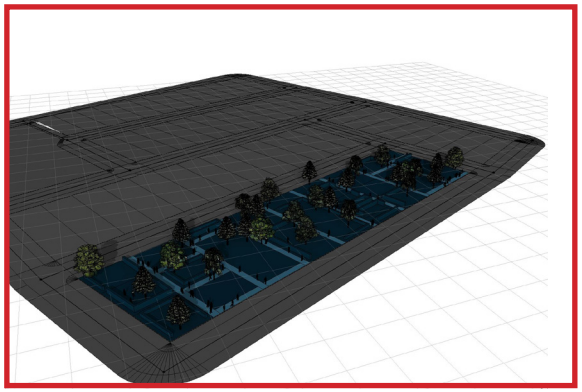


Figure 5.51.4 The permeability of the site can be displayed. The darker the area, the more permeable the material.

5.5 ParkSpace Rule

The spacing of the landscape units (or spacing between the pathways) can be altered with a single variable.

Table 5.5.1

Rules			
Rule File	Parkspace.cga	Assign...	
Start Rule	greenspace	Select...	
Parkspace		Default Style...	
Display			
textureDisplay	**false**	Off / On	
thematicDisplay	Thematics Off	Thematics Off	
colour	#FFFFFF		
transparency	1		
Model Options			
landscapeType	**Natural**	Natural	
sidewalkHeight	0.2		
Paths			
unitWidth	15		
rotation	0		
perviousHardscape	false	Off / On	
pathType	Paver Grey Ashlar	Paver Grey Ashlar	
VEGETATION			
hedgeType	Hedge Standard	Hedge Standard	
sodScale	1		
sodType	Random	Random	
hedgePercentage	70		
treePercentage	15		
maxTreesAnAcre	**500**		
treeType	Random	Random	
LINK TO OBJECT ATTRIBUTES			
cutVolume	0		

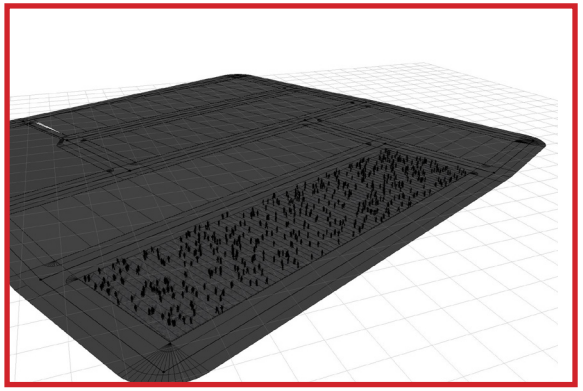


Figure 5.52.1 The landscape unit width is set to 0 metres.

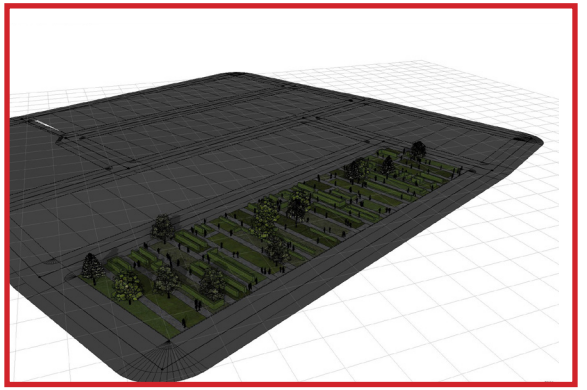


Figure 5.52.2 The landscape unit width is set to 5 metres.

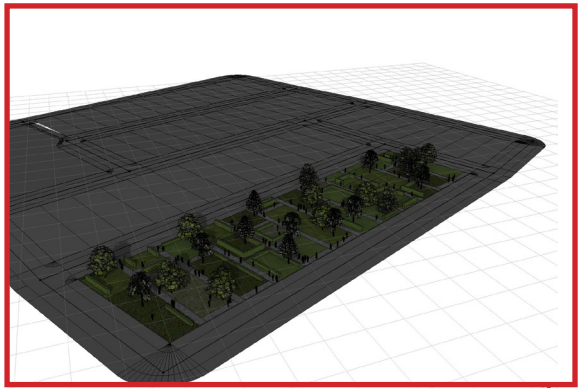


Figure 5.52.3 The landscape unit width is set to 10 metres.

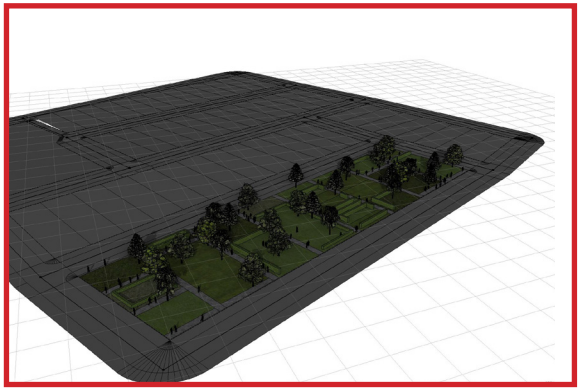


Figure 5.52.4 The landscape unit width is set to 15 metres.

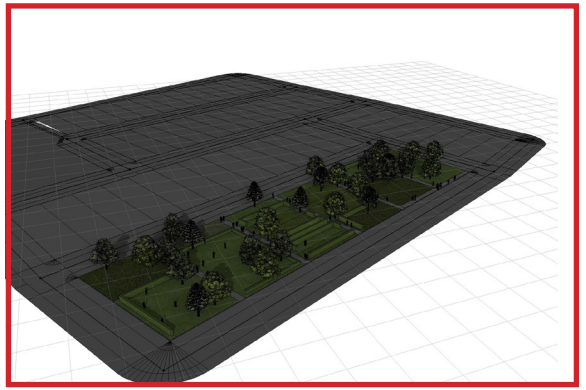


Figure 5.52.5 The landscape unit width is set to 20 metres.

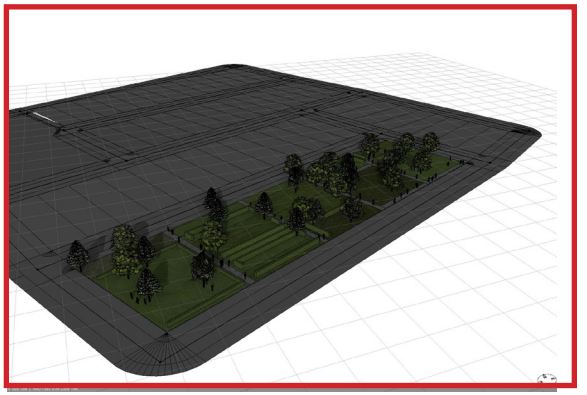
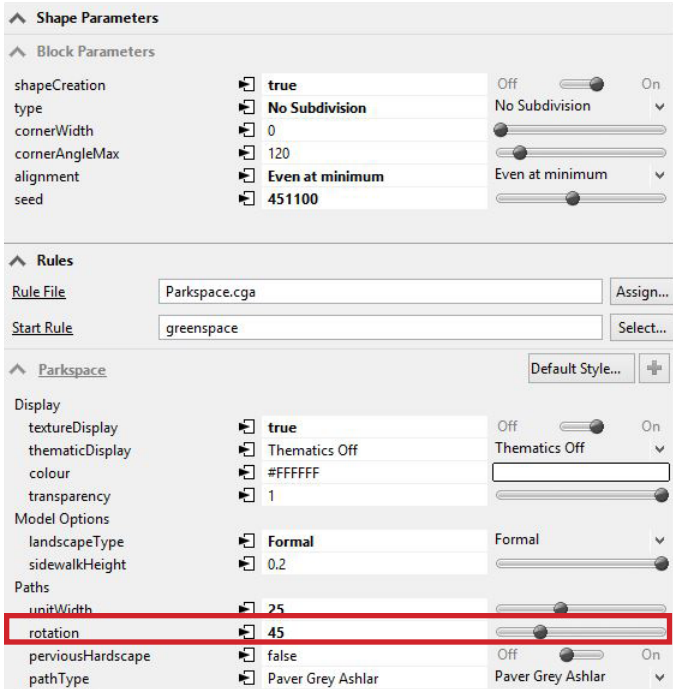


Figure 5.52.6 The landscape unit width is set to 25 metres.

5.5 ParkSpace Rule

The rotation of the landscape units can be altered with a single variable.

Table 5.5.1



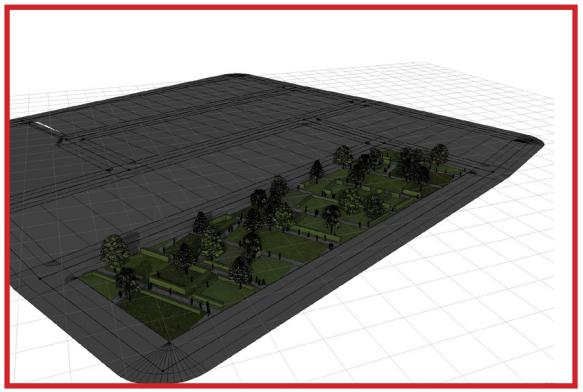


Figure 5.53.1 The landscape units are rotated 15 degrees from being perpendicular to the street.

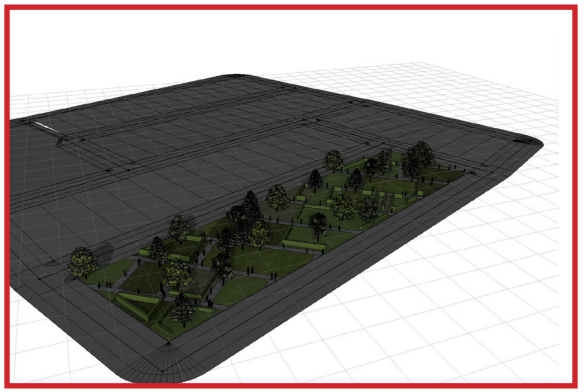


Figure 5.53.2 The landscape units are rotated 30 degrees from being perpendicular to the street.

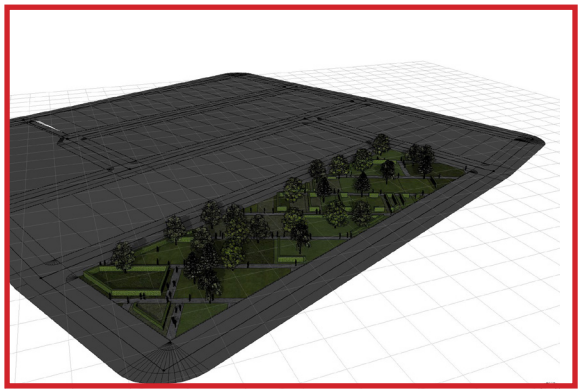


Figure 5.53.3 The landscape units are rotated 45 degrees from being perpendicular to the street.

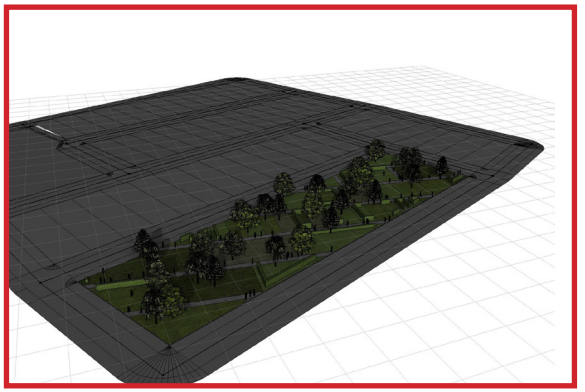


Figure 5.53.4 The landscape units are rotated 60 degrees from being perpendicular to the street.

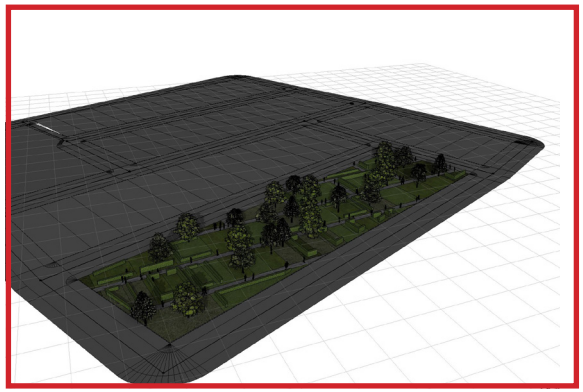


Figure 5.53.5 The landscape units are rotated 75 degrees from being perpendicular to the street.

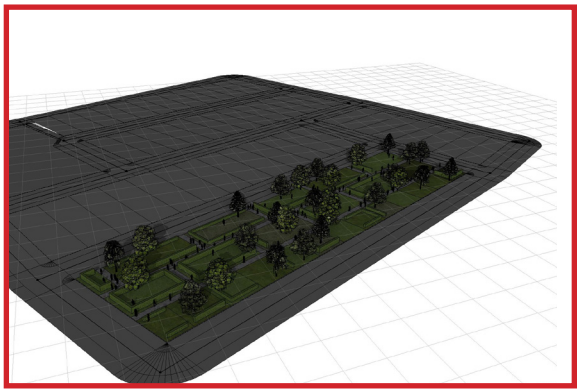


Figure 5.53.6 The landscape units are rotated 90 degrees from being perpendicular to the street.

5.5 ParkSpace Rule

The material being used for the pathways can be altered with a single variable.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

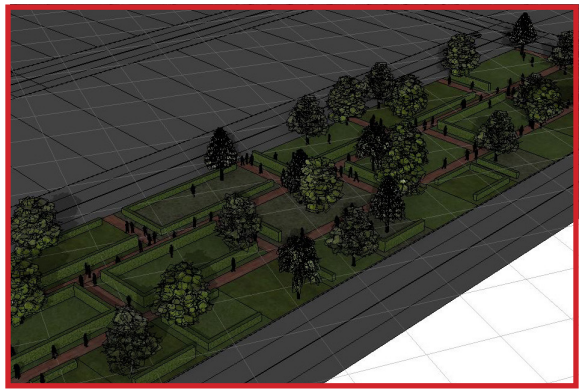


Figure 5.54.1 A red brick is being used for the path material.

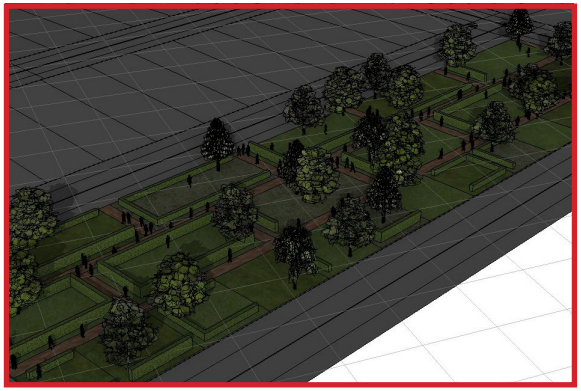


Figure 5.54.2 A brown brick is being used for the path material.

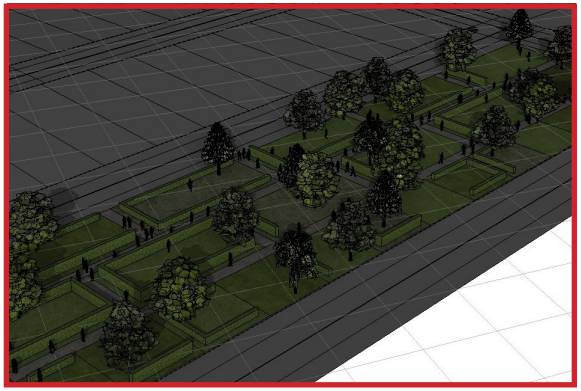


Figure 5.54.3 A grey concrete is being used for the path material.

5.5 ParkSpace Rule

The percentage of landscaped units that will incorporate hedges can be shifted with a single variable.

Table 5.5.1

Rules		
Rule File	Parkspace.cga	Assign...
Start Rule	greenspace	Select...
Parkspace		Default Style...
Display		
textureDisplay	**true**	Off / On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off / On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	

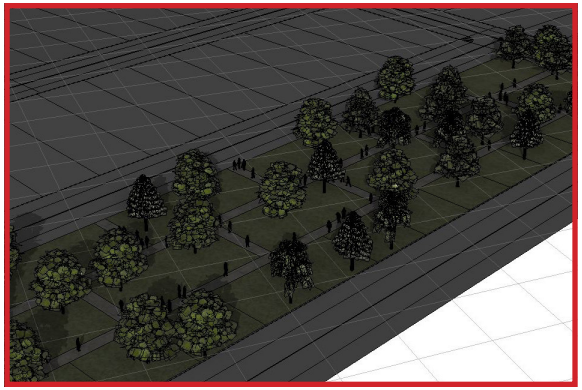


Figure 5.55.1 Hedges will be a part of the landscape in 0% of the landscaped units.

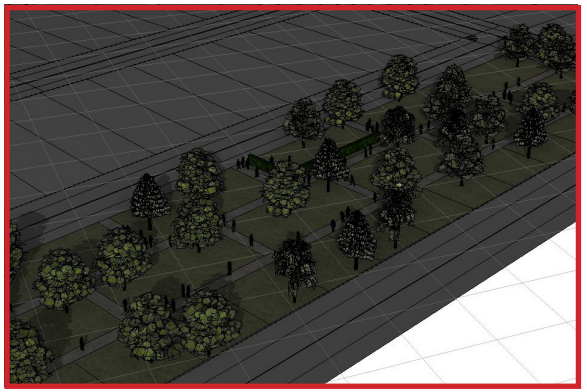


Figure 5.55.2 Hedges will be a part of the landscape in 25% of the landscaped units.

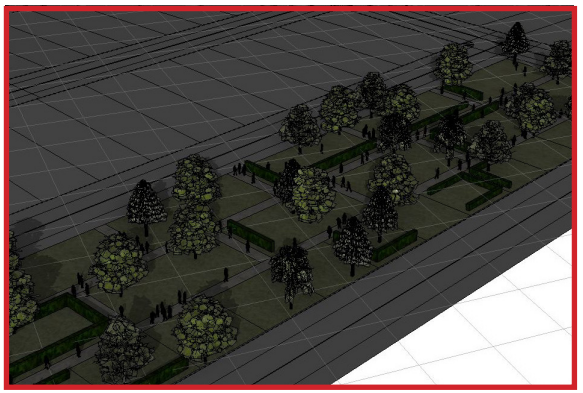


Figure 5.55.3 Hedges will be a part of the landscape in 50% of the landscaped units.

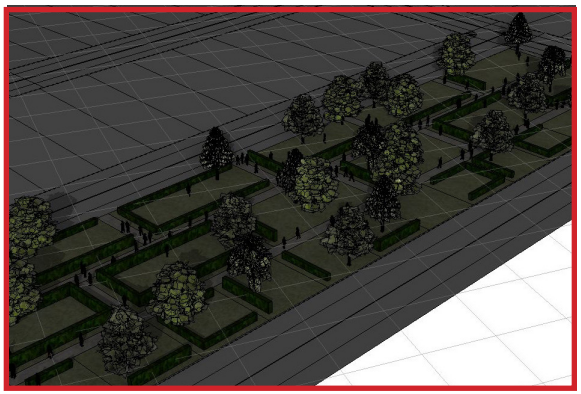


Figure 5.55.4 Hedges will be a part of the landscape in 75% of the landscaped units.

5.5 ParkSpace Rule

The material being used for the pathways can be altered with a single variable

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

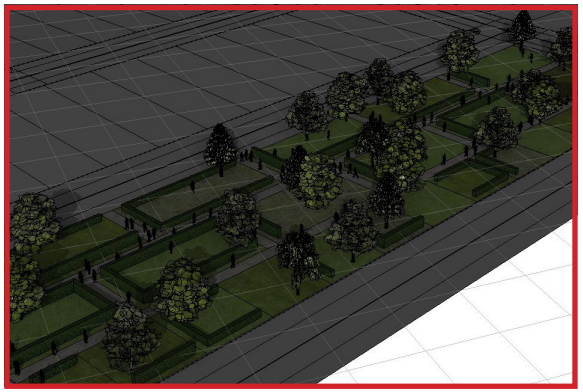


Figure 5.55.5 The hedge is set to a dense type.

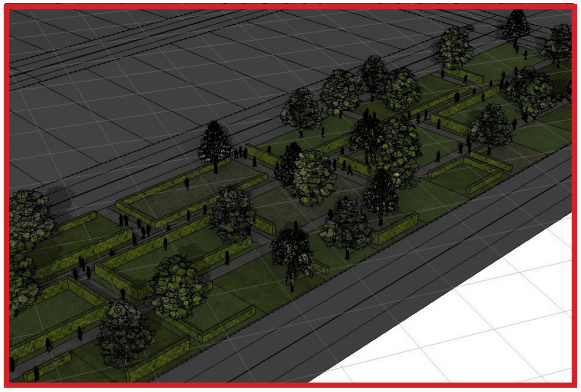


Figure 5.55.6 The hedge is set to a Cypress planting.

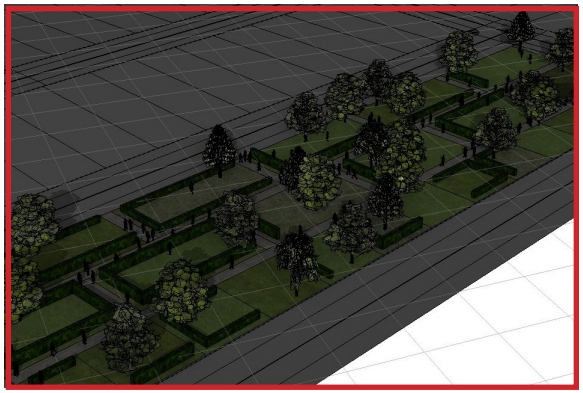


Figure 5.55.7 The hedge is set to a Boxwood planting.

5.5 ParkSpace Rule

The material being used for the sod can be altered with a single variable.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

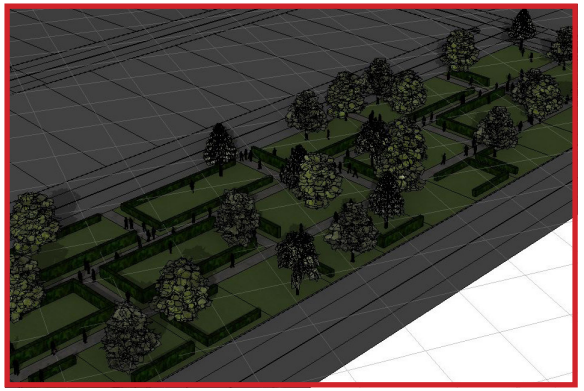


Figure 5.55.8 The sod is set to a generic grass.

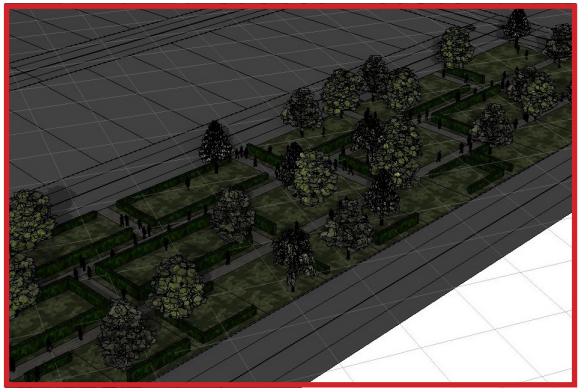


Figure 5.55.9 The sod is set to a park type grass.

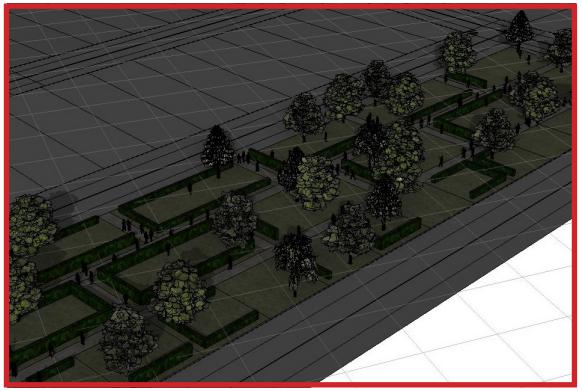


Figure 5.55.0 The sod is set to a light rye grass.

5.5 ParkSpace Rule

The percentage of landscaped units that will incorporate trees can be shifted with a single variable.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

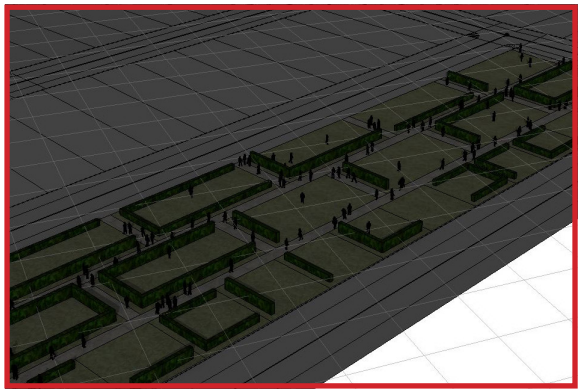


Figure 5.56.1 Trees will be a part of the landscape in 0% of the landscaped units.

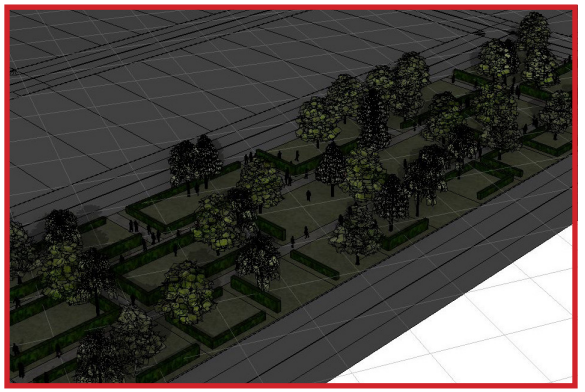


Figure 5.56.2 Trees will be a part of the landscape in 25% of the landscaped units.

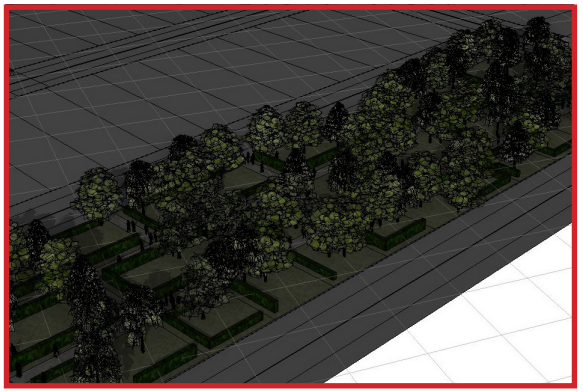


Figure 5.56.3 Trees will be a part of the landscape in 50% of the landscaped units.

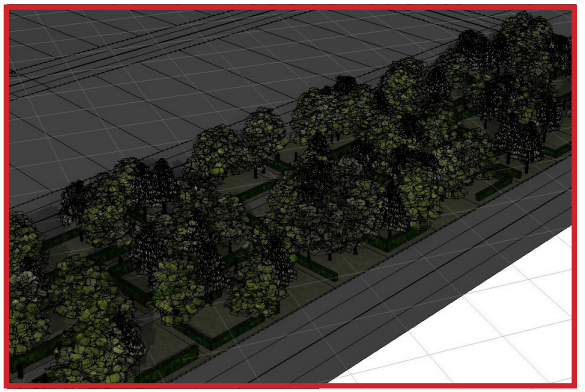


Figure 5.56.4 Trees will be a part of the landscape in 75% of the landscaped units.

5.5 ParkSpace Rule

The number of trees found in the overall landscape can be switched with a single variable.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

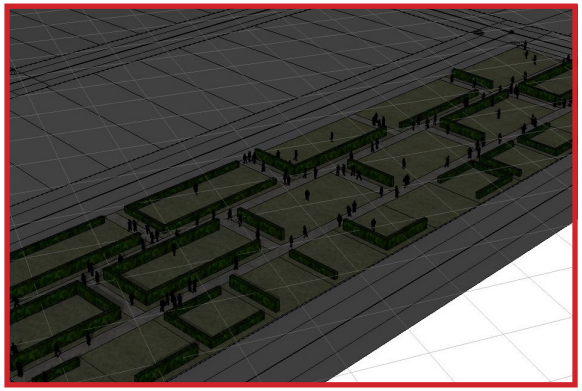


Figure 5.56.5 The overall landscape is set to have 0 trees per acre.

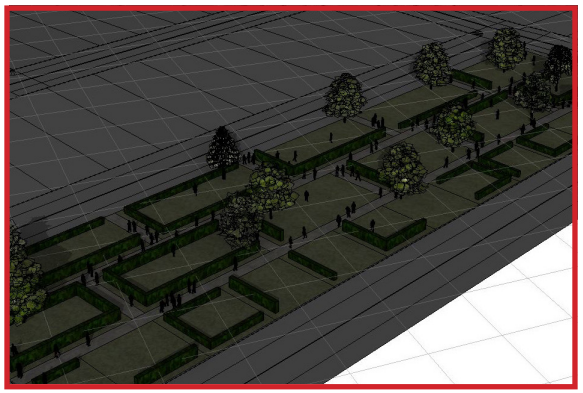


Figure 5.56.6 The overall landscape is set to have 25 trees per acre.

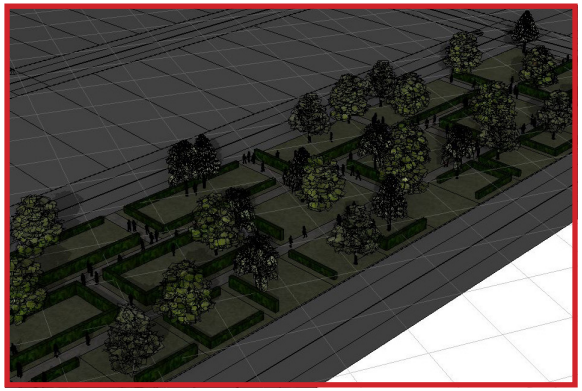


Figure 5.56.7 The overall landscape is set to have 50 trees per acre.

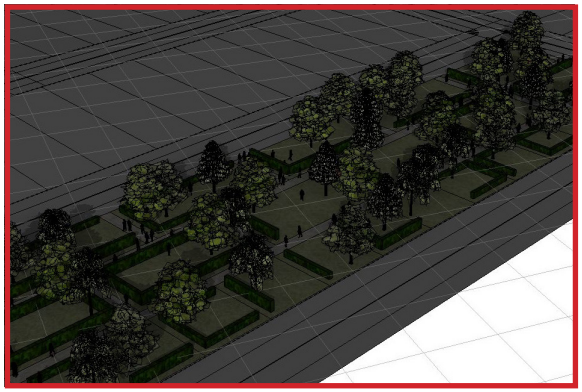


Figure 5.56.8 The overall landscape is set to have 75 trees per acre.

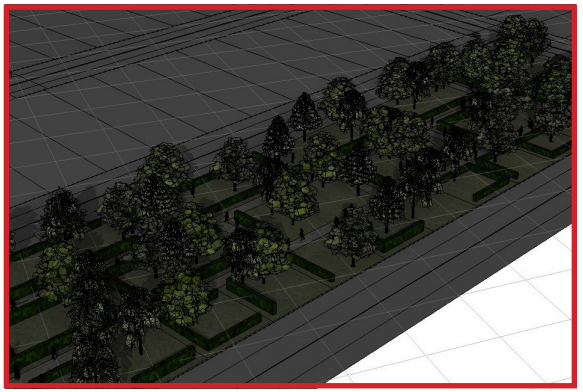


Figure 5.56.9 The overall landscape is set to have 100 trees per acre.

5.5 ParkSpace Rule

The type of trees can be altered based on a list that was imported from ESRI.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

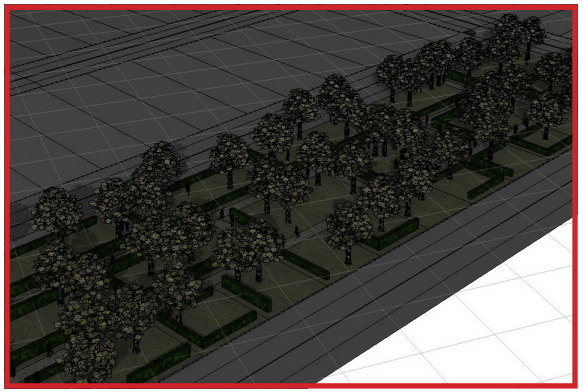


Figure 5.57.1 The trees are changed to an American Chestnut.

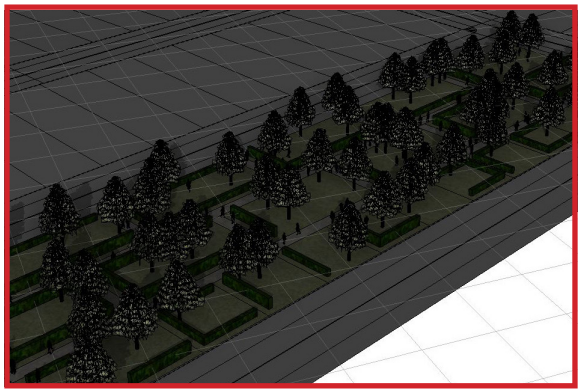


Figure 5.57.2 The trees are changed to a Balsam Fir.

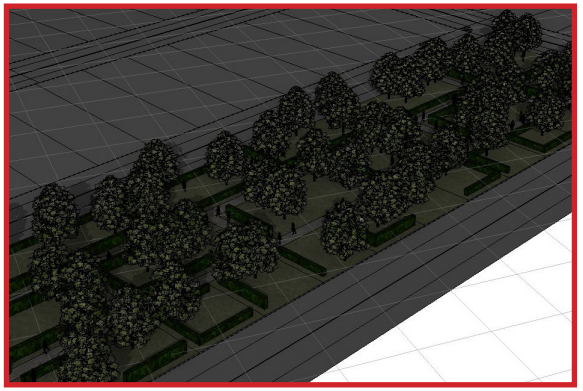


Figure 5.57.3 The trees are changed to a Douglas Fir.

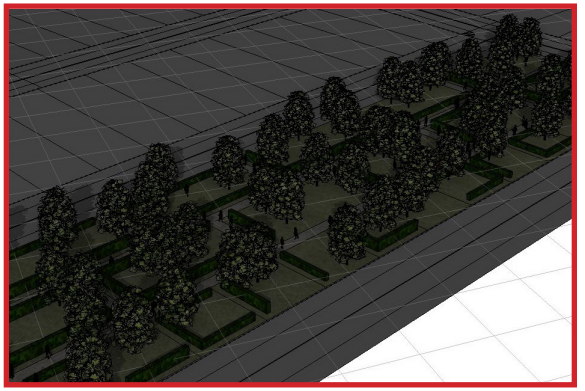
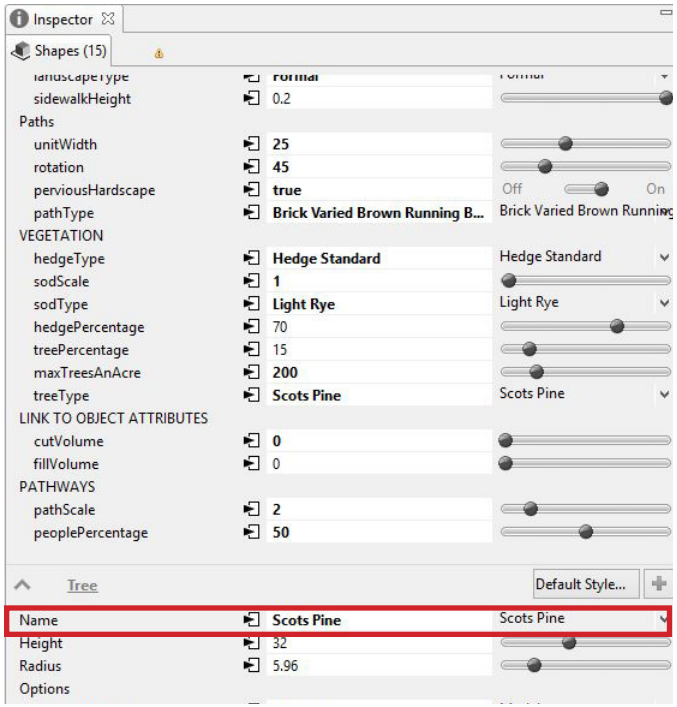


Figure 5.57.4 The trees are changed to a Scots Pine.

5.5 ParkSpace Rule

The type of trees can be altered based on a second list that was imported from ESRI and informed by best case scenarios for each tree.

Table 5.5.1



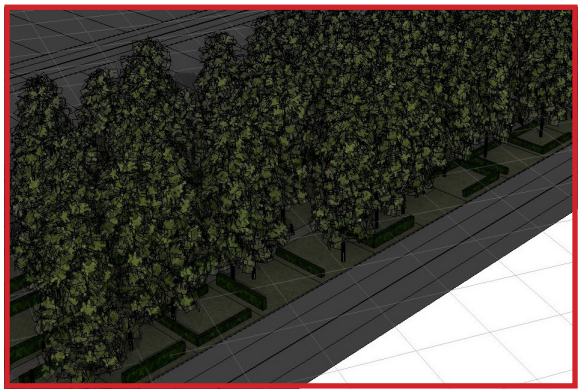


Figure 5.57.5 The American Chestnut in ideal growing conditions according to a preset table which has been imported.

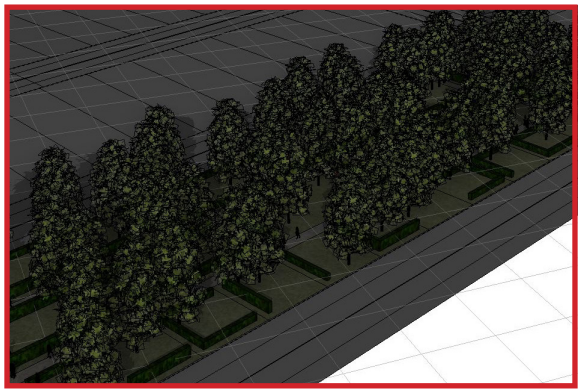


Figure 5.57.6 The Balsam Fir in ideal growing conditions according to a preset table which has been imported.

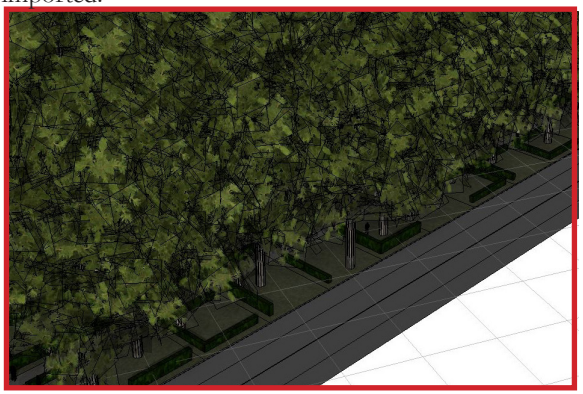


Figure 5.57.7 The Douglas Fir in ideal growing conditions according to a preset table which has been imported.

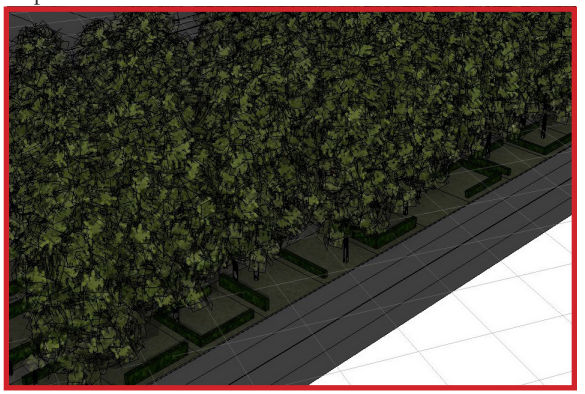


Figure 5.57.8 The Scots Pine in ideal growing conditions according to a preset table which has been imported.

5.5 ParkSpace Rule

The number of people found in the landscape can be switched by a single variable.

Table 5.5.1

Parkspace		Default Style...
Display		
textureDisplay	**true**	Off — On
thematicDisplay	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
Model Options		
landscapeType	**Formal**	Formal
sidewalkHeight	0.2	
Paths		
unitWidth	**25**	
rotation	**45**	
perviousHardscape	false	Off — On
pathType	Paver Grey Ashlar	Paver Grey Ashlar
VEGETATION		
hedgeType	Hedge Standard	Hedge Standard
sodScale	1	
sodType	Random	Random
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	Random	Random
LINK TO OBJECT ATTRIBUTES		
cutVolume	0	
fillVolume	0	
PATHWAYS		
pathScale	2	
peoplePercentage	**50**	

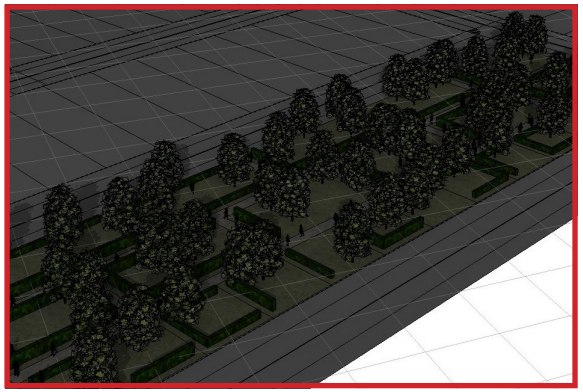


Figure 5.58.1 The percentage of the people found in the landscape is set at 20%.

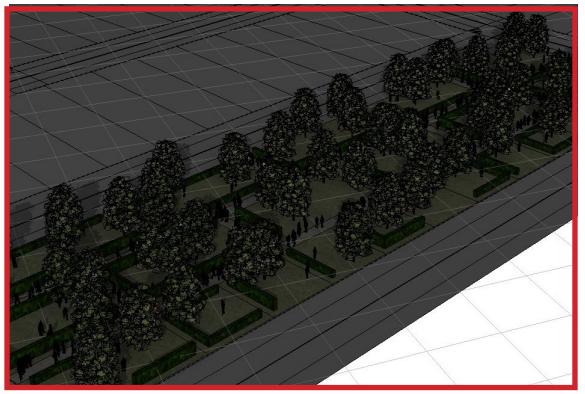


Figure 5.58.2 The percentage of the people found in the landscape is increased to 40%.

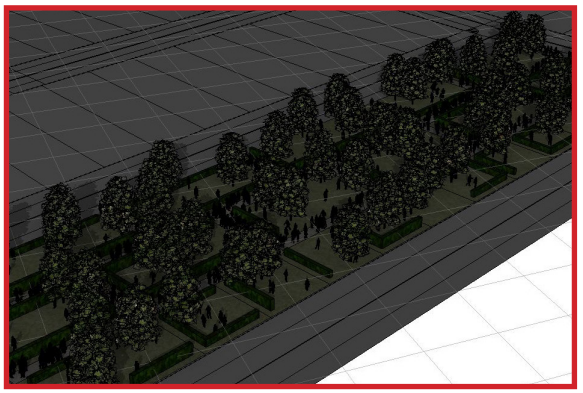


Figure 5.58.3 The percentage of the people found in the landscape is increased to 60%.

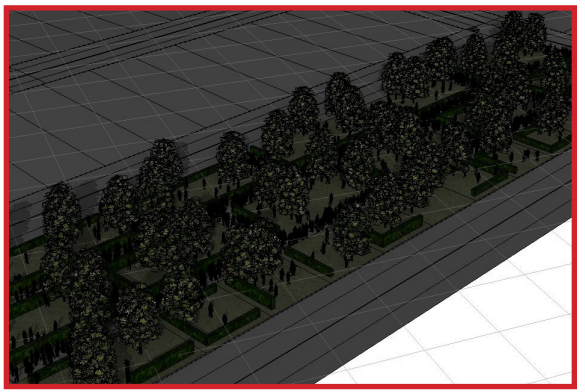


Figure 5.58.4 The percentage of the people found in the landscape is increased to 80%.

5.5 ParkSpace Rule

The detail for each tree can be altered with a single variable. This can assist with reducing the size of the visual file.

Table 5.5.1

VEGETATION		
hedgeType	**Hedge Standard**	Hedge Standard
sodScale	**1**	
sodType	**Light Rye**	Light Rye
hedgePercentage	70	
treePercentage	15	
maxTreesAnAcre	**200**	
treeType	**Scots Pine**	Scots Pine
LINK TO OBJECT ATTRIBUTES		
cutVolume	**0**	
fillVolume	0	
PATHWAYS		
pathScale	**2**	
peoplePercentage	**50**	
Tree		Default Style...
Name	**Scots Pine**	Scots Pine
Height	32	
Radius	5.96	
Options		
Representation	Model	Model
Transparency	0	
OverwriteColor		
RandomRotation	true	Off On
RandomBrightness	false	Off On
RandomHeights	**Mature and young**	Mature and young
Reporting	None	None

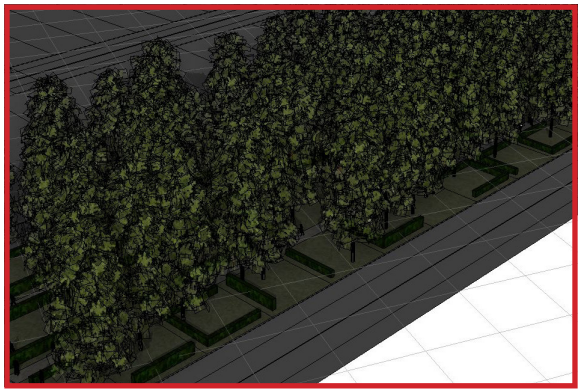


Figure 5.58.5 The level of detail for each of the trees is set to a 3d model level of detail.

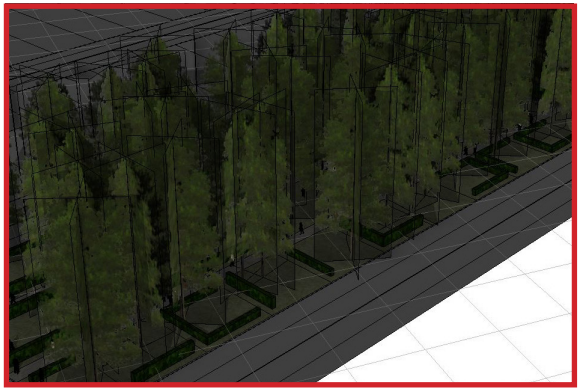


Figure 5.58.6 The level of detail for each of the trees is set to a 2d model level of detail.

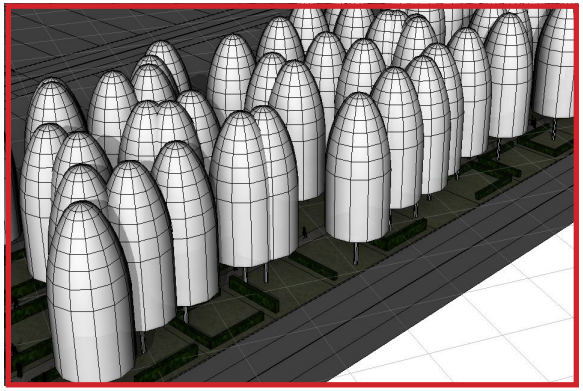


Figure 5.58.7 The level of detail for each of the trees is set to an analytical level of detail.

5.5 ParkSpace Rule

The reports which are currently able to be generated from the rule are as shown.

Table 5.5.2

Reports

Report	N	%	Sum	%	Avg	Min	Max
Common Name	0	0.00	0.00	0.00	0.00	0.00	0.00
Construction, Cut/Fill, Cost	1	0.00	0.00	0.00	0.00	0.00	0.00
Construction, Cut/Fill, Cut Volume (m3)	1	0.00	0.00	0.00	0.00	0.00	0.00
Construction, Cut/Fill, Fill Volume (m3)	1	0.00	0.00	0.00	0.00	0.00	0.00
Construction, Grass Area (m2)	25	0.00	4211.48	0.00	168.46	60.41	270.13
Construction, Grass Cost	25	0.00	42114.79	0.00	1684.59	604.11	2701.31
Construction, Hardscape Area (m2)	14	0.00	814.45	0.00	58.17	19.19	276.52
Construction, Hardscape Cost	14	0.00	20361.24	0.00	1454.37	479.84	6913.01
Construction, Tree Cost	57	0.00	14250.00	0.00	250.00	250.00	250.00
Contintents of Species	0	0.00	0.00	0.00	0.00	0.00	0.00
Crown Radius	57	0.00	249.66	0.00	4.38	4.38	4.38
Crown Shape	0	0.00	0.00	0.00	0.00	0.00	0.00
Genus	0	0.00	0.00	0.00	0.00	0.00	0.00
Hardiness Zone Max	57	0.00	399.00	0.00	7.00	7.00	7.00
Hardiness Zone Min	57	0.00	171.00	0.00	3.00	3.00	3.00
Maximum Height of Species	57	0.00	2565.00	0.00	45.00	45.00	45.00
Minimun Height of Species	57	0.00	1425.00	0.00	25.00	25.00	25.00
Site Conditions, Slope (%)	1	0.00	0.00	0.00	0.00	0.00	0.00
Site Conditions, Stormwater Runoff (m3/hr)	39	0.00	30781.52	0.00	789.27	230.17	5003.80
Species	0	0.00	0.00	0.00	0.00	0.00	0.00
Total Height	57	0.00	1425.00	0.00	25.00	25.00	25.00
Trunk Height	57	0.00	327.75	0.00	5.75	5.75	5.75
Trunk Radius	57	0.00	249.66	0.00	4.38	4.38	4.38
Wikipedia URL for Species	0	0.00	0.00	0.00	0.00	0.00	0.00

5.6 Advanced Building Rule

The advanced building rule had been developed as a more comprehensive building rule. It includes the previous zoning and landscape rules and adds additional building setbacks and green roofs as well as facade elements such as window percentage and entrances according to LEED neighbourhood design parameters.

Going forward this tool would need to be further developed to be more associative and the LEED parameters would need to be included as a range instead of the default use.

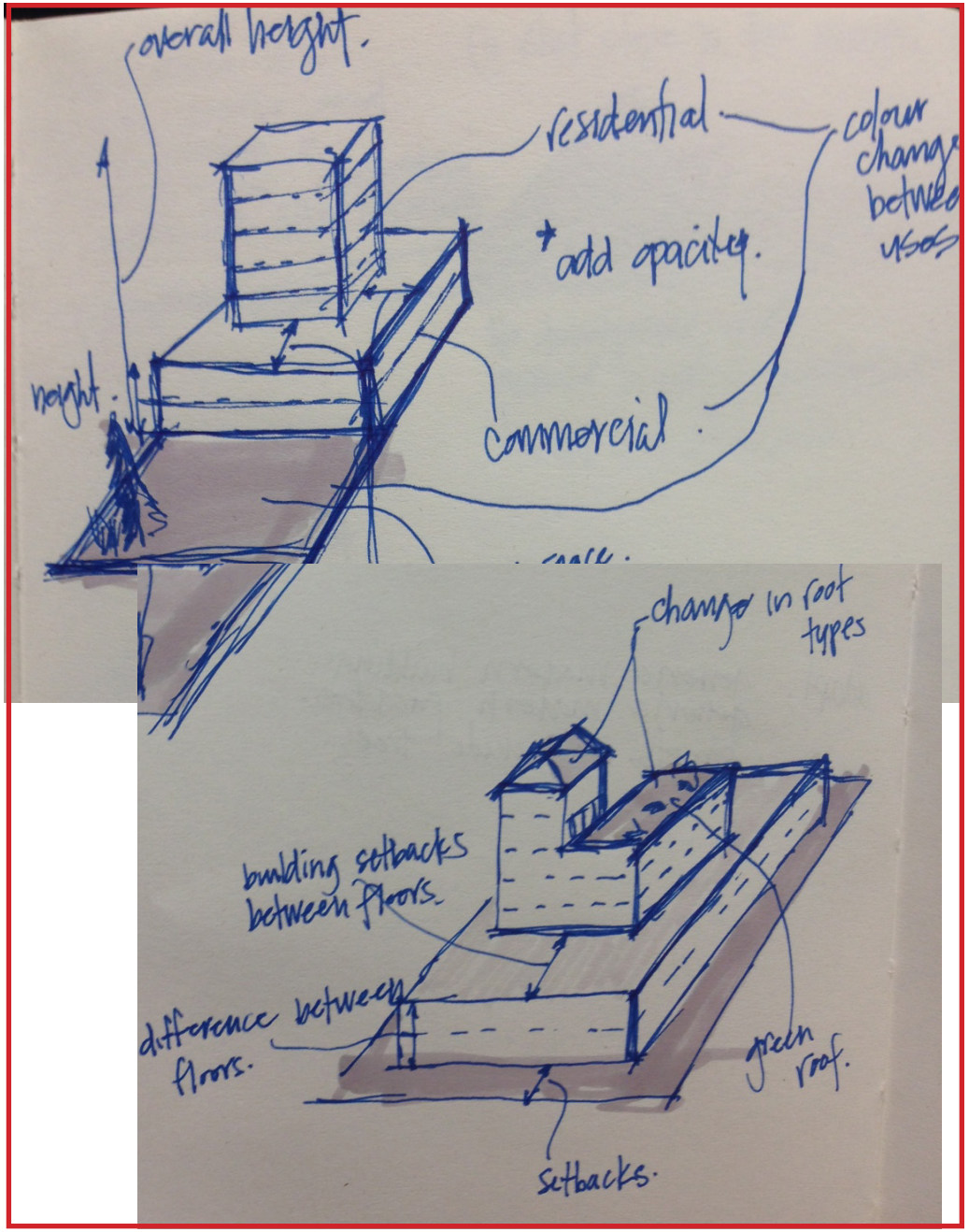
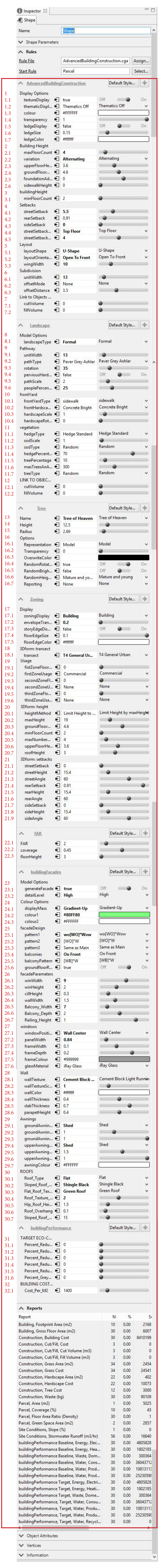


Figure 5.60

CGA Script / Associated English Explanation / Parametric Variable Result



CGA Script

```
/**
 * File:    AdvancedBuildingConstruction.cga
 * Code modified from ESRI's Building Construction obtained from
Example_05_Urban_Design_2015/rules/Buildings_Advanced_Buildings/
Support at :
http://www.arcgis.com/home/item.
html?id=18baa6129da342a388f7c1b6bae69df3 on October 01 2015.
 * Author:  Grafton
 * Adapted  October 09 2015
 */

version "2015.0"

const assetDirectory = "Grafton_Files/assets/Landscape_Design_ParkSpace"
const assetDirectory2 = "Grafton_Files/assets/Buildings_Advanced_
Building/"

23 - 30 import buildingFacades:"Grafton_Files/rules/supportingTools/
buildingFacades.cga"
8 - 16  import Landscape:"Grafton_Files/rules/supportingTools/
greenspaceAttributes.cga"
17 - 22 import Zoning:"Grafton_Files/rules/supportingTools/Zoning.cga"
        import envReports:"Grafton_Files/rules/supportingTools/Environment
Reporting.cga"
30 - 31 import buildingPerformance:"Example_05_Urban_Design_2015/rules/
Buildings_Advanced_Building/Support/Building Performance.cga"
```

Create a rule and call it Advanced Building Construction
The system automatically inputs the time that the rule was created, the author of the rule and the version of the system that the rule was created in.
This particular rule has been modified from an original Building Construction rule that was created by ESRI in thier Urban Design Rules tutorial.

Each Parametric variable has to be created in a hierarchal fashion prior to starting the rule.
Other rules can be imported into the rule which is being created. In this case, The Zoning, Landscape, Environmental Reports, Building Performance and Building Facades have all beeen imported.

Asset directories have been imported from both ParkSpace and Advanced Buildings rules. The assets will allow for texture to be created, as well as 3d people and trees to populate the visual output.

```
##Display

1       @Group("Display Options",0) @Order(1)
1.1     attr textureDisplay = true

        @Group("Display Options") @Order(2)
        @Range("Thematics Off", "Solid Color", "Usage", "Peak Runoff/
Permeability")
1.2     attr thematicDisplay = "Thematics Off"

        @Group("Display Options") @Order(3)
1.3     attr colour = "#FFFFFF"

        @Group("Display Options") @Order(4) @Range(0,1)
1.4     attr transparency = 1

        @Group("Display Options") @Order(10)
1.5     attr ledgeDisplay = false

        @Group("Display Options") @Order(11)
1.6     attr ledgeSize = 0.15

        @Group("Display Options") @Order(12)
1.7     attr ledgeColor = "#ffffff"
```

In this case the first section of variables that are created in this rule have to do with the 1 Display Variables.
The individual variables within the display control are as follows:
1.1 The decision between displaying the building, the building envelope or both is made.
1.2 The decision of which thematic layer is turned on is discussed. The default is that the thematics are turned off, but the usage and permeability tool can be insightful.
1.3 The decision of the colour display is carried over from the zoning tool.
1.4 The decision of how transparent the building envelope should be is made. Typically it is left at 40%.
1.5 The decision to display the edge between floors in order to differentiate the floors is made. Typically it is left off but allows to quickly see how many floors are within a building.
1.6 The decision of how prominant this differentiation is being displayed at. is set to a minimal amount of 0.15 metres.
1.7. The colour of the edge is usually left as black.

```
texturingOn = textureDisplay          # Shorthand.
thematicsOn = thematicDisplay != "Thematics Off"
coloringOn = !thematicsOn             # Shorthand.

thematicColor =
        case thematicDisplay == "Peak Runoff/Permeability":
                # Specific materials will be colored down the road, but
everything else will use white.
                "#FFFFFF"
        case thematicDisplay == "colour":
                colour
        case thematicDisplay == "Usage":
                Zoning.usageColor(Zoning.firstZoneUsage)
        else:
                "#FFFFFF"
```

The more permeable sections are darker in colour.

```
Lot -->
Parcel
```

This rule has three rules within it. The first rule generates the parcel from the lot. The lot is created which is again generated from the preexisting road and block tools.

```
##Building Height

        @Group("buildingHeight",1) @Order(1) @Range(2,20)
3.1     attr minFloorCount = Zoning.minFloorCount

        @Group("Building Height") @Order(2) @Range(2,20)
2.1     attr maxFloorCount = Zoning.maxNumberOfFloors

        @Group("Building Height") @Order(3) @
Range("None","Increasing","Decreasing","Alternating","Random")
2.2     attr variation = "None"

        @Group("Building Height") @Order(4) @Range(3,5) @Description("Floor-
to-floor height (residential buildings are normally constructed with a floor-to-
floor height of about 3m, office buildings up to 4m)")
2.3     attr upperFloorHeight = Zoning.upperFloorHeight

        @Group("Building Height") @Order(5) @Range(3,7)
2.4     attr groundFloorHeight = Zoning.groundFloorHeight

        @Description("Adjust to place front door at exact elevation.")
        @Group("Building Height",1) @Order(6) @Range(-4.1,4.1)
2.5     attr foundationAdjustment = 0

        @Description("Applied to entire parcel to match sidewalk. If rule is applied to
static shape, then adjust this to zero.")
        @Group("Building Height",1) @Order(7) @Range(0, 0.2)
2.6     attr sidewalkHeight = 0
```

In this case the second section of variables have to do with the building height.
3.1 The decision on what the minimum number of floors is going to be
2.1 The decision on what the maximum number of floors is going to be

2.2 The decision on how the massing of the overall building is going to be laid out is made. There are a couple of options on how the building can be varied, but the default shows no variation.

2.3 The decision on the height of the upper floors is set to be determined by the associated usage.

2.4 The decision on the height of the ground floors is set to be determined by the associated usage.

2.5 The decision on the foundation adjustment is set to 0. On steeper sections of land, this variable allows for the overall building to be lifted out of the ground so that it sits above the ground.

2.6 The decision on the sidewalk height again helps to rectify the issues with the topography so that the sidewalk can align the base of the building,

```
##Setbacks

        @Group("Setbacks",2) @Order(1) @Range(0,20)
4.1     attr streetSetback = Zoning.streetSetback

        @Group("Setbacks") @Order(2) @Range(0,10)
4.2     attr sideSetback = Zoning.sideSetback

        @Group("Setbacks") @Order(2) @Range(0,10)
4.3     attr rearSetback = Zoning.rearSetback

        @Group("Setbacks") @Order(3) @Range("None","2 Stepbacks","2nd
Floor","Top Floor","Increasing","Decreasing","Alternating","Random")
4.4     attr streetSetbackMode = "None"

        @Group("Setbacks") @Order(4) @Range(0,10)
4.5     attr streetSetbackAdditionalDistance = 2
```

In this case the fourth section of variables has to do with the 4 Setbacks.
4.1 The setback from the street is determined based on the imported zoning rules.

4.2 The setback from the sideyard property line is determined based on the imported zoning rules.

4.3 The setback from the rear yard property line is determined based on the imported zoning rules.

4.4 The additional setback from the street which allow for a variety of massing options are determined based on several options but the default is set at none.
4.5 The overall distance that these additional setbacks will be from the street will be setback at an additional 2 metres from the front of the building.

```
##Layout

        @Group("Layout",3) @Order(1) @Range("Along Street","Along Front","L-
Shape Left","L-Shape Right","U-Shape","Total Area")
5.1     attr layoutShape = "Along Street"

        @Group("Layout") @Order(2) @Range("Open To Back","Open To Front")
5.2     attr layoutOrientation = "Open To Back"

        @Group("Layout") @Order(3) @Range(7,20)
5.3     attr wingWidth = 13
```

In this case, the fifth section of variables has to do with the overall 5. Layout of the buildings.
5.1 The decision on how the building is laid out in association to the street. The default is set to align the building to the street.

5.2 The decision on where the courtyard is. The default is set to the back of the building.

5.3 The decision on the depth of each section of the building is set to a default of 13 metres.

```
##Subdivision

        @Group("Subdivision",4) @Order(1) @Range(10,50)
6.1     attr unitWidth = 15

        @Group("Subdivision") @Order(2) @
Range("None","Increasing","Decreasing","Alternating","Random")
6.2     attr offsetMode = "None"

        @Group("Subdivision") @Order(3) @Range(0,10)
6.3     attr offsetDistance = 3.5
```

In this case, the sixth section of variables has to do the the 6. Subdivision of units.
6.1 The decision on the unit width of each subdivision of the building is set to a default of 15 metres.

6.2 The decision on how the units are spaced in association to the street are set to a default of no offset.

6.3 The decision on the offset distance is set at 3.5 metres.

```
##Cut and Fill

        @Description("These are used for internal calculations - they must be set to
'Source=Object'")
        @Group("Link to Objects Attributes",99) @Order(1)
7.1     attr cutVolume = 0

        @Description("These are used for internal calculations - they must be set to
'Source=Object'")
        @Group("Link to Objects Attributes",99) @Order(2)
7.2     attr fillVolume = 0
```

In this case, the seventh section of variables has to do with the cut and fill of the land.

7.1 The decision sets the cut volume at 0 square metres

7.2 The decision sets the fill volume at 0 square metres

```
@Hidden
attr lotArea = geometry.area
@Hidden
attr elevation = scope.elevation
@Hidden
attr foundationHeight = 0
```

These @Hidden rules are menat to help with the transition of the rule to a site with a greater topographic condition as seen in the Beta test site.

```
##Functions

offsetStreetDistance = case offsetMode == "None": 0 else: offsetDistance
mainWingWidth =
        case streetSetbackMode == "None": wingWidth +
offsetStreetDistance
        else:    wingWidth + streetSetback + offsetStreetDistance

getHeight(idx,n) = groundFloorHeight + (nFloors(idx,n)-1)*upperFloorHeight
nFloors(idx,n) =
        case variation == "None" || n < 2 : maxFloorCount
        case variation == "Increasing"    : minFloorCount +
rint((maxFloorCount-minFloorCount)*idx/(n-1))
        case variation == "Decreasing"    : minFloorCount +
rint((minFloorCount-maxFloorCount)*(1-idx/(n-1)))
        case variation == "Alternating"   : minFloorCount +
rint((maxFloorCount-minFloorCount)*(idx%2))
        else                              : rint(rand(minFloorCount-
0.49,maxFloorCount+0.49))

getFloorHeight(idx) = case idx == 0: groundFloorHeight
                                      else: upperFloorHeight
```

The functions discuss the series of if than statements that will determine the shape of the buildings.

```
##Generate Footprint
@StartRule
Parcel -->
        set(material.opacity, transparency)
        alignScopeToAxes(y)
        t(0,sidewalkHeight,0)
        set(lotArea, geometry.area)
        set(elevation,scope.elevation)
        set(foundationHeight, scope.sy)
        report("Construction, Cut/Fill, Cost", envReports.
calculateCutAndFillCost(cutVolume, fillVolume))
        report("Construction, Cut/Fill, Cut Volume (m3)", cutVolume)
        report("Construction, Cut/Fill, Fill Volume (m3)", fillVolume)
        report("Parcel, Area (m2)", lotArea)
        report("Site Conditions, Slope (%)", geometry.angle(maxSlope)/90)
        set(buildingFacades.textureDisplay, textureDisplay)
        set(buildingFacades.thematicDisplay, thematicDisplay)
        set(buildingFacades.colour, colour)
        set(buildingFacades.transparency, transparency)
        set(buildingFacades.textureDisplay, textureDisplay)
        set(buildingFacades.upperFloorHeight, upperFloorHeight)
        set(buildingFacades.groundFloorHeight, groundFloorHeight)
        set(buildingFacades.disableMassDisplay, disableMassDisplay)
        #
        set(Landscape.textureDisplay, textureDisplay)
        set(Landscape.thematicDisplay, thematicDisplay)
        set(Landscape.colour, colour)
        set(Landscape.transparency, transparency)
        #
        set(Zoning.foundationHeight, foundationHeight)
        set(Zoning.adjustFoundation, foundationAdjustment)
        #
        set(buildingFacades.Photovoltaic_Roof.Display_Textures,
textureDisplay)
        set(buildingFacades.Photovoltaic_Roof.Display_Thematics,
thematicDisplay)
        set(buildingFacades.Photovoltaic_Roof.Solid_Color, colour)
        set(buildingFacades.Photovoltaic_Roof.Transparency, transparency)
        set(buildingFacades.Photovoltaic_Roof.Level_of_Detail,
buildingFacades.Level_of_Detail)
        #
        ParcelStep1
```

The second rule generates the footprint from the parcel.
The rule starts with the parcel.
It sets the opacity, aligns the footprint to the y axis, sets the lot area, the elevation, the foundation height and the sidewalk height.

It then generates the reports to do with construction costs,.

The building facades and landscape imports are set up.

```
xx-->
        set(material.opacity,0.5)
        translate(rel, world, 0,0.1,0)
        color(1,0,0)

ParcelStep1 -->
        case thematicsOn && thematicDisplay != "Usage":
                color(thematicColor)
                ParcelStep2
        else:
                ParcelStep2


ParcelStep2 -->
        case Zoning.zoningDisplay == "Building":
                BuildingAndYards
        case Zoning.zoningDisplay == "Envelope":
                Zoning.ZoningEnvelope
        else:
                BuildingAndYards
                Zoning.ZoningEnvelope


BuildingAndYards -->
        #t(1',foundationHeight,1')
        SetbackStreet
```

The parcel is split between the builable area and the yard.

```
SetbackStreet -->
        setback(streetSetback) {street.front: GreenSpace("frontyard") |
remainder : SetbackBack}

SetbackBack -->
        setback(rearSetback) {street.back: GreenSpace("border") | remainder
: SetbackLeft }

SetbackLeft -->
        setback(sideSetback) {street.left: GreenSpace("border") | remainder :
SetbackRight }

SetbackRight -->
        setback(sideSetback) {street.right: GreenSpace("border") | remainder
: BuildableArea }

#BuildableArea2 --> colour(0,1,1) X.

/*
Yards -->
        # Do not squash this one as we did Building.
        setback(streetSetback) {streetSide: GreenSpace("frontyard")
                | remainder :
                setback(rearSetback) {street.back: GreenSpace("border")
                | remainder :
                setback(sideSetback) {street.side: GreenSpace("border") |
remainder : NIL }}}
*/
```

The type of greenspace being used based on its location is set up.

```
BuildableArea -->
        s('1,0,'1)
        BuildableAreaDispatch
```

An if-than case is set up to determine the buildable area based on the layout types. If sections that do not meet the layouts will become landscape sections of the lots.

```
BuildableAreaDispatch -->
        case layoutShape == "Along Street":
                case layoutOrientation == "Open To Back":
                        setback(mainWingWidth) { street.front : Layout |
remainder : GreenSpace}
                else:
                        setback(mainWingWidth) { noStreetSide : Layout
| remainder : GreenSpace }
        case layoutShape == "Along Front":
                case layoutOrientation == "Open To Back":
                        setback(mainWingWidth) { front : Layout |
remainder : GreenSpace }
                else:
                        setback(mainWingWidth) { back : Layout |
remainder : GreenSpace }
        case layoutShape == "L-Shape Left":
                case layoutOrientation == "Open To Back":
                        shapeO(mainWingWidth,0,0,wingWidth) { shape :
Layout | remainder : GreenSpace }
                else:
                        shapeO(0,0,mainWingWidth,wingWidth) { shape :
Layout | remainder : GreenSpace }
        case layoutShape == "L-Shape Right":
                case layoutOrientation == "Open To Back":
                        shapeO(mainWingWidth,wingWidth,0,0) { shape :
Layout | remainder : GreenSpace }
                else:
                        shapeO(0,wingWidth,mainWingWidth,0) { shape :
Layout | remainder : GreenSpace }
        case layoutShape == "U-Shape":
                case layoutOrientation == "Open To Back":
                        shapeO(mainWingWidth,wingWidth,0,wingWidth)
{ shape : Layout | remainder : GreenSpace }
                else:
                        shapeO(0,wingWidth,mainWingWidth,wingWidth)
{ shape : Layout | remainder : GreenSpace }
        else:
                Layout

Layout -->
        case offsetDistance > 0 || (variation != "None" && maxFloorCount
!= minFloorCount ):
                split(x){ ~unitWidth: Unit(split.index,split.total) }*
        else:
                FootprintCheck(0,1)
```

The layout is determined based on an if-than statement which is based on the offset distances.

```
Unit(idx,n) -->
        case n < 2 || offsetStreetDistance <= 0:
                FootprintCheck(idx,n)
        case offsetMode == "Increasing":
                split(z){ offsetDistance*(1-idx/(n-1)) :
GreenSpace("building") | ~1: FootprintCheck(idx,n) | offsetDistance*idx/(n-
1) : GreenSpace("building") }
        case offsetMode == "Decreasing":
                split(z){ offsetDistance*idx/(n-1) : GreenSpace("building")
| ~1: FootprintCheck(idx,n) | offsetDistance*(1-idx/(n-1)) :
GreenSpace("building") }
        case offsetMode == "Alternating":
                split(z){ offsetDistance*(idx%2) : GreenSpace("building")
| ~1: FootprintCheck(idx,n) | offsetDistance*((idx+1)%2) :
GreenSpace("building") }
        case offsetMode == "Random":
                40% : split(z){                              ~1:
FootprintCheck(idx,n) | offsetDistance  : GreenSpace("building") }
                10% : split(z){ offsetStreetDistance/2:
GreenSpace("building") | ~1: FootprintCheck(idx,n) | offsetDistance/2:
GreenSpace("building") }
                40% : split(z){ offsetStreetDistance  :
GreenSpace("building") | ~1: FootprintCheck(idx,n) }
                else: FootprintCheck(idx,n)
        else:
                FootprintCheck(idx,n)


FootprintCheck(idx,n) -->
        case geometry.isConcave:
                convexify(3) FootprintSizeCheck(idx,n)
        else:
                FootprintSizeCheck(idx,n)


FootprintSizeCheck(idx,n) -->
        case geometry.nFaces > 1:
                comp(f){all: alignScopeToAxes(y) FootprintSizeCheck(idx,n)
}
        case scope.sx < 4 || scope.sz < 4:
                GreenSpace
        else:
                Footprint(idx,n)


##Generate Mass

@StartRule
Footprint -->
        case thematicsOn:
                color(thematicColor)
                Footprint2(0,1)
        else:
                Footprint2(0,1)
```

The second rule generates a building from the footprint generated in the first rule.

```
Footprint2(idx,n) -->
        set(buildingFacades.textureDisplay, textureDisplay)
        set(buildingFacades.thematicDisplay, thematicDisplay)
        set(buildingFacades.colour, colour)
        set(buildingFacades.transparency, transparency)
        set(buildingFacades.upperFloorHeight, upperFloorHeight)
        set(buildingFacades.groundFloorHeight, groundFloorHeight)
        set(buildingFacades.disableMassDisplay, disableMassDisplay)
        #
        set(Landscape.textureDisplay, textureDisplay)
        set(Landscape.thematicDisplay, thematicDisplay)
        set(Landscape.colour, colour)
        set(Landscape.transparency, transparency)
        #
        set(Zoning.foundationHeight, foundationHeight)
        set(Zoning.adjustFoundation, foundationAdjustment)
        #
        set(buildingFacades.Photovoltaic_Roof.Display_Textures,
textureDisplay)
        set(buildingFacades.Photovoltaic_Roof.Display_Thematics,
thematicDisplay)
        set(buildingFacades.Photovoltaic_Roof.Solid_Color, colour)
        set(buildingFacades.Photovoltaic_Roof.Transparency, transparency)
        set(buildingFacades.Photovoltaic_Roof.Level_of_Detail,
buildingFacades.Level_of_Detail)
        #
        Footprint(idx,n)
```

The facade, landscape and zoning settings are imported from other rules and set up.

```
Footprint(idx,n) -->
        alignScopeToAxes(y) s('1,0,'1) t(0,elevation-scope.elevation,0)
        Foundation
        t(0, foundationHeightAdjusted, 0)
        report("Building, Footprint Area (m2)", geometry.area)
        report("Parcel, Coverage (%)", geometry.area/lotArea*100)
        extrude(getHeight(idx,n))
        Envelope
```

The footprint is aligned to the y axis and the reports are created that discuss the building footprint area and lot coverage.

```
foundationHeightAdjusted = foundationHeight + foundationAdjustment
Foundation -->
        case thematicsOn && thematicDisplay == "Usage":
                color(Zoning.usageColor(Zoning.usagePerFloor(0)))
                FoundationStep2
        else:
                FoundationStep2

FoundationStep2 -->
        extrude(foundationHeightAdjusted)
        comp(f){side : buildingFacades.Wall}
```

The foundation adjustment is setup.

```
#Split Floors
Envelope -->
        split(y){   ~groundFloorHeight: FloorEnvelope(split.index,split.total)
                        | { ~upperFloorHeight: FloorEnvelope(split.
index,split.total) }* }

FloorEnvelope(idx,n) -->
        s('1,0.02,'1) t(0,'-1,0) comp(f){top: FloorArea(idx,n) }

FloorArea(idx,n) -->
        case streetSetbackMode == "None":
                Floor(idx,n)
        case streetSetbackMode == "2nd Floor" && idx > 1:
                setback(streetSetbackAdditionalDistance){ object.front:
NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "Top Floor" && idx == n-1:
                setback(streetSetbackAdditionalDistance){ object.front:
NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "2 Stepbacks" && idx > n*0.8:
                setback(streetSetbackAdditionalDistance){ object.front:
NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "2 Stepbacks" && idx > n*0.5:
                setback(streetSetbackAdditionalDistance/2){ object.front:
NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "Increasing":
                setback(streetSetbackAdditionalDistance*idx/(n-1)){ object.
front: NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "Decreasing":
                setback(streetSetbackAdditionalDistance*(1-idx/(n-1))){
object.front: NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "Alternating" && idx%2 == 1:
                setback(streetSetbackAdditionalDistance){ object.front:
NIL | remainder: Floor(idx,n) }
        case streetSetbackMode == "Random":
                30% : setback(streetSetbackAdditionalDistance){ object.
front: NIL | remainder: Floor(idx,n) }
                30% : setback(streetSetbackAdditionalDistance){ object.
back: NIL | remainder: Floor(idx,n) }
                else: Floor(idx,n)
        else:
                Floor(idx,n)

Floor(idx,n) -->
        Floor(idx,n,Zoning.usagePerFloor(idx))

Floor(idx,n,usage) -->
        case thematicDisplay == "Usage":
                color(Zoning.usageColor(usage))
                FloorStep2(idx,n,usage)
        else:
                FloorStep2(idx,n,usage)
```

The building massing and configuration is created based on layout, offsets, and setbacks.

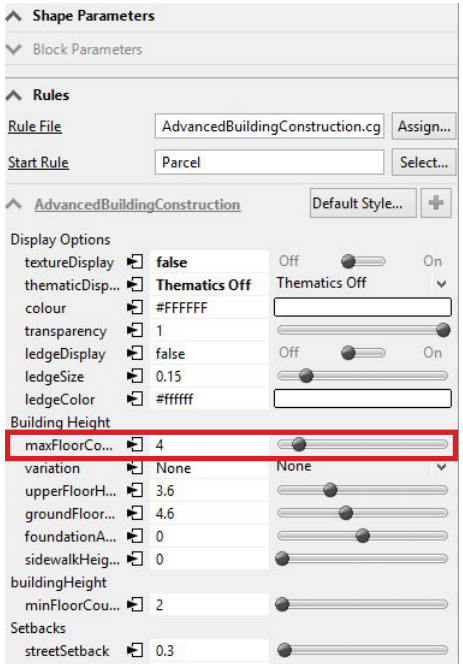
```
FloorStep2(idx,n,usage) -->
        report("Building, Gross Floor Area (m2)", geometry.area)
        report("Parcel, Floor Area Ratio (Density)", geometry.area/lotArea)
        report("Construction, Building Cost", geometry.area *
buildingPerformance.Cost_Per_M2)

        report("Construction, Waste (kg)",
                geometry.area * Zoning.constructionWastePerUsage(usage)
* (1-buildingPerformance.Percent_Reduction_Construction_Waste))

        report("buildingPerformance Target, Waste, Domestic (kg/yr)",
                geometry.area * Zoning.domesticWastePerUsage(usage) *
(1-buildingPerformance.Percent_Reduction_Domestic_Waste))
        report("buildingPerformance Target, Energy, Heating Consumption
(kWh/yr)",
                geometry.area * Zoning.
heatingConsumptionPerUsage(usage) * (1-buildingPerformance.Percent_
Reduction_Heating_Energy_Consumption))
        report("buildingPerformance Target, Energy, Electrical Consumption
(kWh/yr)",
                geometry.area * Zoning.
electricConsumptionPerUsage(usage) * (1-buildingPerformance.Percent_
Reduction_Electric_Energy_Consumption))
        report("buildingPerformance, Target, Water, Consumption (l/yr)",
                geometry.area * waterConsumption(usage) *
(1-buildingPerformance.Percent_Reduction_Water_Consumption))
        report("buildingPerformance, Target, Water, Produced Greywater (l/
yr)",
                geometry.area * waterConsumption(usage) *
(1-buildingPerformance.Percent_Reduction_Water_Consumption) * Zoning.
percentGreywaterProducedPerUsage(usage))
        report("buildingPerformance, Target, Water, Produced Blackwater (l/
yr)",
                geometry.area * waterConsumption(usage) *
(1-buildingPerformance.Percent_Reduction_Water_Consumption) * (1 -
Zoning.percentGreywaterProducedPerUsage(usage)))
        report("buildingPerformance, Target, Water, Recycled Greywater (l/
yr)",
                geometry.area * waterConsumption(usage) *
(1-buildingPerformance.Percent_Reduction_Water_Consumption) * Zoning.
percentGreywaterProducedPerUsage(usage) * buildingPerformance.Percent_
Greywater_Recycled)

        report("buildingPerformance Baseline, Waste, Domestic (kg/yr)",
                geometry.area * Zoning.domesticWastePerUsage(usage))
        report("buildingPerformance Baseline, Energy, Heating
Consumption (kWh/yr)",
                geometry.area * Zoning.
heatingConsumptionPerUsage(usage))
        report("buildingPerformance Baseline, Energy, Electrical
Consumption (kWh/yr)",
                geometry.area * Zoning.
electricConsumptionPerUsage(usage))
        report("buildingPerformance Baseline, Water, Consumption (l/yr)",
                geometry.area * waterConsumption(usage))
        report("buildingPerformance Baseline, Water, Produced Greywater
(l/yr)",
                geometry.area * waterConsumption(usage) * Zoning.
percentGreywaterProducedPerUsage(usage))
        report("buildingPerformance Baseline, Water, Produced Blackwater
(l/yr)",
                geometry.area * waterConsumption(usage) * (1 - Zoning.
percentGreywaterProducedPerUsage(usage)))

        StoryEdgeDisplay
        extrude(getFloorHeight(idx))
        FloorMassFacades(idx,n)

waterConsumption(usage) = Zoning.waterConsumptionPerUsage(usage) *
(1-buildingPerformance.Percent_Reduction_Water_Consumption)

StoryEdgeDisplay -->
        case ledgeDisplay :
                case coloringOn:
                        color(ledgeColor)
                        offset(ledgeSize, border)
                        extrude(-ledgeSize) X.
                else:
                        offset(ledgeSize, border)
                        extrude(-ledgeSize) X.
        else: NIL



##Subdivide

FloorMassFacades(idx,n) -->
        buildingFacades.FloorMass(idx,n)

GreenSpace -->
        GreenSpace("main")


GreenSpace(id) -->
        report("Parcel, Green Space Area (m2)",geometry.area)
        Landscape.GreenSpace(id, thematicColor)
```

Reports are generated for the GFA, the FAR, the building construction costs, the building performance costs, and attributes to do with landscape costs, amounts and sizes.

5.6 Advanced Building Rule

The overall height of the building mass can be altered without altering the height of the building envelope

Table 5.6.1



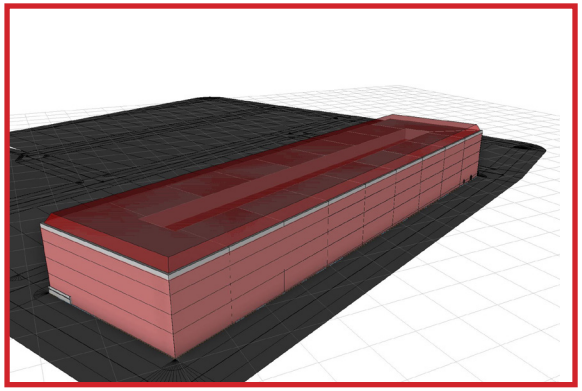


Figure 5.61.1 The default of the advanced building tool

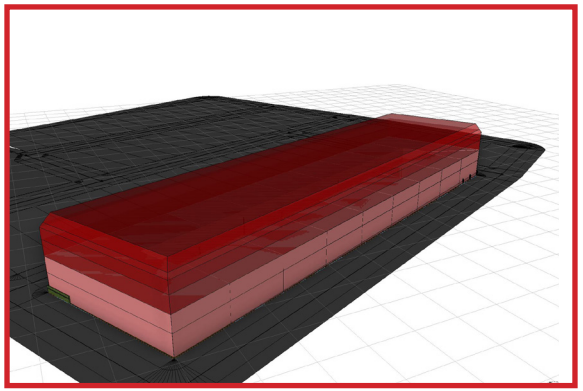


Figure 5.61.2 The overall building height is reduced to 2 floors.

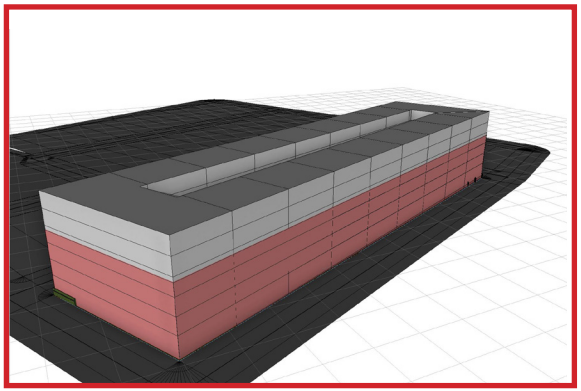


Figure 5.61.3 The overall building height is increased to 6 floors

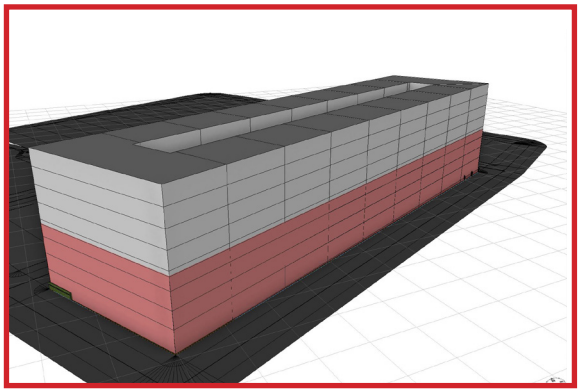


Figure 5.61.4 The overall building height is increased to 8 floors.

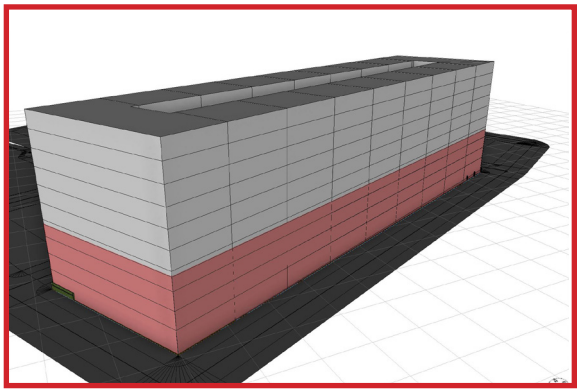
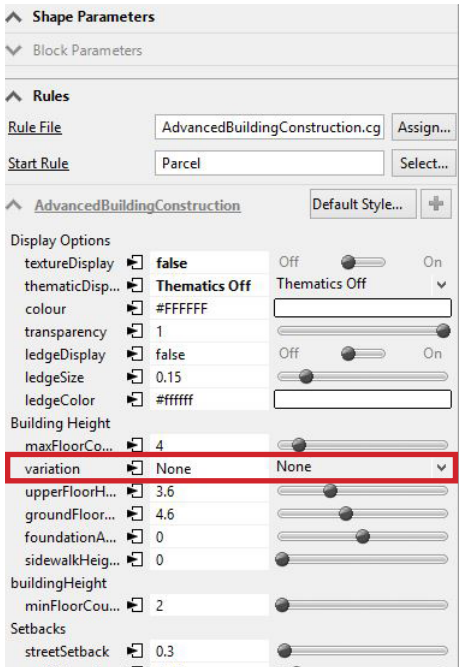


Figure 5.61.5 The overall building height is increased to 10 floors.

5.6 Advanced Building Rule

A variation in the building mass between the maximum and minimum number of floors is possible with a single variable.

Table 5.6.1



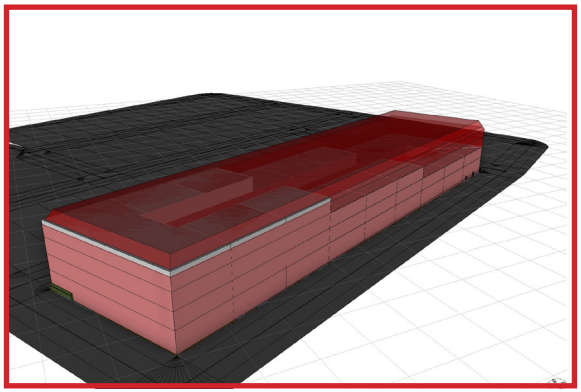


Figure 5.62.1 A change in the overall floor height increases from 2 floors to 4 while staying within the building envelope.

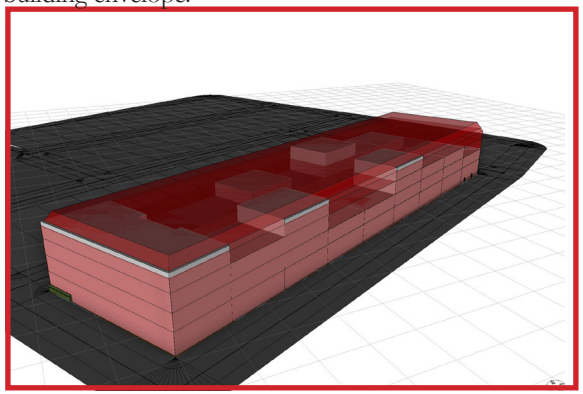


Figure 5.62.2 A change in the overall floor height alternates between 2 floors and 4 while staying within the building envelope

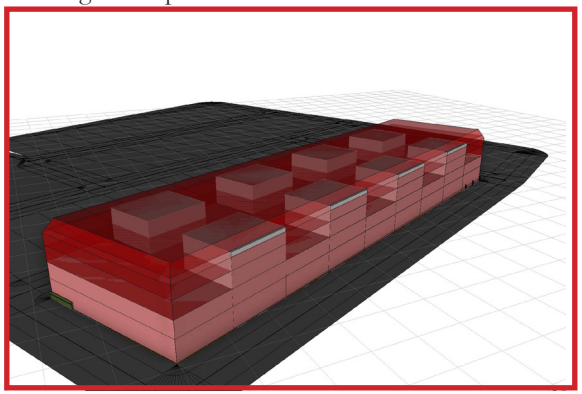
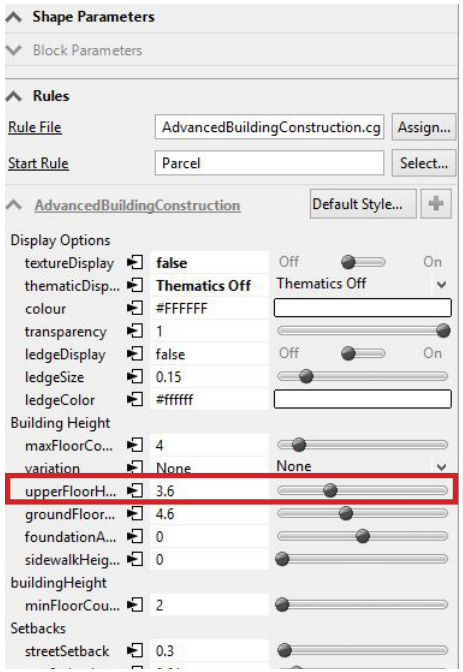


Figure 5.62.3 A change in the overall floor height alternates between 2 floors and 4 while staying within the building envelope

5.6 Advanced Building Rule

The height of the upper floors can be changed through a single variable.

Table 5.6.1



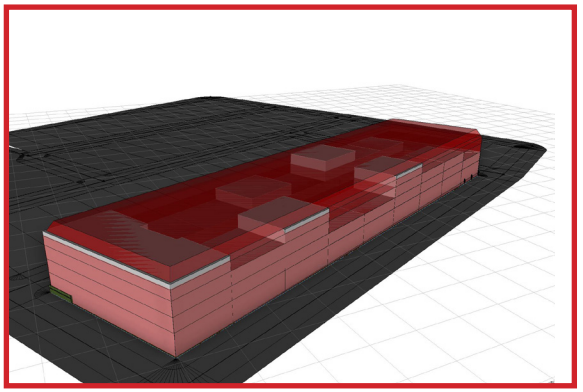


Figure 5.62.4 The upper floors have a height of 3 metres.

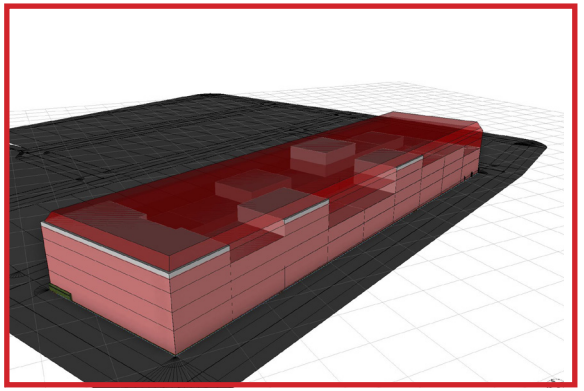


Figure 5.62.5 The upper floor heights are increased to 3.5 metres

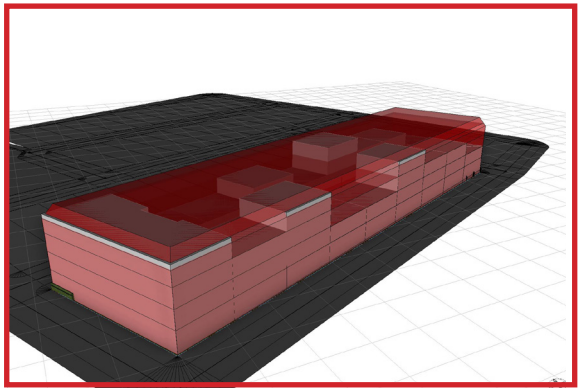
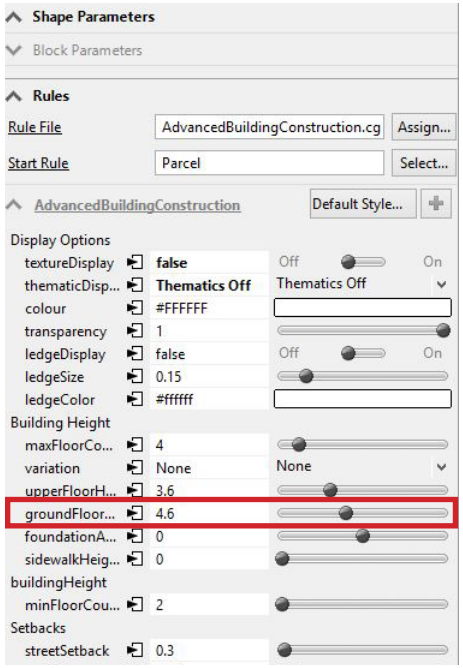


Figure 5.62.6 The upper floor heights are increased to 4 metres.

5.6 Advanced Building Rule

The height of the ground floor can be changed through a single variable.

Table 5.6.1



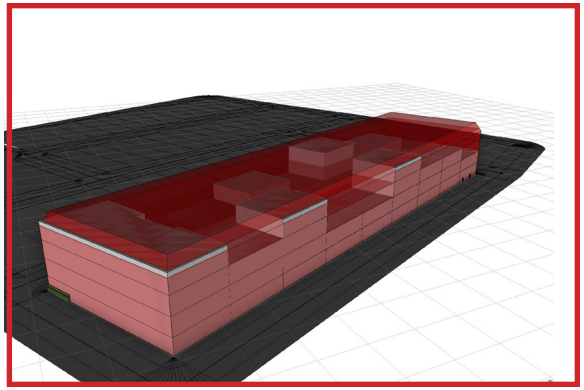


Figure 5.63.1 The ground floor have a height of 3 metres.

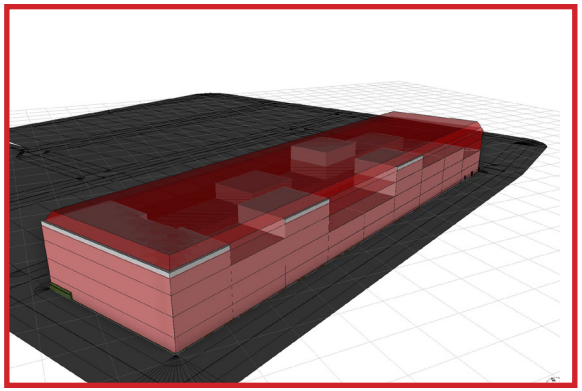


Figure 5.63.2 The ground floor heights are increased to 4 metres.

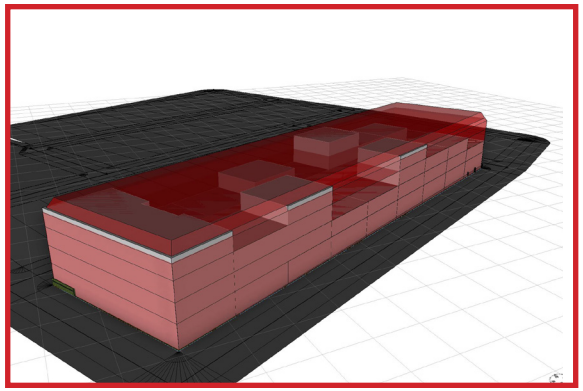


Figure 5.63.3 The ground floor heights are increased to 5 metres.

5.6 Advanced Building Rule

The front street setback can be altered to determine the location for the build-able area through a single variable.

Table 5.6.1

Start Rule	Parcel	Select...
AdvancedBuildingConstruction		Default Style...
Display Options		
textureDisplay	**false**	Off On
thematicDisp...	**Thematics Off**	Thematics Off
colour	#FFFFFF	
transparency	1	
ledgeDisplay	false	Off On
ledgeSize	0.15	
ledgeColor	#ffffff	
Building Height		
maxFloorCo...	4	
variation	None	None
upperFloorH...	3.6	
groundFloor...	4.6	
foundationA...	0	
sidewalkHeig...	0	
buildingHeight		
minFloorCou...	2	
Setbacks		
streetSetback	0.3	
rearSetback	0.91	
sideSetback	0	
streetSetback...	None	None
streetSetback...	2	
Layout		
layoutShape	Along Street	Along Street

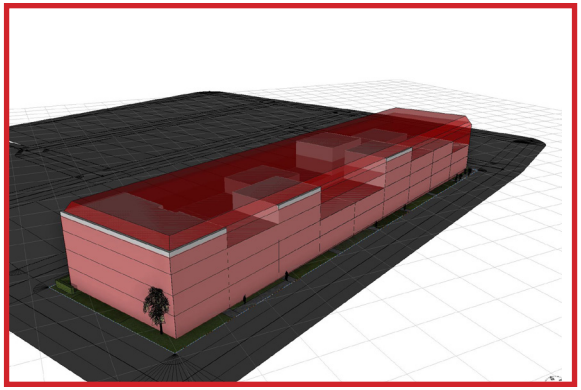


Figure 5.63.4 The front street setback to build-able area is set to a standard 3.048 metres.

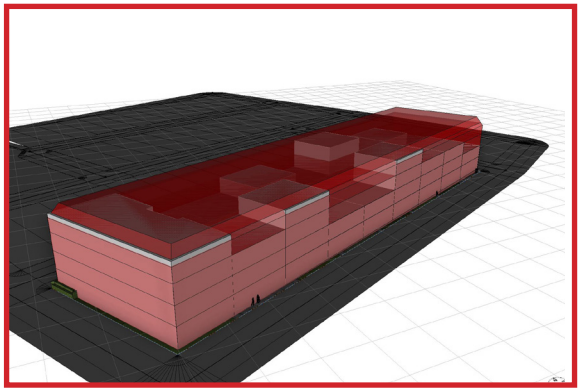


Figure 5.63.5 The front street setback to build-able area is reduced to 1 metre.

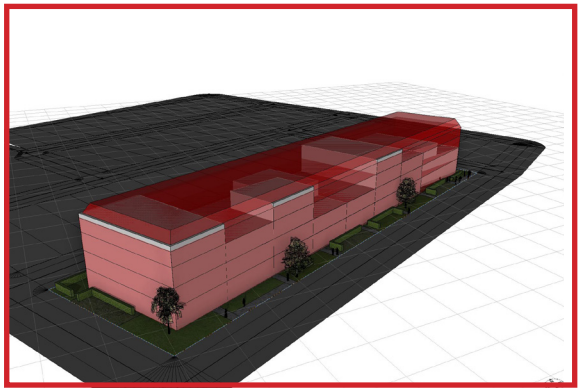


Figure 5.63.6 The front street setback to build-able area is increased to 5.5 metres to meet the maximum allowable by LEED ND.

5.6 Advanced Building Rule

An additional setback can be installed to allow for the building to step-back from the street. This will allow for more sunlight to get to the

Table 5.6.1

Display Options		
textureDisplay	false	Off On
thematicDisp...	Thematics Off	Thematics Off
colour	#FFFFFF	
transparency	1	
ledgeDisplay	false	Off On
ledgeSize	0.15	
ledgeColor	#ffffff	
Building Height		
maxFloorCo...	4	
variation	None	None
upperFloorH...	3.6	
groundFloor...	4.6	
foundationA...	0	
sidewalkHeig...	0	
buildingHeight		
minFloorCou...	2	
Setbacks		
streetSetback	0.3	
rearSetback	0.91	
sideSetback	0	
streetSetback...	None	None
streetSetback...	2	
Layout		
layoutShape	Along Street	Along Street
layoutOrient...	Open To Back	Open To Back
wingWidth	13	
Subdivision		

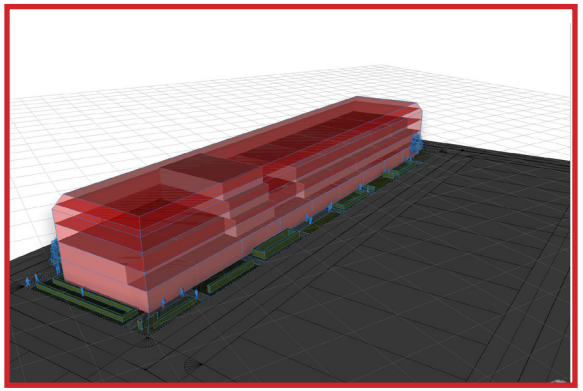


Figure 5.64.1 Each floor is setback so that the overall setback is 5 metres.

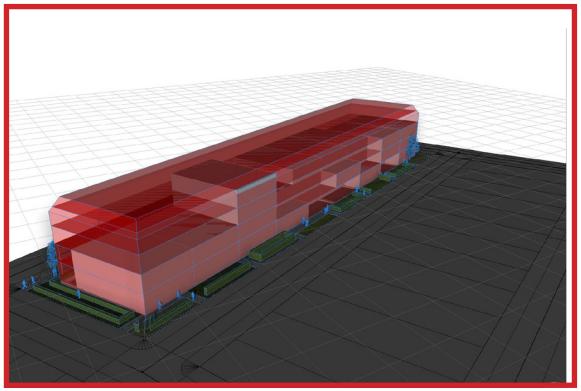


Figure 5.64.2 The building floors are setback randomly so that there are some overhanging floors.

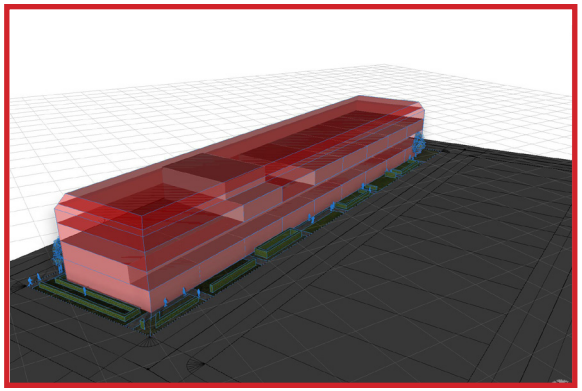


Figure 5.64.3 The top floor is setback by 5 metres.

5.6 Advanced Building Rule

The overall assemblage of buildings are configured in a overall block pattern.

Table 5.6.1

thematicDisp...	**Thematics Off**	Thematics Off
colour	#FFFFFF	
transparency	1	
ledgeDisplay	false	Off On
ledgeSize	0.15	
ledgeColor	#ffffff	
Building Height		
maxFloorCo...	4	
variation	None	None
upperFloorH...	3.6	
groundFloor...	4.6	
foundationA...	0	
sidewalkHeig...	0	
buildingHeight		
minFloorCou...	2	
Setbacks		
streetSetback	0.3	
rearSetback	0.91	
sideSetback	0	
streetSetback...	None	None
streetSetback...	2	
Layout		
layoutShape	Along Street	Along Street
layoutOrient...	Open To Back	Open To Back
wingWidth	13	
Subdivision		
unitWidth	15	
offsetMode	None	None
offsetDistance	3.5	

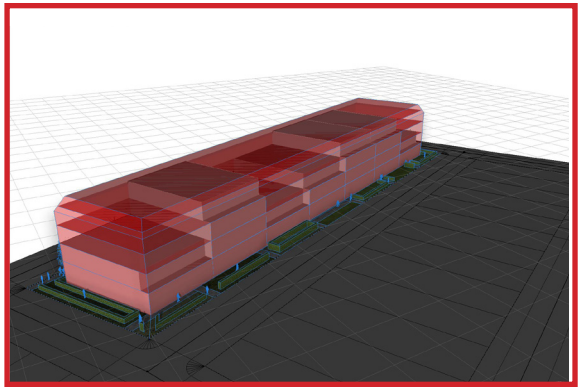


Figure 5.64.4 The overall build-able area is built up.

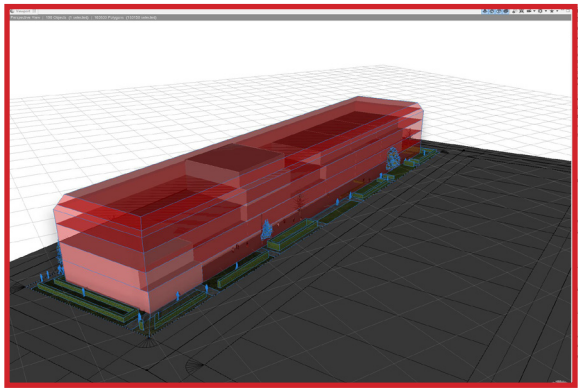


Figure 5.64.5 An assemblage of buildings is created with an overall L shape.

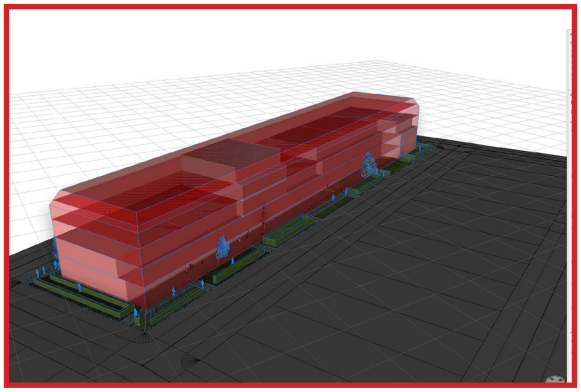


Figure 5.64.6 An assemblage of buildings is created with an overall L shape.

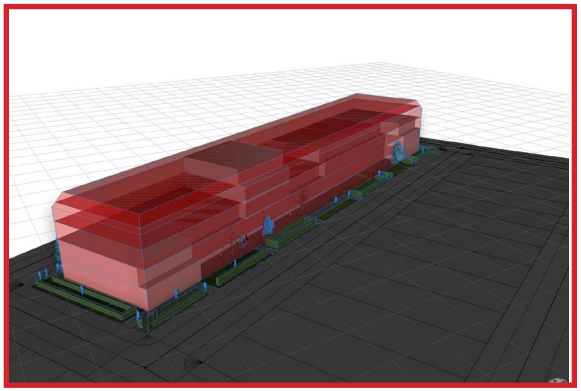


Figure 5.64.7 An assemblage of buildings is created with an overall U shape.

5.6 Advanced Building Rule

An additional setback can be installed to allow for the building to step-back from the street. This will allow for more sunlight to get to the street. This is done through a single variable.

Table 5.6.1

transparency	1	
ledgeDisplay	false	Off On
ledgeSize	0.15	
ledgeColor	#ffffff	
Building Height		
maxFloorCo...	4	
variation	None	None
upperFloorH...	3.6	
groundFloor...	4.6	
foundationA...	0	
sidewalkHeig...	0	
buildingHeight		
minFloorCou...	2	
Setbacks		
streetSetback	0.3	
rearSetback	0.91	
sideSetback	0	
streetSetback...	None	None
streetSetback...	2	
Layout		
layoutShape	Along Street	Along Street
layoutOrient...	Open To Back	Open To Back
wingWidth	13	
Subdivision		
unitWidth	15	
offsetMode	None	None
offsetDistance	3.5	
Link to Objects ...		
cutVolume	0	

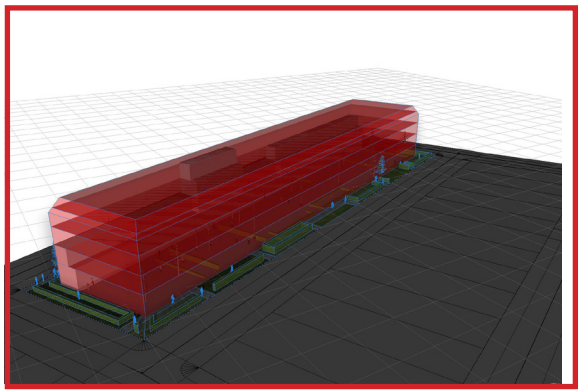


Figure 5.65.1 The depth of the building is set to 5 metres.

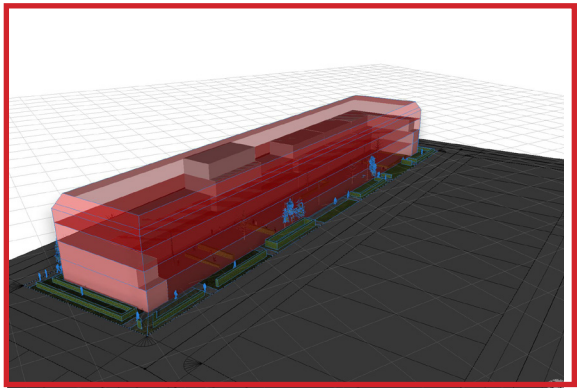


Figure 5.65.2 The depth of the building is set to 10 metres.

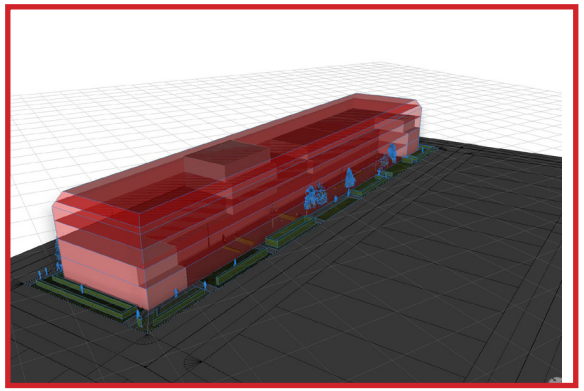


Figure 5.65.3 The depth of the building is set to 15 metres.

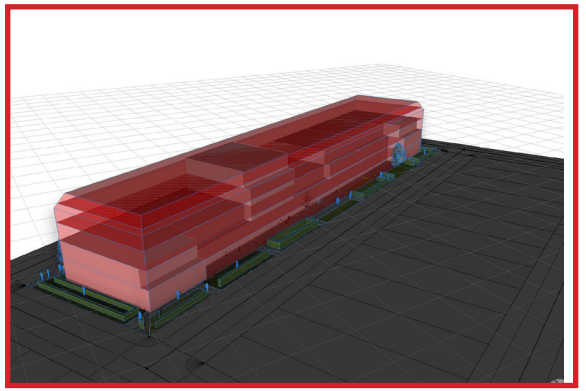


Figure 5.65.4 The depth of the building is set to 20 metres.

5.6 Advanced Building Rule

Building units can be offset in different patterns by a single variable.

Table 5.6.1

transparency	1	
ledgeDisplay	false	Off On
ledgeSize	0.15	
ledgeColor	#ffffff	
Building Height		
maxFloorCo...	4	
variation	None	None
upperFloorH...	3.6	
groundFloor...	4.6	
foundationA...	0	
sidewalkHeig...	0	
buildingHeight		
minFloorCou...	2	
Setbacks		
streetSetback	0.3	
rearSetback	0.91	
sideSetback	0	
streetSetback...	None	None
streetSetback...	2	
Layout		
layoutShape	Along Street	Along Street
layoutOrient...	Open To Back	Open To Back
wingWidth	13	
Subdivision		
unitWidth	15	
offsetMode	None	None
offsetDistance	3.5	
Link to Objects ...		
cutVolume	0	

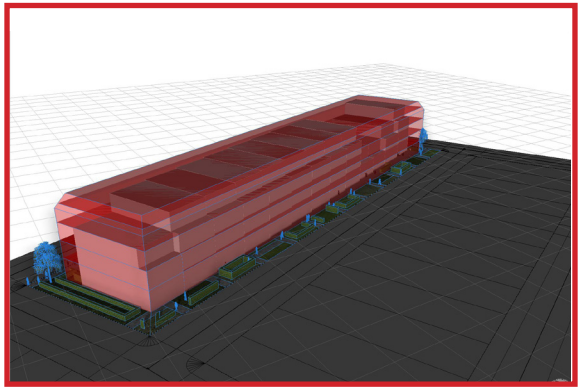


Figure 5.65.5 The building units are offset by an increasing amount to allow for views.

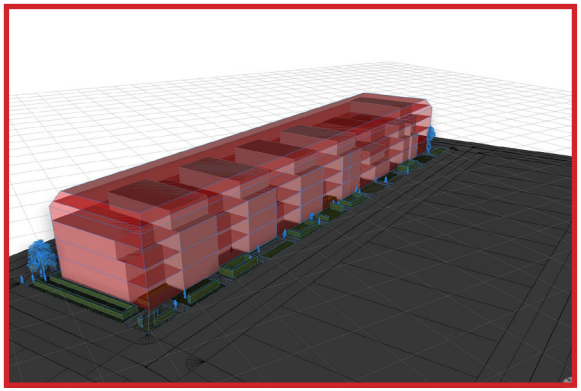


Figure 5.65.6 The building units are offset by alternating locations to allow for units to each get their own exterior space.

5.6 Advanced Building Rule

Building unit width can be increased and subdivided through a single variable.

Table 5.6.1

transparency	1	
ledgeDisplay	false	Off On
ledgeSize	0.15	
ledgeColor	#ffffff	
Building Height		
maxFloorCo...	4	
variation	None	None
upperFloorH...	3.6	
groundFloor...	4.6	
foundationA...	0	
sidewalkHeig...	0	
buildingHeight		
minFloorCou...	2	
Setbacks		
streetSetback	0.3	
rearSetback	0.91	
sideSetback	0	
streetSetback...	None	None
streetSetback...	2	
Layout		
layoutShape	Along Street	Along Street
layoutOrient...	Open To Back	Open To Back
wingWidth	13	
Subdivision		
unitWidth	15	
offsetMode	None	None
offsetDistance	3.5	
Link to Objects ...		
cutVolume	0	
fillVolume	0	

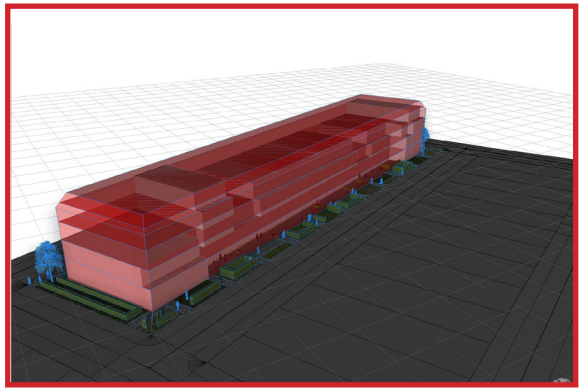


Figure 5.66.1 The individual unit width is set to 10 metres.

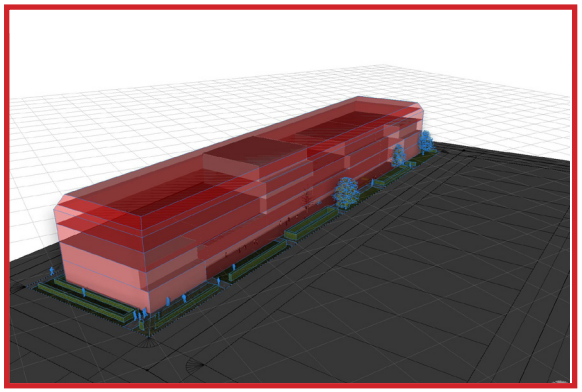


Figure 5.66.2 The individual unit width is set to 20 metres.

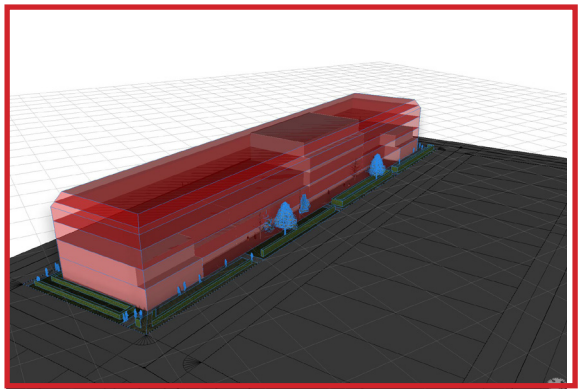


Figure 5.66.3 The individual unit width is set to 30 metres.

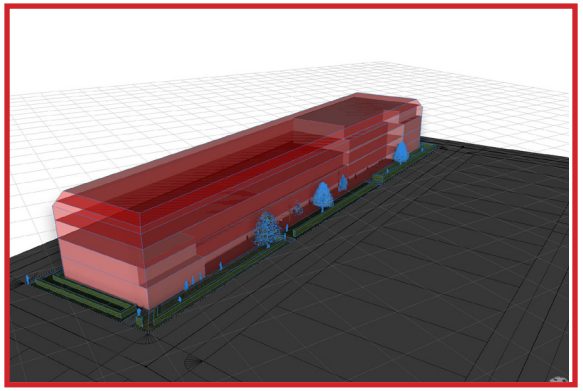
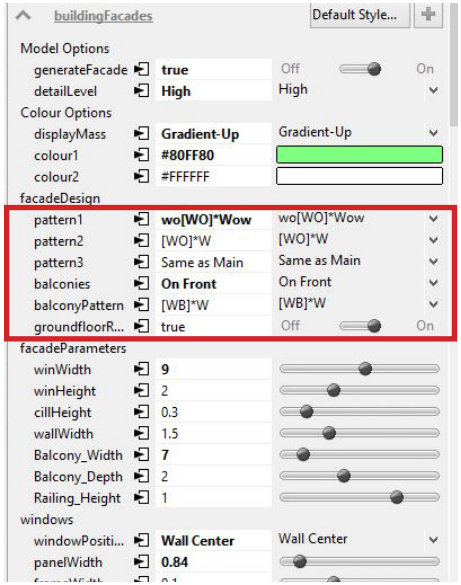


Figure 5.66.4 The individual unit width is set to 50 metres.

5.6 Advanced Building Rule

The facades are largely imported from an pre-existing ESRI file and so these are only showing some of the capabilities which have been altered throughout this practicum.

Table 5.6.1



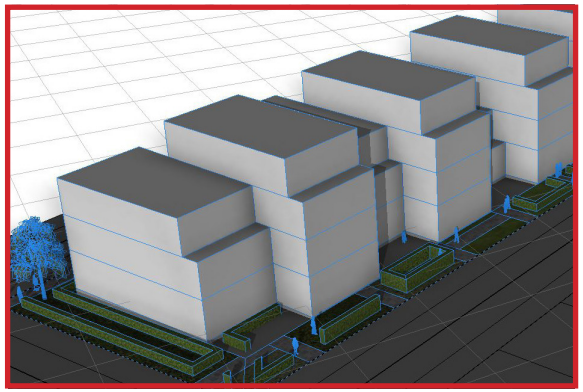


Figure 5.67.1 The removal of the building envelope.

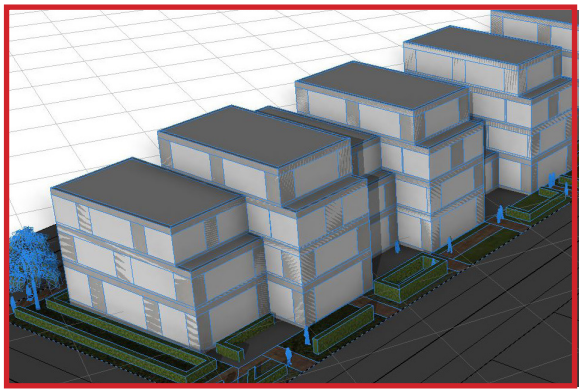


Figure 5.67.2 The addition of windows.

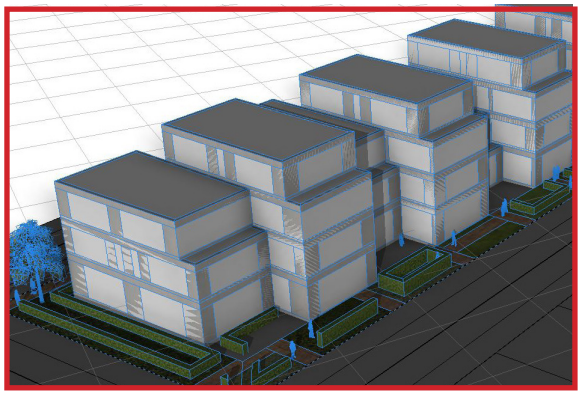


Figure 5.67.3 The alteration of window patterns.

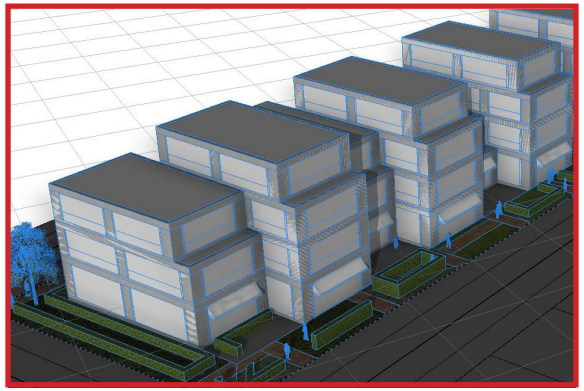


Figure 5.67.4 The addition of awnings to the ground floor.

Figure 5.67.5 The addition of a brick facade.

5.6 Advanced Building Rule

The importation of the contextual topographical map helps to give an understanding of how the buildings fit within their context,

Figure 5.67.6

5.7 Test The Transferability To a Different Topography

While a rule was not created for this particular concept, the advanced building rule was brought into the beta site in Kenora to determine the transferability of the rules.

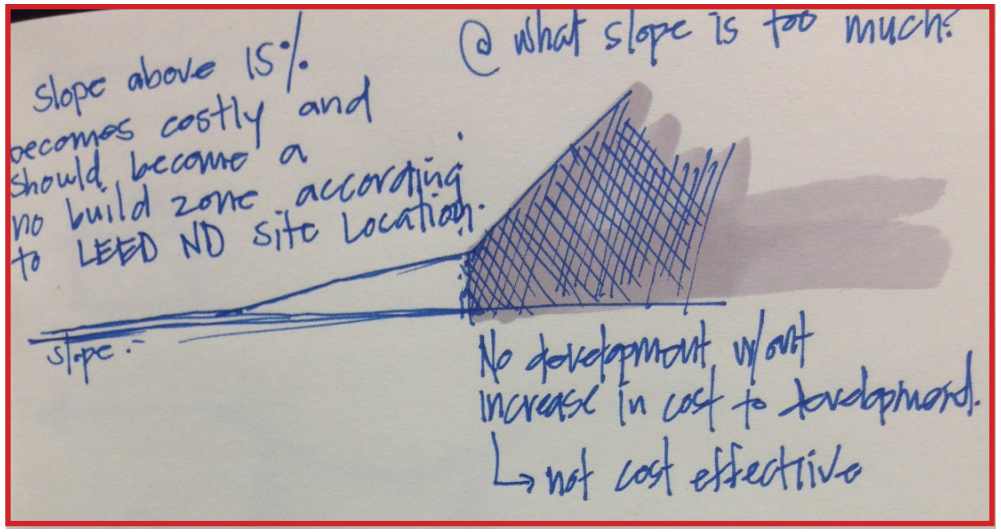


Figure 5.70

5.7 Test The Transferability To a Different Topography

The Advanced Building Rule is transferred to the Beta site to determine the transferability of rules on a site with a steep topography. The results were not what was being sought.

The rule was supposed to generate an error code for any sections of land with a slope over 15% and designate them as no build areas, It was supposed to prohibit buildings from being generated in these areas. While the error codes are generated and displayed in red, the program still allows for buildings to be generated in those areas.

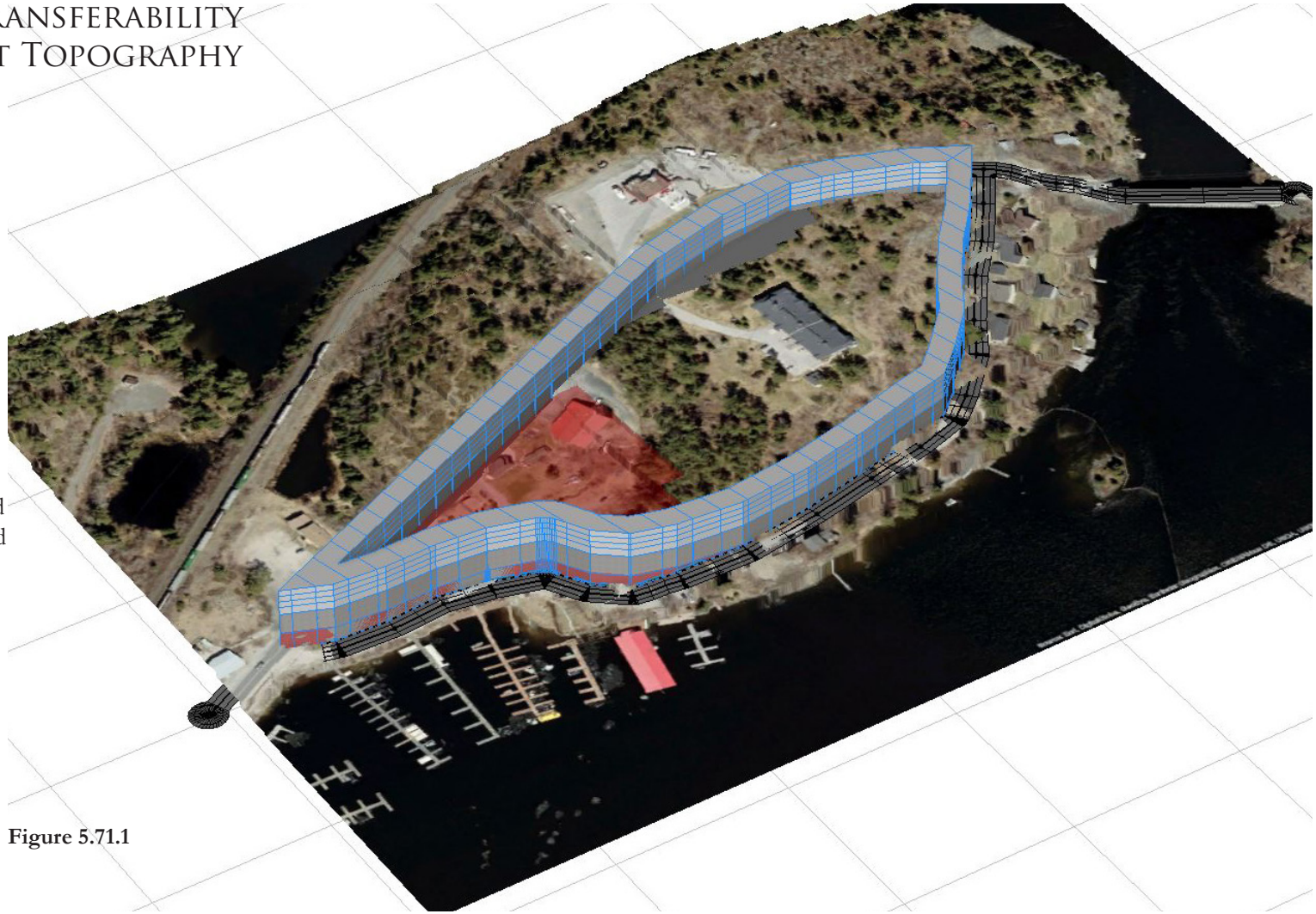


Figure 5.71.1

5.7 Test The Transferability To a Different Topography

A similar result occurs when the buildings are aligned to the street.

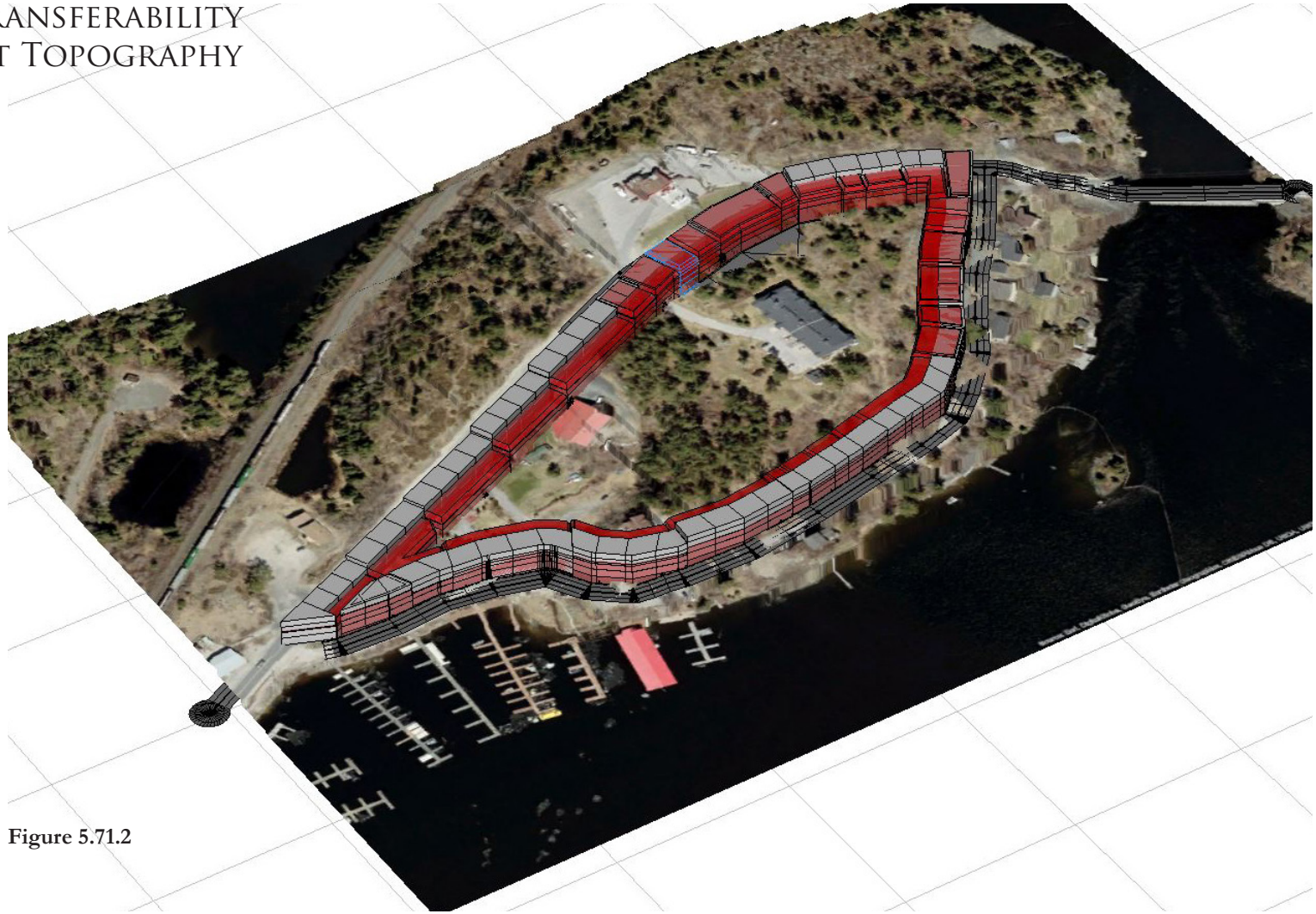


Figure 5.71.2

5.7 Test The Transferability To a Different Topography

A similar result occurs when the block is subdivided into straight lots.

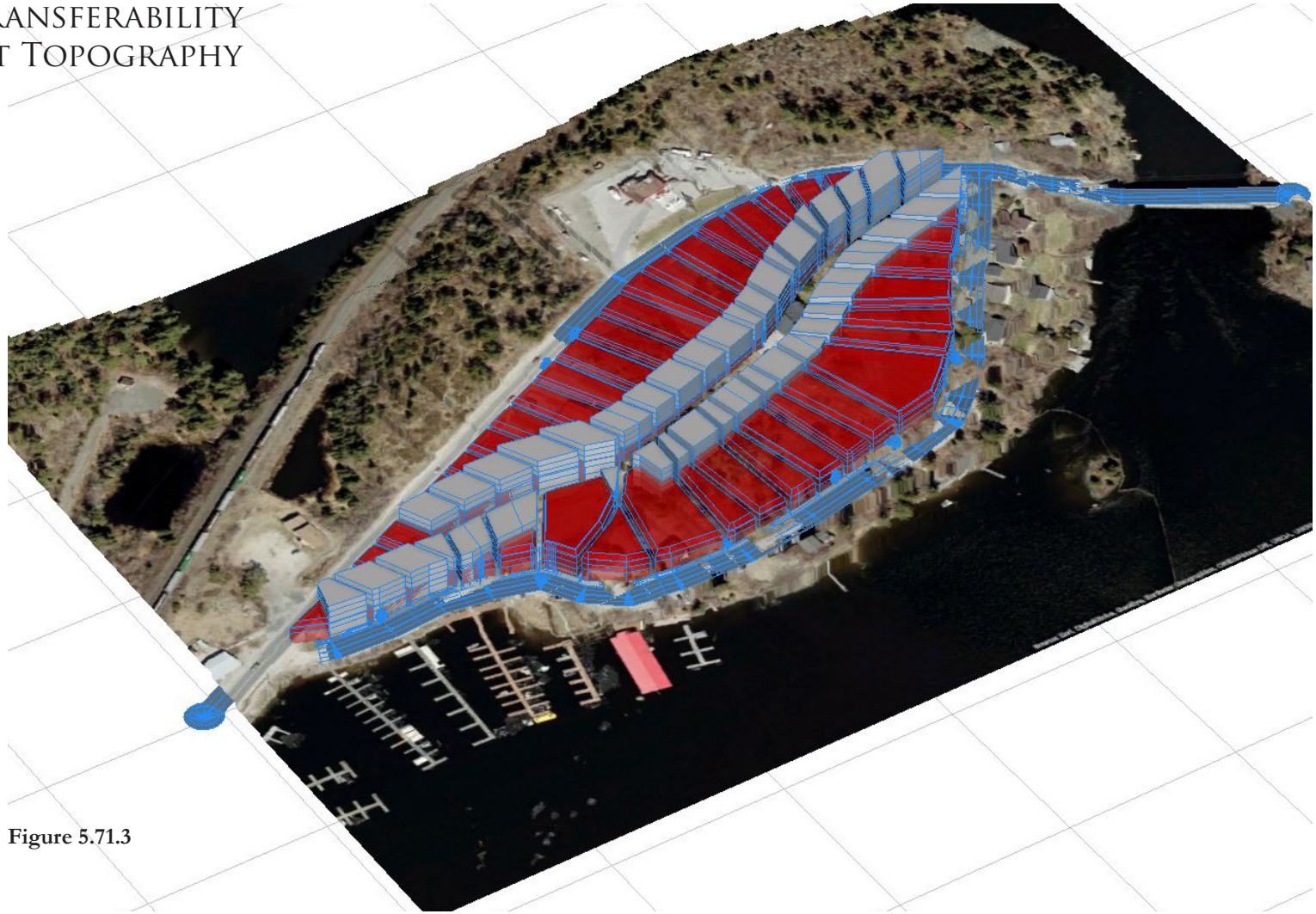


Figure 5.71.3

5.7 Test The Transferability To a Different Topography

The reports which are currently able to be generated from the rule are as shown.

Table 5.6.2

Reports

Report	N	%	S
Building, Footprint Area (m2)	10	0.00	2168
Building, Gross Floor Area (m2)	30	0.00	6007
Construction, Building Cost	30	0.00	8410199
Construction, Cut/Fill, Cost	3	0.00	0
Construction, Cut/Fill, Cut Volume (m3)	3	0.00	0
Construction, Cut/Fill, Fill Volume (m3)	3	0.00	0
Construction, Grass Area (m2)	34	0.00	2454
Construction, Grass Cost	34	0.00	24541
Construction, Hardscape Area (m2)	22	0.00	402
Construction, Hardscape Cost	22	0.00	10073
Construction, Tree Cost	12	0.00	3000
Construction, Waste (kg)	30	0.00	90109
Parcel, Area (m2)	1	0.00	5025
Parcel, Coverage (%)	10	0.00	43
Parcel, Floor Area Ratio (Density)	30	0.00	1
Parcel, Green Space Area (m2)	2	0.00	2857
Site Conditions, Slope (%)	1	0.00	0
Site Conditions, Stormwater Runoff (m3/hr)	56	0.00	16640
buildingPerformance Baseline, Energy, Elec...	30	0.00	4805828
buildingPerformance Baseline, Energy, Hea...	30	0.00	1802185
buildingPerformance Baseline, Waste, Dom...	30	0.00	300364
buildingPerformance Baseline, Water, Cons...	30	0.00	36043712
buildingPerformance Baseline, Water, Prod...	30	0.00	10813113
buildingPerformance Baseline, Water, Prod...	30	0.00	25230598
buildingPerformance Target, Energy, Electri...	30	0.00	4805828
buildingPerformance Target, Energy, Heati...	30	0.00	1802185
buildingPerformance Target, Waste, Dome...	30	0.00	300364
buildingPerformance, Target, Water, Consu...	30	0.00	36043712
buildingPerformance, Target, Water, Produ...	30	0.00	10813113
buildingPerformance, Target, Water, Produ...	30	0.00	25230598
buildingPerformance, Target, Water, Recycl...	30	0.00	0

6.0 Reflection

This practicum has been an exploration of simulation modeling which is a key research tool discussed in Linda Groat and David Wang's Architectural Research Methods. The parametric modeling capabilities are more advanced than standard simulation models as they add an algorithm component allowing for the variables to be altered once the code is written. These parametric models have been developed and manipulated "not only to dynamically model [environments] spatially and operationally in 3d, [but also to] … project costs in real time" (Wang, 350) The exploration has given me the opportunity to explore a practical technology in its infancy; with the potential to be incorporated into the practices of landscape design, urban design and land development.

If there is a potential for a new technology to assist in the design and development process within the professional field of landscape architecture, urbanism or development, it is important that an attempt is made to understand that technology in its infancy prior to it becoming mainstream. Throughout this exploration, I have learned a lot about the potential of the technology, but I have also learned about the trials and tribulations involved with testing a new technology and gained a new appreciation of the effort involved in creating new technologies.

Throughout this process, my understanding and appreciation of the landscape and landscape architecture has not changed. This exploration has however uncovered the fact that although a technology can be developed by landscape architects and city planners, it does not necessarily mean that it is capable of incorporating everything that may be important to a landscape architect. In its current form, CityEngine is too reliant on preset road and block conditions and influenced heavily by city development and infrastructure. Although it is capable of generating associative and parametric simulation models, the models are mainly based on city form, buildings and only simple ideas of the landscape.

In its current form, there are concerns about the limits of the technology in generating valid urban forms, as well as the massive quantities of data and complex algorithms required to improve the plausible technological responses to the queries and variables. These concerns are further compounded when taking into consideration the landscape as an open system complicated by "projections of urban growth [and] how wildlife habitats would respond to alterations in urban infrastructure. In these instances the need to harmonize data from a wide variety of databases is [increasingly demanding in both monetary and time cost]" (Wang, 365)

CityEngine is incapable of first considering the preexisting ecological processes or the complexity of the open systems involved within a site. Therefore it does not get any closer to realizing a way in which my understanding of landscape (where landscapes and urban infrastructures are impermanent complex open systems) can be represented or simulated. As the technology continues to develop, it should begin to incorporate more aspects of the landscape such as wind patterns, animal networks, soil strata and precipitation in order for the program to reach its potential of dealing with issues related to a more open notion of landscape architecture. As computer coding and the inner workings of programs becomes more main stream, the development and value of this program to the profession of landscape design may be able to grow exponentially as there would be a reduce time cost, but it will depend significantly on the data which is able to be collected and imported into the system.

Throughout the exploration, it has been uncovered that the completeness of data is an issue in two ways. The first is that the metadata datasets available in Canada are largely incomplete compared to the large American cities. This results in the incompatibility of certain rules and sequences written in CityEngine to be able to operate. The second issue is that for the most part, the metadata datasets which have been researched, calculated and imported are largely to do with building and civil infrastructures and not landscape infrastructures or features.

This program could prove to be a very useful tool provided the metadata dataset can be built up to include a number of environmental factors. The possibility of collecting trees (including their height, caliper, canopy width and height, age, and health), soil (type, health and saturation levels), animals (habitats and individual counts), as well as sun, wind and precipitation levels is demanding in time and monetary cost in both the initial collection as well as the continuous maintenance.

The costs required to collect and maintain the data would need to be weighed against the data's importance in site development. An understanding of the site prior to starting any design or development is irrefutable however, many designers visit a site only a handful of times prior to creating a design response and do not ever come close to being able to fathom how the site exists contextually in time and space.

An overall data collection and continuous maintenance of the landscape metadata across a city or region would allow for a more informative contextual understanding of a site. If a case could be made to all of the industry leaders that this is an important aspect of design and development – to understand a sites significance as a part of a larger open system in terms of both space and time - then perhaps the cost for the data collection and maintenance could be covered. If the industry leaders do not buy into the importance of this dataset, it becomes much more difficult to cover the cost of the maintenance required to have a usable dataset.

Provided the dataset is conceivable, its influence within CityEngine as part of a design and development simulation framework could have exponentially improved impacts on the design solutions as the associative variables would be able to inform the designer where the best possible scenarios would be to cut and fill, or to install buildings, or where it would be conceivable to alter habitat.
Until such time that these types of data can be collected and maintained, CityEngine is more useful for urban design and land development and does not really have the capability for influencing landscape design. It may not become possible or cost effective to develop a database which discusses these landscape infrastructures and features in order to make this tool useful to landscape design.

The accuracy and the spontaneity of the replication is an issue within CityEngine. As landscapes are a part of an open network with multiple variables impacting it, the accuracy of the replication is always going to be skewed as it is impossible to conceive of all of the factors that come into play on a particular site. With the number of factors that are conceived and incorporated into the generated rules and therefor parametric variables, it is nearly impossible to create the identical simulation twice. As the program is built on associative technology and mathematical algorithms, apects of the design cannot be completely controlled by the designer. As CityEngine uses parametric mathematics to assist with the simulations, the aesthetic nature that comes from lived experience cannot be developed through the program and must be incorporated through hand drawings, computer aided drafting and other, more traditional design tools after the initial design framework is created by CityEngine.

The time cost associated with the learning of a new computer code is incredibly high and technology is always advancing. Once this computer coding and the overall program is understood completely it is conceivable that the program will have expanded and been redeveloped making this particular version unusable. It is also conceivable that as the technological age advances, students and designers become more inclined to understand code prior to receiving their design education and the time costs associated with learning the new language of computer code are significantly reduced.

Currently there are a number of possibilities which may come in the advancement of technology in the profession and there are also a number of unknowns. It becomes imperative that we continue to attempt to understand the technological advancements available to the profession in order to increase the possibilities in design.

CityEngine – in its current form - is recommended as a tool for design development in the initial framework stages at a neighbourhood level. It should be incorporated as a simulation model to pattern rapid iterative design responses. It should not be used for final design responses but rather to setup the design frameworks which can then be further developed through more traditional design tools. CityEngine should not be used for regional scaled work as the vast amount of three dimensional visual data becomes too over whelming for most computers and crashes the system. At a streetscape or single site scale, the amount of time required - to write a detailed enough response to the particular site and situation with capable of generating an aesthetic design response; or being livable - would be too costly.

Although this practicum has been a substantial undertaking, I am pleased with the understanding I have gained both in the program itself as well as the understanding of what is required to learn a new technology in its infancy. I continue to believe that new technologies should be incorporated into practice if they have a conceivable opportunity to improve design responses to be more of an open system framework and less a final product.

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