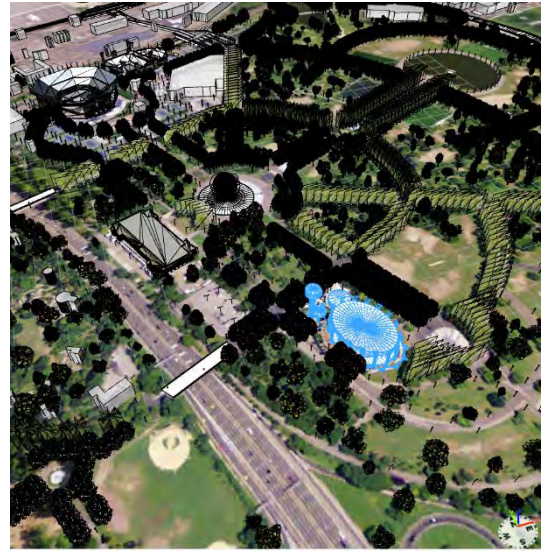


Grant Number: P14AP00278

Project title:

**Visualizing the Past, Present, and Future of New York City's 1964-5 World's Fair Site
Using 3D GIS and Procedural Modeling**



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June 18 2017

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Executive Summary

The National Parks Service awarded faculty in Cornell University's Department of City and Regional with a grant to explore the potential for 4D geographic information systems (GIS) modeling to support historic preservation professionals in the context of an important cultural landscape and municipal park. (The term 4D refers to 3D modeling plus the incorporation of the ability to visualize and analyze change over time.)

Flushing Meadows Corona Park, which is located in the Borough of Queens in New York City, was the site of our investigations. Over the years, steps have been taken to preserve and revitalize this important park. However, substantial questions remain about how best to steward the park's historical assets and cultural landscapes. Its complexity and richness makes the park a particularly useful place to test the capabilities of 4D GIS technology to inform historic preservation and planning efforts. The particular software used by Cornell faculty, graduate and undergraduate students, and staff to model geographic, architectural and landscape information and potential scenarios for the future for Flushing Meadows Corona Park was ESRI's CityEngine.

The outcomes of this research included 3D scenes of the park that are now available online on a research blog.¹ These 'webscenes' include depictions of past, present and future conditions. In the process of creating these scenes, GIS and 3D datasets were collected and compiled in new ways. New 3D models and spatial datasets were also generated by the research team and are available from the research blog or by request from Principle Investigators. Perhaps most valuable in this process was the articulation of specific use case, in which 4D technology may enhance the preservation planning process. We also scanned the landscape of available 3D and GIS tools to understand the relative strengths and weakness of CityEngine. Finally, we proposed specific requirements and desired functionalities for software that would better support cultural landscape preservation efforts.

This report also details our research methods and summarizes our insights into the future of 4D GIS in the practice of preservation planning. We found substantial limitations to the current version of CityEngine as a 4D GIS, and hope to encourage further technological development that can unite architectural and geographical scales, as well as temporal change, to serve interdisciplinary needs of the field of preservation in planning for cultural landscapes and historic districts.

This grant also resulted in the publication of several peer-reviewed publications and a research blog called [A World's Fair Landscape in Time](#). We encourage the reader to review those available materials as well.

¹ See [A World's Fair Landscape in Time](#) at <http://blogs.cornell.edu/3dgis/>.

Introduction

This research began with the premise that 3D geographic information systems (GIS) and even 4D GIS (3D visualization with an added time dimension) could afford benefits for preservation efforts within cultural landscapes and historic districts. This research details the potential for 4D GIS modeling to support historic preservation professionals in the quest to better understanding landscape change and to analyze preservation alternatives in the stewardship of large-scale sites. Faculty, graduate and undergraduate students, and staff at Cornell University, and a high school student from Lehman Alternative Community School, were involved as a research team in exploring and documenting an important cultural landscape – Flushing Meadows Corona Park - in the field as well as in digital space.

Flushing Meadows Corona Park is located in the Borough of Queens in New York City. Now, a municipal park, it has undergone enormous change from inhabitation by indigenous people prior to European settlement in the 17th century, to infamous dump site, to the location of two world's fairs in 1939-40 and 1964-65, and as a municipal park and location of notable sports stadia. Despite these dramatic changes, the past remains embedded in the park's landscapes. Artifacts left over from the fairs include the park's infrastructure, former pavilions, public art, pathways, and fountains. Over the years, steps have been taken to preserve and revitalize this important park. However, substantial questions remain about how best to steward the park's historical assets and cultural landscapes—and its continued public recreational use. This complexity and richness, as well as the importance of the park to the city and to the history of modern architecture and planning, makes it a particularly useful place to test the capabilities of 4D GIS technology to inform historic preservation and park-planning efforts. The research team examined, tested, and documented various 3D and GIS platforms, but focused mainly on CityEngine, a procedural modeling tool that can be used to produce scenes using specified rules.

Results of this research suggest that a 4D GIS platform could substantially benefit the preservation of cultural landscapes and historic districts. These benefits might include the enhanced analysis of historical integrity and landscape change by 3D visualization, the ability to collect and integrate multiple forms of data, and query and analysis capabilities to evaluate change through time. However, we also find that more technological development is needed if architectural and geographic data is to serve preservation needs holistically.

There are still substantial gaps between the architectural and geographic tools that are available (e.g. as represented in CityEngine and other available software) and what is needed more fully to bridge disciplines and scales ranging from character-defining features on buildings and in landscapes, to data that encompasses a whole landscape or district. At the conclusion of this paper, we suggest ways in which technology could be developed to serve better the needs of preservation professionals, parks officials, and the public.

The Use of 3D and 4D GIS in Historic Preservation

Geographic information systems (GIS) are increasingly used in preservation practice. Applications range from analytical and predictive techniques to identify cultural resources (Bertron, 2013), to web-based GIS tools for heritage inventory (J. Paul Getty Trust and World Monuments Fund., 2017), to rapid survey and online public engagement in Los Angeles’s city-scale comprehensive survey effort (Berstein & Hansen, 2016), and the development of a participatory GIS web tool in Austin, Texas (City of Austin and University of Texas at Austin, 2017; Minner, Holleran, Roberts, & Conrad, 2015). These innovations illustrate the value of GIS and its growing importance to preservation practice

Meanwhile, advances in laser measurement of cultural resources support the production of increasingly detailed 3D building models (CyArk, 2013; Hughes & Loudon, 2005; Tyler, 2015; Haddad, 2011; English Heritage, 2011). Engineers and architects use Building Information Modeling (BIM) software to combine 3D modeling with detailed analysis related to life cycle and energy usage (Minner & Chusid, 2016). The development of online 3D platforms and tools, such as Google Earth, support a growing and globally distributed network of users who generate and share 3D images of buildings and structures.

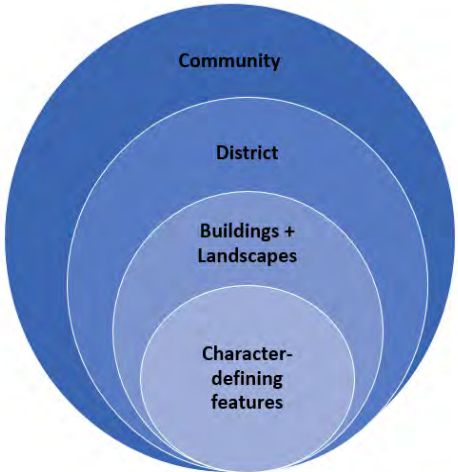
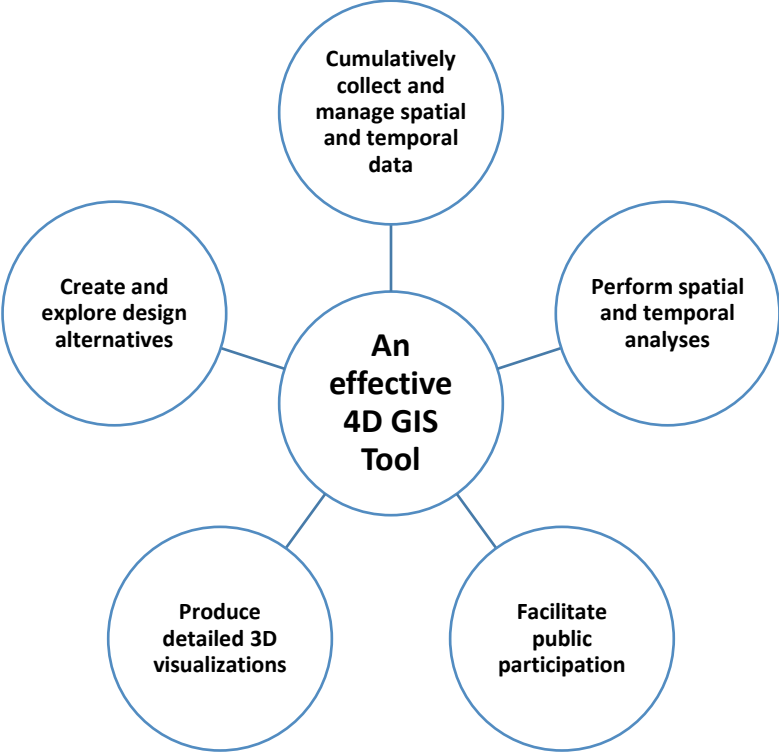
These areas of innovation—2D GIS and 3D modeling—remain largely separate areas of technological advancement in heritage conservation. However, governments and institutions around the world are beginning to integrate 3D GIS for planning and preservation purposes. Examples include Auckland’s development of a Unitary Plan (Eagle Technology, 2013), analysis of infill development in Portsmouth, New Hampshire’s historic downtown (Minner & Chusid, 2016), Honolulu’s modeling of transit-oriented development (Carlisle, Schmidt, & Contreras, 2017), and the University of Rochester’s use of 3D for campus planning (ESRI, 2011). In addition, there is an expanding literature on geodesign, which focuses on the use of GIS tools for design purposes (Minner, 2017).



Preservation practice at the landscape or district scale involves multiple domains of architectural, geographic, and historical knowledge, data, and methods.

The aim of our research was to examine the potential use of 3D and 4D GIS for preservation practice. Preservation planning involves an increasingly diverse set of practices that bridge data and methods associated with allied design fields, planning and geography, and history. This is especially the case in the management of cultural landscapes and historic districts, where preservationists must take into account many different aspects of landscape elements as well as change over time. At the scale of district or landscape, preservationists and planners need the ability to develop, visualize, and analyze alternative preservation and design scenarios.

Thus, 4D GIS modeling tools could contribute to multiple advancements in the planning process. For instance, spatial and temporal data could be collected and stored cumulatively. A 4D GIS tool could provide the ability to analyze spatial data. It could lead to better visualization both spatially and temporally. It could help to facilitate public participation, or as discussed later in this report, allow citizens to contribute models that could be added to the collection of data. It could provide the ability to create and explore design alternatives. In other words, a robust tool for preservation planning could provide the user with the ability to test designs, to perform analysis, and to engage the public with information about the past, present, and possible futures.



Integration across multiple scales is desirable for preservation in cultural landscapes, historic districts, or communities.

Another desired aspect of a 4D GIS tool for preservation planning, is the ability to store, analyze and design at multiple, integrated scales. These are nested scales from the individual character-defining feature of a building or landscape, to the scale of buildings to whole districts and to the community as a whole.

Organization of this Report

The next section provides an overview of different kinds of 3D modeling approaches from physical models to design-based models. A following section describes 3D and GIS tools for comparison with CityEngine, which was the primary software package that the research team evaluated

for its potential as a 4D GIS tool. Next is a description of use cases employed in the creation of 4D models. Detailed descriptions of the process of creating the models follow. A Results section focuses on resulting 3D models and an evaluation of CityEngine as a 4D GIS tool. Conclusions and recommendations follow. Appendices include a list of related websites, publication and presentations (Appendix A) and an additional table listing technical details and observations of 3D and GIS applications (Appendix B).

An Array of 3D Modeling Techniques

Many world's fair and city officials, and scholars have studied the landscape of Flushing Meadows Corona Park over the years and replicated its landscapes in miniature. These studies include multiple 3D modeling efforts ranging from the creation of physical models built of wood and plastic to animation that places representations of world's fair pavilions in a game environment. The simulation of actual landscapes, past and present, has served a variety of functions, from instilling awe and entertainment, to public education, to planning, preservation, and design.

Physical Models

The photograph below is of the Panorama of the City of New York, which was constructed prior to the 1964-65 world's fair and updated in 1992 (Queens Museum, 2017). The panorama illustrates major limitation of physical models, which is the necessity to physically and permanently change the models to represent different points in time. The physical model has no embedded record of the change and the viewer cannot return to views of an earlier landscape, as one can using digital tools.



Panorama of New York. Photo credit: [Chris Devers on Flickr](#) (CC).

Prior to the opening of both the 1939-40 and 1964-65 world's fairs, large physical models were created by fair officials for planning purposes. The 3D models were created as a method of visualizing fair pavilions as they were being designed and constructed.

3D Game Environments

The Queens Museum also houses another 3D model – this time digital. The Chronoleap interactive game allows visitors to step onto a mat that represents a map of the 1964-65 world’s fair. A monitor allows the visitor to “leap” into history, or at least view on the monitor above, a 3D rendering of a scene from the 1964 world’s fair. [A video on the project’s research blog](#) website shows the display for the former General Electric Pavilion (Minner, 2017)



Lori Walters, a faculty researcher at the University of Central Florida, produced the game. She has been using the software packages Maya and Unity to create games for teaching youth Science Technology Engineering and Mathematics (STEM) skills by encouraging them to engage with the history of the 1964-65 world’s fair. Dr. Walters has also been experimenting with 3D laser-scanning, which produces point-clouds that can capture existing conditions of the New York State Pavilion in high relief.

Recent movies such as *Tomorrowland* and *Iron Man 2* also used sophisticated techniques to generate a 3D world’s fair landscape as a backdrop.

Free Online Web Tools

World’s fair and sports enthusiasts have modeled buildings and other elements of the landscape at Flushing Meadows Corona using Sketchup. As a result there are a substantial number of 3D models of former and current

landscape features and buildings that have been saved online and publicly shared on the 3D Warehouse site at <https://3dwarehouse.sketchup.com> (3D Warehouse, 2017). These models can be downloaded and viewed in Google Earth as well as in other 3D software packages.

Preservation and Design Tools

Another set of 3D modeling tools commonly used for design and preservation purposes enable a user to create, maintain and share information to aid in the creation of a plan for action. This set of tools includes both architectural and geographic tools. Some of these tools have been used at Flushing Meadows for large-scale construction projects. They also may have been used in a recent competition to envision new uses for the New York State Pavilion from the 1964 world’s fair. In the next section, we describe some of the 3D and GIS tools particularly useful in the generation of digital models.

A Scan of 3D Modeling and GIS Applications for Design

The research team’s evaluation of available 3D and GIS tools for preservation and design paid particular attention to the scale at which they operate and their advantages and limitations. Four tables in this report provide an overview. The tables were created for comparing CityEngine to other software.

Table 1. 3D and GIS Tools: Scales and Users

Application	Scale	Users
Autocad	Individual Building, Architectural Scale	Architects, Engineers, Designers
Revit (BIM)	Individual Building, Architectural Scale	Architects, Engineers, Designers
Rhino 3D	Individual Building, Architectural Scale, other scales	Architects, Engineers, Designers
ArcGIS 10.3	Greater than Building Scale, Geographic	Planners, Geographers
ArcGlobe	>Building, Geographic, for display over large area	Planners, Geographers
ArcScene	>Building, Geographic for display on smaller area that has greater detail	Planners, Geographers
ArcGIS Pro	>Building, Geographic	Planners, Geographers
Open Source GIS	>Building, Geographic	Planners, Geographers
Tygron	>Building, Geographic	Planners
CityEngine	>Building, Geographic	Movie Industry, Planners
Unity	Any scale, Geographic “scenes”	Game Developers, some planners
Maya	Any scale	Movie Industry, Graphic Designers
3D Max	Any scale	Movie Industry, Graphic Designers
Sketchup	Individual Building, Architectural	Public, Architects, Planners
Minecraft	Districts	Kids and other enthusiasts

In investigating available 3D and GIS tools, we identified different packages associated with various scales and particular user groups. The tools in grey in the table below represent tools used for modeling an individual building and are used primarily by architects, engineers, and other designers. The tools in blue are primarily used by planners and geographers and are typically used at a scale greater than an individual building. The 3D tools in yellow are primarily used by game developers

and professionals in the movie industry, although there are some examples of the use of Unity by planners. We perceived CityEngine as having similarities to the tools used at a geographic scale used by planners and geographers, as well as the platforms coded in yellow. Therefore, CityEngine is highlighted as Green on the table. Finally, the tools in purple are 3D tools that are commonly used by the public. Although Minecraft is a game that is primarily used by youth and game enthusiasts, it is included as an example of a 3D tool that has engaged new populations in preservation and planning.

Table 2 provides a brief description of each tool as well as information about primary scale of use and user groups. Table 3 discusses the strengths, limitations, and uses of each of the software packages in historic preservation. Table 4 is in Appendix B and includes additional technical information about interoperability, creating topography, and opportunities for crowdsourcing efforts.

More about CityEngine

The primary software studied in this research project was CityEngine, which has been described as both a 3D GIS tool and a procedural modeling tool. Procedural modeling involves the ability to create rules using a specialized computer language called “CGA shape grammar.” Within the computer program, these rules can be applied at different scales, from the building, to a street or block, to an entire model city. For instance, rules applied to a single building can specify building materials, fenestration, and other aspects of a building façade. Another set of rules could be applied to the city scale to randomly generate future buildings according to zoning regulations. Rules can also be used to generate landscape features such as a single tree or random vegetation within a specified area.

CGA rules can also make aspects of a 3D scene interactive. For instance, buildings set as “dynamic” enable a graphic interface of sliders, toggles, and text entry areas so that changes can be made on the fly. However, these features are accessible only on the desktop version and must be viewed on a machine that has CityEngine installed.

At the outset of the research project, we hoped CityEngine would prove to be a robust tool for collecting, storing, and displaying geographic and architectural information. Flushing Meadows Corona Park and the former world’s fair landscapes are well documented from a variety of sources. In order to bring together this vast array of information from multiple sources that ranged from online, crowdsourced contributors of 3D models, to archival documents, to geodatabases produced by planning consultants and the parks department, multiple software platforms were used in concert with CityEngine.

Several of the tools (e.g. ArcGIS 10.3, AutoCAD, Revit, Rhino, Maya, and Sketchup) were used in conjunction with CityEngine to create 3D models for this research project. Research assistants tested the interoperability of 3D models produced in these software applications with CityEngine. Some of the other software applications were used to complete scenes.

Table 2: Basic information about commonly used 3D and GIS applications

Application	License	Description	Type/Level of Expertise Required to operate	Best Scale(s) for this software	Primary Users
CityEngine	Commercial	CityEngine allows users to generate 3D models of cities using "procedural modeling." This is the creation of buildings, streets, and other landscape features using procedures or rules. NOTE: Works on PC and MAC (unlike ArcGIS, which must be run on a Windows operating system and is also an ESRI product)	Can be intimidating to users who are not familiar with using other 3D modeling software. It helps for the operator to have basic scripting tools.	Best used at the district scale. Many deployments show a downtown district. Probably most immediately useful scale/use is creating a scenario for a new development from scratch, especially where all new development and those developments are standardized with common components (e.g. a new district of vertical mixed use buildings).	Still fairly new, does not seem like it has established a regular community of users. Has been used by some planners and also originated in the movie industry.
AutoCAD	Commercial	This is a widely used Computer Assisted Drawing (CAD) program. It is used in a range of professions and applications for 2D drafts/diagrams and 3D models. Noted among architects for its usefulness in organizing information within diagrams and drawings in the form of various layers.	Beginners can navigate the software to create 2D and basic 3D models and diagrams Expertise in a given field and extensive practice with the program is necessary to fully utilize it to create detailed schematics and 3D models.	Good at very detailed depictions of individual buildings Often used for measured drawings and floorplans including interior diagrams Can accurately model small details to scale Detailed 3D models of small objects and features	Civil engineers, architects, graphic designers, mechanical engineers, drafters

Table 2: Basic information about commonly used 3D and GIS applications

Application	License	Description	Type/Level of Expertise Required to operate	Best Scale(s) for this software	Primary Users
ArcGIS 10.3	Commercial	The ArcGIS suite is one of the most widely used sets of GIS tools available. The ArcGIS suite consists of an assortment of apps that each handle various tasks associated with mapping and processing data on large geographic scales. With a wide assortment of tools, ArcGIS has found a diverse audience in a large assortment of fields with users ranging from the curious everyday citizen to highly involved professionals. The use of its geodatabase allows large ArcGIS projects that utilize different file types and features to be stored in a single location. This allows for compatibility between features that each have their own file types.	<p>The level of expertise required in ArcGIS depends on what the user is seeking to accomplish. For the everyday person interacting with ArcGIS it is important to be able to read and interpret data as one of the greatest strengths of the program is its applications in data analytics.</p> <p>As projects become more involved they are often facilitated by those with more experience with GIS programs and specialization or training in a given field or application.</p>	<p>Best suited for geographic scales above the size of building</p> <p>Little ability to model smaller scales such as buildings, individual details or individual objects</p>	<p>Planners, geographers, environmentalists, local government use for planning, managing property data, and managing infrastructure</p> <p>Businesses; Asset management</p> <p>Utilities and Communications; Gas, electric and water companies utilize ArcGIS to monitor their infrastructure</p> <p>Environmentalists</p>

Table 2: Basic information about commonly used 3D and GIS applications

Application	License	Description	Type/Level of Expertise Required to operate	Best Scale(s) for this software	Primary Users
ArcGlobe	Commercial	A part of the ArcGIS 3D Analysis extension that displays 3D representations of data on a preexisting model globe. The globe is constructed from data collected by ESRI and input by users. As such it is more of an interactive program than one in which users create their own models and maps. Because of its global scale, ArcGlobe can process, analyze and display a very large volume of GIS data. Users can pan in and out of specific locations for further analysis and data collection.	<p>The main purpose of ArcGlobe is to serve as a powerful tool to analyze data. There is not much training or expertise necessary to use the tools of ArcGlobe, if the user is familiar with ArcGIS. Can readily create animations and models.</p> <p>As ArcGlobe is tightly integrated with the rest of the ArcGIS suite, familiarity with ArcGIS is helpful</p> <p>Familiarity with navigating raster and vector data is useful</p>	Best suited for huge scales, such as the global scale. However, it is also useful at smaller scales and can provide data at the street level.	Planners and geographers; local government use for planning, managing property data, and managing infrastructure
ArcScene	Commercial	A part of the ArcGIS 3D Analysis extension that allows users to create 'scenes' or 3D representations of a particular set of data. In doing so users can create maps and renditions with more detail and individual user input.	<p>Familiarity and practice with ArcScene is necessary to produce base maps and to properly upload data as layers as well as to manage the various layers.</p> <p>As many of the 3D tools utilized in ArcScene are universal across the ArcGIS suite, familiarity with ArcGIS and associated programs will help users more comfortably navigate and render their projects in ArcScene.</p>	<p>Condensed areas with a mixture of data types.</p> <p>The total land mass that may be modeled in ArcScene is dependent on the volume of data that is being imported into the project</p>	Planners and geographers; local government use for planning, managing property data, and managing infrastructure

Table 2: Basic information about commonly used 3D and GIS applications

Application	License	Description	Type/Level of Expertise Required to operate	Best Scale(s) for this software	Primary Users
ArcGIS Pro	Commercial	ArcGIS Pro is an ESRI product that was recently added to ArcGIS suite of apps. The new application brings together the ability to display 2D and 3D GIS data and to publish it using the web platform ArcGIS Online.	Recommended to have proficiency with ArcGIS.	Best suited for geographic scales above the size of building Little ability to model smaller scales such as buildings, individual details or individual objects. There are limitations as to the number of features that can be included when uploaded to ArcGIS Online.	Planners and geographers; local government use for planning
Google Earth	Freemium Google Earth Pro is intended for commercial use, unsure if open source	Not 3D package per se, but able to view and share 3D models created using Sketchup	Little to no prior experience is necessary to operate the software For certain uses experience with other software is useful, such as experience with GIS programs	Suitable for nearly any scale. But mostly geographic	Public, Planners Widely used in a variety of applications i.e. -emergency rescue relief -education -geographic studies
Maya	Commercial	Computer animation software for 3D modeling, simulation and rendering.	Maya is difficult to master and requires extensive practice and familiarity with the software.	Can be used to create nearly anything, however even small models of individual objects may require several people and a large time investment -size, level of detail, and complexity of the project determine the time and difficulty of the project	Animators, Graphic Artists, Game Designers

Table 2: Basic information about commonly used 3D and GIS applications

Application	License	Description	Type/Level of Expertise Required to operate	Best Scale(s) for this software	Primary Users
Revit (BIM)	Commercial	Software created for BIM (Building Information Modeling) that is most often used to draft buildings and track progress on active projects. Most suited for smaller residential buildings but is also effective at modeling larger buildings and sites	Training and practice are necessary to operate the software effectively, however the learning curve is not quite as steep as more complex CAD programs	Individual buildings	Architects, engineers, designers, contractors
Rhinoceros 3D (Rhino)	Commercial	Commercial 3D computer graphics and CAD	Similar to most CAD programs, familiarity with CAD will make it easier to learn Rhino -mastering Rhino is difficult due to the nature of the program with most users seeking to render complex curved surfaces and shapes	There is no set scale for Rhino, however, like most CAD programs the scale and detail of the project determines the time and effort required for completion	Architects, engineers, designers (product, graphic and industrial)
Sketchup	Freemium	3D modeling program that can be used for modeling individual objects and buildings.	Known for its user friendly interface and accessibility to beginners, Sketchup is the preferred software for amateur 3D modelers	Best suited for smaller scales such as the individual building scale and smaller Also regularly used to create models of individual features such as windows and doors	Public, Planners
Tygron Engine	Commercial	'Serious gaming' platform that can read GIS files to make simulated 3D environment. The main purpose of this application is to create serious games to aid in public education and discourse, not detailed 3D models.	Not fully evaluated.	District or community scale.	Planners

Table 2: Basic information about commonly used 3D and GIS applications

Application	License	Description	Type/Level of Expertise Required to operate	Best Scale(s) for this software	Primary Users
Unity	Commercial	3D game engine	Unity is favored among beginners in game design and development due to its compatibility with multiple common programming languages. However, the necessity for prior coding knowledge and a general sense for game development make it less accessible to the general public	Suitable for any scale, but is not expressly a 3D modeling software, but a game development platform	Game Developers
3ds Max	Commercial	A part of the Autodesk Suite of tools, used primarily in the creation of 3d models and animations.	3ds Max is widely used by professionals and has a substantial learning curve.	Large range of possibilities, from small models to huge cityscapes, from short animations blending into full feature films	Professional animators, Game developers
Minecraft	Commercial	A 3D game spanning multiple platforms (phones, consoles, computers) where users can hand craft objects and landscapes with 3d cubes (one cube at a time) as well as utilize various map building software packages	Beginners can easily utilize Autodesk's tinkercad to create 3D objects. These can then be directly exported to a Minecraft .schematic file.	Large scale type projects, a Minecraft building block is 1m ³ (one meter cubed) so intimate detail is unobtainable.	Kids, Gamers

Table 3. Software Strengths, Limitations, and Uses in Historic Preservation

Application	Strengths	Primary Limitations	Applications in historic preservation and heritage conservation
CityEngine	<p>Procedural modeling - ability to generate large areas using rules. Can apply textures using rules. Can construct a cityscape using a set of rules where do not have precise information about buildings</p> <p>Creating simple in-house 3D renders of buildings. Simple textures are available to add details</p>	<p>Memory limitations on size of exported web-scenes</p> <p>Memory limitations on the system the program is being run on, even more so than CAD or large 3D models and animations, CityEngine files are typically huge and systems may not be able to process them</p> <p>More description of Strengths and Limitations in Use Cases and in results section of this report.</p>	<p>CGA rules have been used to "recreate" ancient Roman cities by generating likely column and roof types on buildings whose actual historic form and construction are unknown (Saldana, 2014)</p> <p>ESRI features a use case of procedural modeling to enable the public to experience ancient Pompeii (ESRI, 2017).</p>
AutoCad	<p>Drafting</p> <p>2D Drafts</p> <p>Editing, and circulation of drawings and designs</p> <p>Strengths in editing are attributed to features such as layers, styles, blocks, and sheets</p> <p>One of, if not the most widely used CAD software</p> <p>Accessibility and popularity among professionals</p> <p>Versatile</p>	<p>Expensive updates are constantly being released with features that are difficult to master or that create functionality problems within the software adding further complexity to the program</p> <p>Almost exclusively used in professional or educational environments, not user friendly for the everyday user</p> <p>Because of the wide number of uses across various industries the tools and programs aren't specifically tailored to any one use or profession</p>	<p>AutoCAD is often used in models and renditions of historic sites to recreate what the building, room, or feature may have originally appeared or may appear after refurbishment. In such instances AutoCAD is used to draw the underlying skeleton with basic lines which are then exported to other programs to create the final rendition.</p>
ArcGIS 10.3	<p>Creating and manipulating maps of different scales</p> <p>Compiling and organizing 'field' data. Field data here means any</p>	<p>Software and extensions are pricey and while the geodatabase is convenient for storing information within ArcGIS it can lead to inconvenience when working with other programs.</p>	<p>ArcGIS has many applications in preservation and conservation. 3D maps can be used to survey existing historic districts and to create datasets representing economic activity and pedestrian traffic in mapped areas. Conversely datasets can be made to represent adverse</p>

Table 3. Software Strengths, Limitations, and Uses in Historic Preservation

Application	Strengths	Primary Limitations	Applications in historic preservation and heritage conservation
	<p>information collected outside a conventional office setting</p> <p>Compiled information can easily be integrated onto relevant maps to create models demonstrating the effects the input data may have on a corresponding environment</p> <p>Compilation, organization, and analysis of big data</p> <p>Sharing information</p> <p>Finding and analyzing data patterns</p> <p>3D mapping at larger scales that require less individual details</p> <p>3D data analytics</p> <p>Topographic modeling and analysis</p>	<p>While ArcGIS 10.3 has features that allow for easier import of CAD produced 3D models it is still limited in its ability to draft in 3D within the program itself.</p>	<p>effects on historic districts due to activity in surrounding areas. These datasets and maps may also be used to predict the changes created by investments in historic districts.</p>
ArcGlobe	<p>Visualizing and interpreting GIS data on a very large scale</p> <p>Data collected and used on a smaller scale GIS program, e.g. ArcGIS can be exported to ArcGlobe to assess the same data on a global scale</p> <p>3D animations representing data based on GIS datasets</p> <p>Handling very large data sets</p> <p>Rendering raster and vector data of all resolutions</p>	<p>ArcGlobe is directly tied to ArcGIS and as such has limited compatibility with programs outside of the ArcGIS suite.</p> <p>Single elevation surface prevents users from viewing and analyzing below surface data</p> <p>Completely reliant on data input to create displays</p>	<p>There is limited documentation about ArcGlobe for use in historic preservation or heritage conservation as most sites are on a scale more appropriate for ArcGIS or other programs.</p> <p>ArcGlobe may be used in preservation and conservation in much the same manner as ArcGIS.</p>

Table 3. Software Strengths, Limitations, and Uses in Historic Preservation

Application	Strengths	Primary Limitations	Applications in historic preservation and heritage conservation
ArcScene	<p>Creating 3D scenes of specific locations</p> <p>Can represent multiple layers of depth from the sky above the scene to underground infrastructure</p> <p>Layers are also utilized to render different classes of data which may then be stacked in multiple ways to provide varying perspectives for analysis.</p> <p>Best suited for data analysis</p> <p>Rendering subsurface data and volume</p>	<p>Memory limitations put restraints on the size of the 3D scene</p> <p>Memory limitations also affect the size of imported data</p>	<p>Has been used in historic preservation efforts. See (Richardson, Alario, & Gravatt, 2009)</p>
ArcGIS Pro	<p>Can bring together 2D and 3D GIS data and prepare it to be shared on ArcGIS Online.</p>	<p>Webscene from ArcGIS Pro to ArcGIS Online allows for no more than 2,000 features, which limits the amount of detail and scale of data shared online.</p> <p>Hard to display higher resolution terrain because of computing power,</p> <p>No direct georeferenced tool, have to do it in ArcGIS</p>	<p>Relatively new application. No specific uses identified.</p>

Table 3. Software Strengths, Limitations, and Uses in Historic Preservation

Application	Strengths	Primary Limitations	Applications in historic preservation and heritage conservation
Google Earth	<p>Google Earth images can serve as the foundation for many different projects</p> <p>Often the foundation of GIS based maps and models -Photos geotagged in Google Earth are particularly useful for ensuring accuracy in scale</p> <p>Compatibility with CAD is useful for creating realistic models as well as renders of projects to be completed in the future</p> <p>Flexible scale from global view to street view</p> <p>Comprehensive coverage of the globe</p> <p>Versatile</p>	<p>Limited analysis tools.</p>	<p>Historical Imagery function in Google Earth Pro displays older images of locations. However, "historical imagery" only goes as far back as about 2001 for most places.</p> <p>Google Earth and Sketchup have been promoted as tools to visualize infill and other kinds of change in historic districts and main streets (Morrison, 2010).</p> <p>The locations of properties on the National Register of Historic Places can also be downloaded from the National Parks Service as a .kmz and displayed in Google Earth (National Parks Service, 2017).</p>
Maya	<p>Detailed and realistic 3D models</p> <p>3D animations</p> <p>2D animations</p>	<p>Very difficult to use</p> <p>Primarily a tool for visualization, not for storage or retrieval of specific information (attributes) associated with 3D models.</p>	<p>There is a student thesis documenting the use of Maya. See (Yabe, 2014)</p>
Revit (BIM)	<p>Interactive' 3D models of buildings</p> <p>Models can be used to track buildings in various stages of development</p> <p>3D models can be annotated with 2D drafting elements</p> <p>Models can be paired with corresponding data</p> <p>Parametric constraints</p> <p>Scheduling and documentation</p> <p>Integrating design with engineering and drafting</p>	<p>Most often used to document buildings that have been detailed in other programs</p>	<p>Revit is becoming fairly common for architectural projects and can be used for planning construction and alternation associated with historic buildings and sites. The growing use of BIM and its potential in historic preservation practice is discussed in (Kapp, 2009)</p>

Table 3. Software Strengths, Limitations, and Uses in Historic Preservation

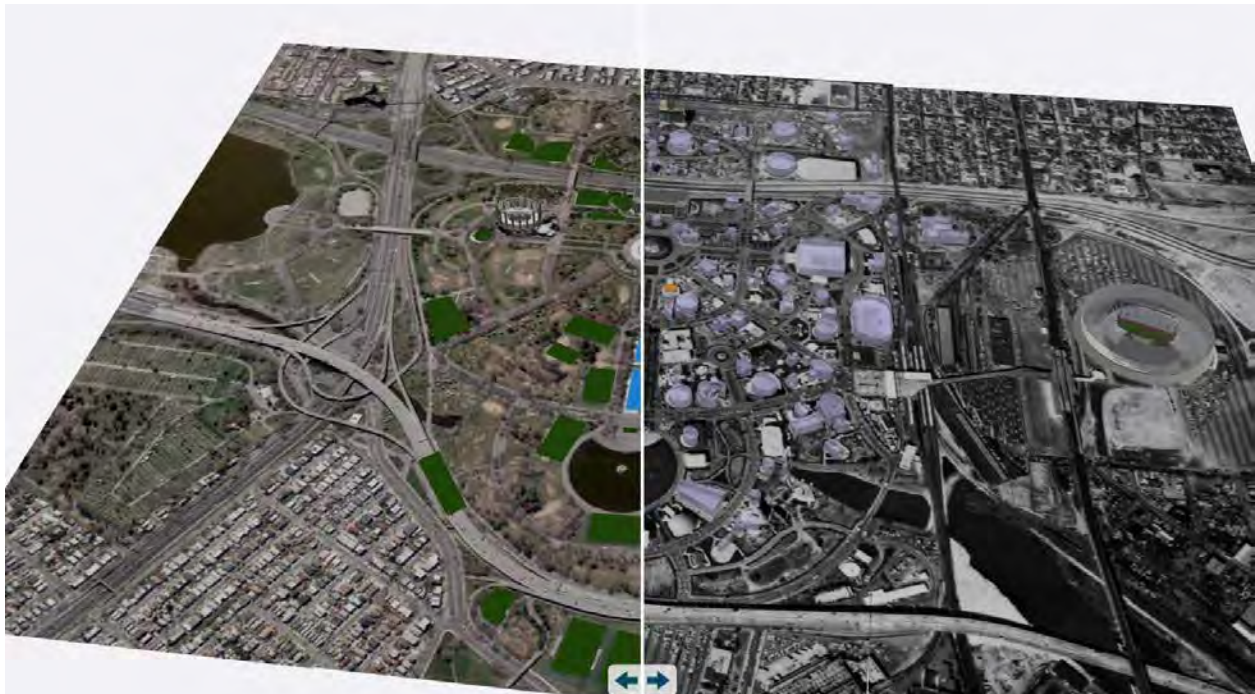
Application	Strengths	Primary Limitations	Applications in historic preservation and heritage conservation
Rhinoceros 3D (Rhino)	<ul style="list-style-type: none"> -Curves and free form surfaces -Detailed 3D models -Industrial and product design -Line work -Parametric design through Grasshopper -Powerful tools and plug-ins 	Not fully evaluated.	Examples of the use of Rhino in documenting historic building features was found and like Revit, its use in architecture and engineering have grown. See (Kapp, 2009).
Sketchup	<ul style="list-style-type: none"> -Free -Models can easily be integrated and placed into Google Earth -Easy to learn and use -3D Warehouse -An online open source library of free models generated by other users 	Primarily a tool for visualization, not for storage or retrieval of specific information (attributes) associated with 3D models.	Google Earth and Sketchup have been promoted as tools to visualize infill and other kinds of change in historic districts and main streets (Morrison, 2010).
Tygron Engine	Group problem solving Virtual decision simulations	<p>Is a serious gaming engine that allows for import of existing data.</p> <p>Does not support generation of very detailed buildings.</p>	No specific examples identified.
Unity	Supported on multiple gaming platforms	Primarily a tool for visualization, not for storage or retrieval of specific information (attributes) associated with 3D models.	<p>No specific examples identified.</p> <p>-3D gaming engines such as Unity can be used to create detailed 3D models and simulations of cities/sites/buildings, however such simulations would be limited to the designs set by the user</p>
3D Max	Detailed and realistic 3D models and animations.	<p>Learning curve is quite large</p> <p>Primarily a tool for visualization, not for storage or retrieval of specific information (attributes) associated with 3D models.</p>	Unknown
Minecraft	Supported on multiple platforms (perhaps more than any other game engine)	<p>Only a low level of detail is achievable.</p> <p>Primarily a tool for play, not for storage or retrieval of specific information (attributes) associated with 3D models.</p>	Minecraft has been used engage use with historic places. See (Israelsen & Pearson, 2013; Israelsen & Pearson, 2015) Also see blog posts on the National Trust for Historic Preservation’s site (Hower, 2017; Heffern, 2015)

Use Cases for 4D GIS at Flushing Meadows Corona Park

Use cases are employed in the development of new technologies and methods. The research team brainstormed the following use cases to describe potential preservation-related needs at Flushing Meadows Corona Park. The use cases illustrate the potential needs of historic preservation professionals and planners, how 4D GIS might aid in these scenarios, and how well CityEngine performed.

Creative Design and Time Exploration

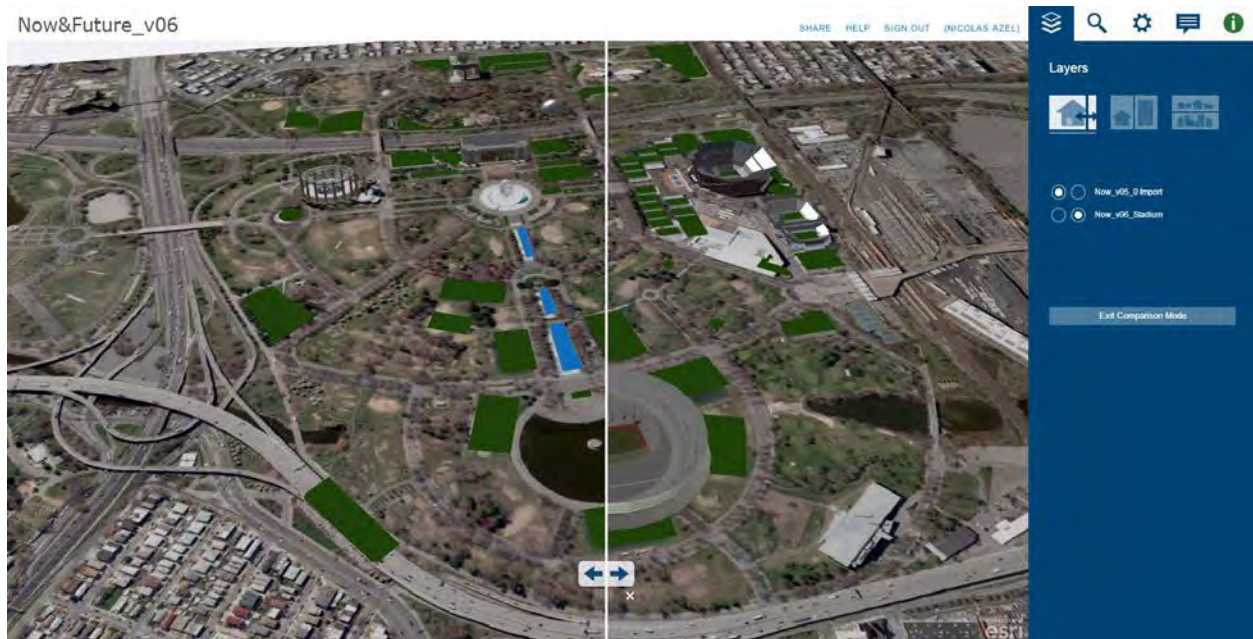
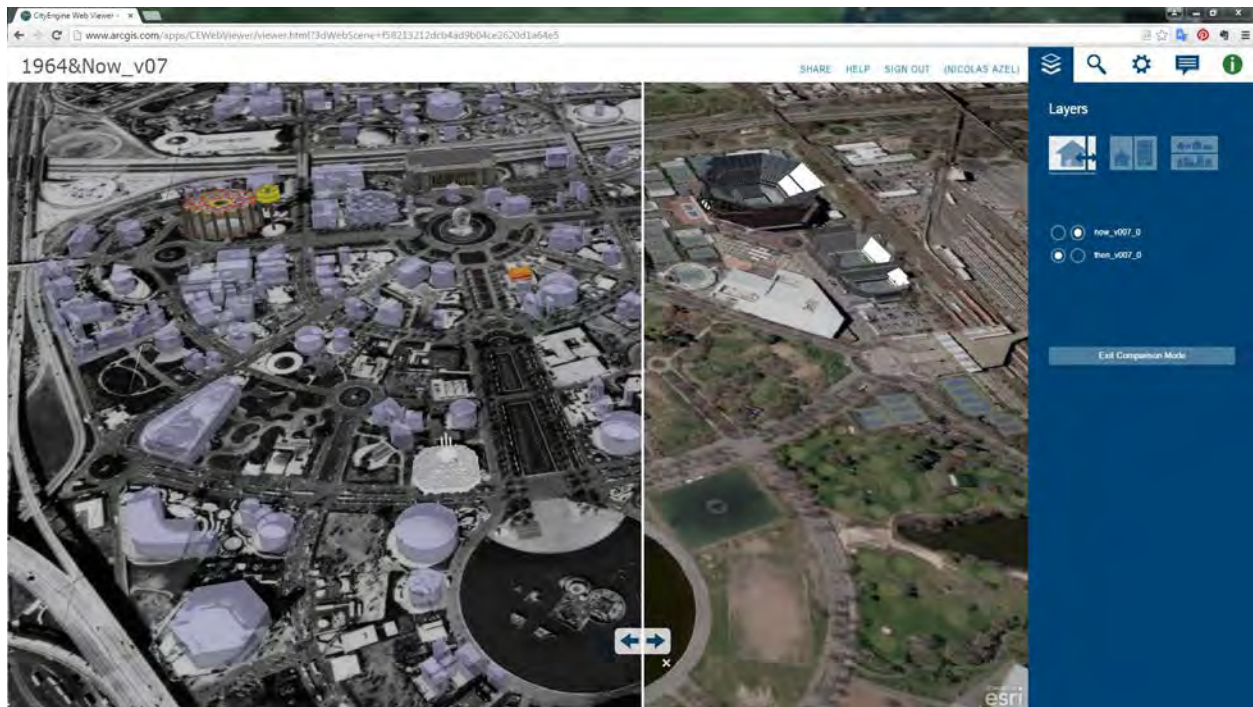
Whether for public education and interpretation of the site for the public, or the creative exploration of a site by a professional preservationist or designer, the ability to visualize change over time is essential. We envisioned preservationists and historians wanting to gather spatial information from a variety of formats in one place and then making comparisons between multiple time periods. We also envisioned members of the public wanting to conduct their own explorations of Flushing Meadows Corona Park, either out of their interest in history or to comment on proposed public interventions in and around the park.



This is a screenshot of a webscene that was created to allow the user to scroll back and forth between current and historical aeriels as well as 3D models.

Models of differing levels of specificity were developed in CityEngine. In early models, we were able to create and export 'webscenes' that allowed a user to slide back and forth between past and existing conditions. We also created models of future scenarios that could be compared to future scenarios. Webscenes allow anyone to view the models without specialized software other than a browser.

There were complications in both the production of webscenes and in their display. For instance, it took a substantial amount of work to successfully export scenes that were small and simple enough that they could be comfortably navigated. Very detailed scenes required large files, which slowed the performance of webscenes considerably. Below are screen shots from early in our research. As the models matured, the level of 3D landscape detail began to impact our options for time display.



As additional 3D landscape features such as benches and trees were added to CityEngine, we could no longer fully support the time-slider feature in webscenes. We found that it became increasingly

difficult for users to navigate them online. Depending on the browser a user selected to access a webscene, they might experience a long time for initial display, difficulties navigating, and error messages related either to the availability of WebGL (an online application that developers use to enable the display of 3D graphics in a web browser) or to a lack of sufficient memory.



Dropping the requirement for webscenes functionality, we began to experiment with the creation of new rules that would allow for representation of continuous landscape change rather than just two points in time. The images to the left shows a rule applied to building footprints. As the year is changed using a slider control, buildings are extruded according to the time period set by the user. A video was created and posted to the research blog that shows year-by-year change. We created code that either extruded a building footprint or populated the center of the building footprint with a detailed 3D model if one was available (see *Time-based Generation of 3D Models and Building Footprints*, page 72, and Appendix D).

A key limitation to this approach is that the continuous timeslider is visible on the desktop version of CityEngine, but not its webscenes. If a 'fly by' movie is created, it can be placed on a website, but then users are not able to freely navigate in the scene. They also have no access to underlying data.

ArcGIS Pro is a newer ESRI application that enables the display of 3D scenes via an online portal called ArcGIS Online. It enables a continuous time slider to be accessed online. Research assistants imported 3D models and 2D GIS data into ArcGIS Pro. (These were the same 3D models and 2D GIS data gathered to create webscenes using CityEngine.) Unfortunately, the 3D scenes that were developed were quite

detailed and the team found that they could not be easily imported into ArcGIS Pro, as there was an upper limit on the number of features (max is 2,0000) that can be displayed online via ArcGIS Online.

Preservation Uses for 4D Visualization

A cultural landscape preservation project at Flushing Meadow might involve creating alternatives for preserving and interpreting the site's pathways, which were designed by the well-known landscape architect Gilmore Clarke for the 1939 world's fair and retained for the 1964 world's fair. Most of the pathways remain. A preservation professional would find it helpful to use 3D visualization to compare the location, condition and context for the world's fair pathways during the two historical events and as they exist today.

Without 3D visualization, this may be accomplished by comparison of historical photos, aerials, and site plans with contemporary photos, site surveys, and aerials. Historic aerials may be georeferenced to a map of existing conditions for comparison. The image at right shows an aerial of existing conditions at Flushing Meadows Corona Park with the historical pathways highlighted.

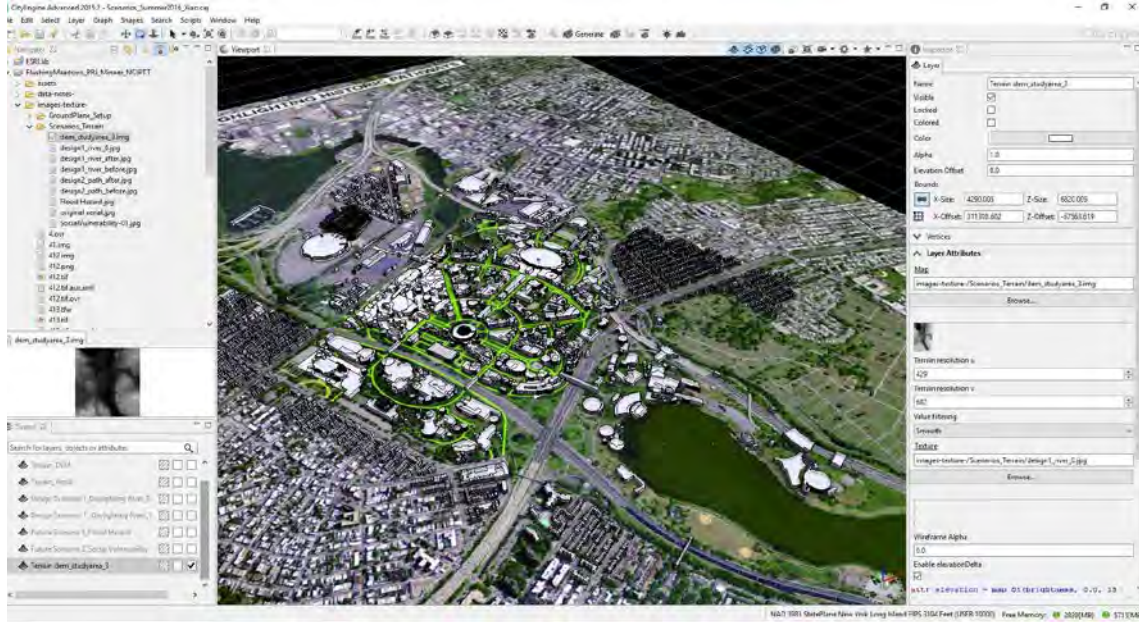
A preservation professional may also wish to model modifications to the pathways, such as stormwater management techniques associated with green infrastructure. For instance, new permeable pavement might be proposed in place of asphalt pathways. Wood chips or permeable pavement might be used in restoring the pathways that have been lost. The preservation professional could create a 3D scene to show what the paths might look like altered. Today, such images are commonly produced both by hand and by computer, but they are inanimate.

A research assistant tested CityEngine's ability to visualize the restoration of historical pathways. The next two screenshots show how the pathways looked in the desktop version of the software. Both of these models include a historical layer showing the locations of former 1964 fair pavilions. This layer can be turned on and off. The final screenshot shows images exported to webscenes and with the former fair pavilions layer turned off and only extant buildings displayed.

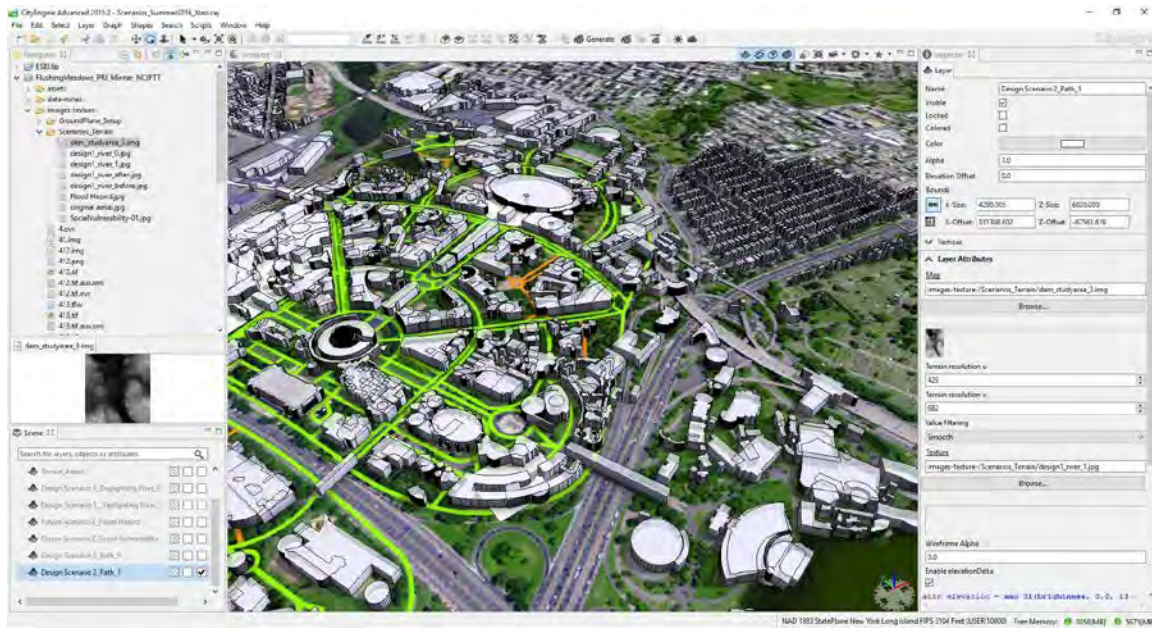


Aerial of existing conditions at Flushing Meadows Corona park with historical pathways highlighted.

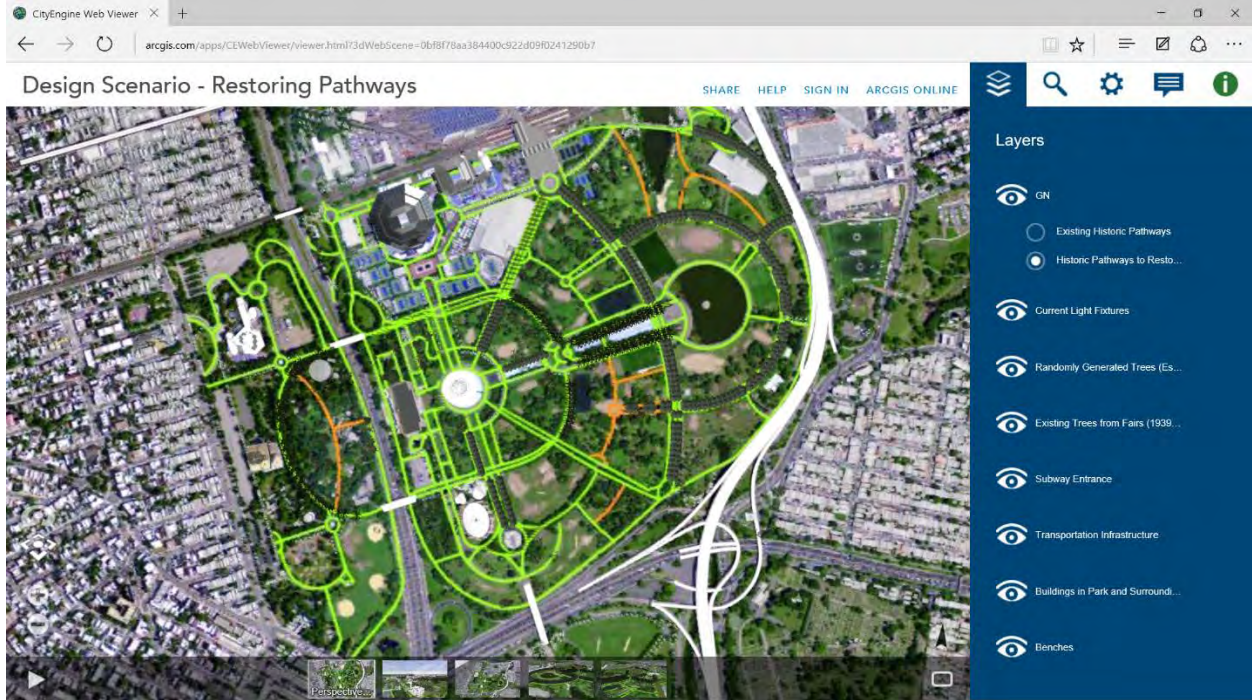
As noted above, an issue in both CityEngine and ArcGIS Pro is the limitation in the number of features that can be uploaded to the web and visualized. When the research team attempted to export all landscape features to a webscene in CityEngine, as well as one in ArcGIS Pro, the results ranged from the inability to view all features to a very slow web-viewing experience.



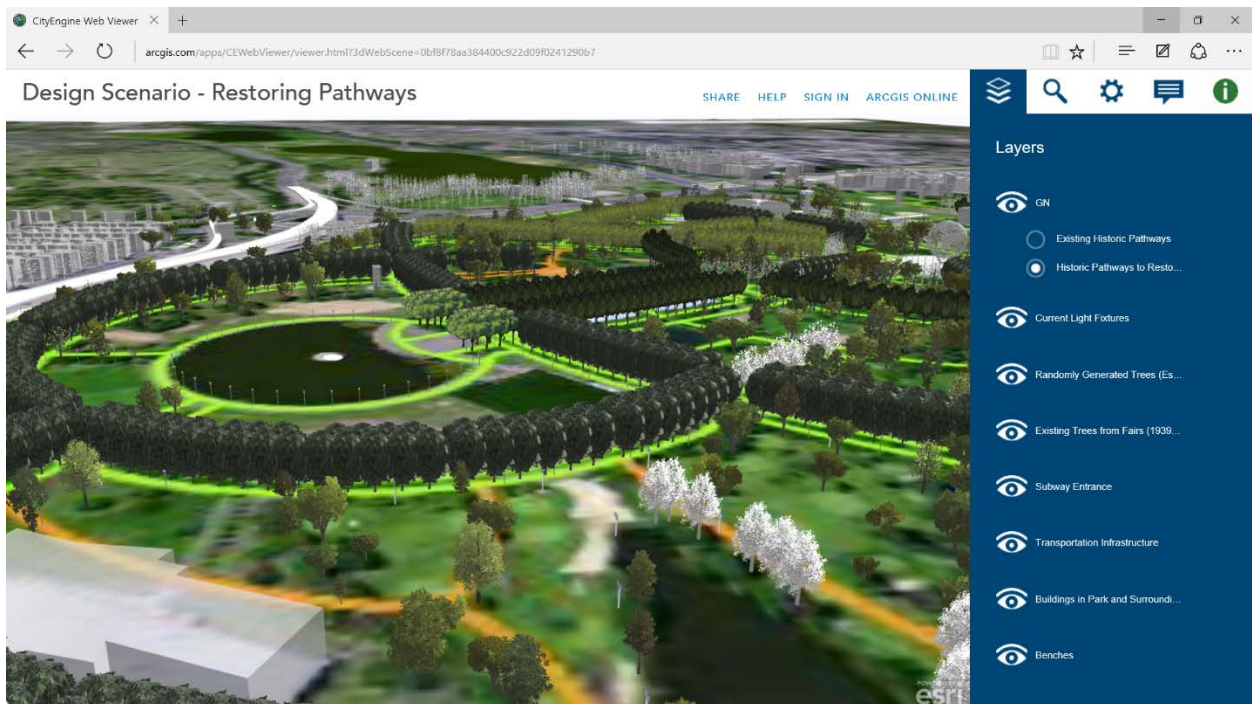
Screenshot of 3D models and other data in CityEngine. Models of both existing and previous buildings (which can be turned on and off). Historical pathways are showing in green.



Screenshot of 3D models and other data in CityEngine. Models of both existing and previous buildings (which can be turned on and off). Historical pathways are showing in green and pathways that could be restored in the future are highlighted in orange.



Screenshot of webscene that was exported to ArcGIS Online. Historical pathways are showing in green and pathways that could be restored in the future are highlighted in orange.



Screenshot of a webscene that was exported to ArcGIS Online from another perspective. Historical pathways are showing in green and pathways that could be restored in the future are highlighted in orange.

A preservation professional who is considering potential treatments for the pathways may wish to engage stakeholders in discussions of the different options and visualized modifications. 3D visualization could be performed ahead of a public workshop to offer pre-identified options or a user-friendly application could be used to show options on the fly. The webscenes can be generated ahead of time and shared with the public. Follow this link to interact with the exported web-scene showing historical pathways that could be restored: [Design Scenario – Restoring Pathways](#). We did not test differences in texturing pathways. Basic textures for pathways can be applied in CityEngine and they can be enhanced with additional software such as LumenRT (Lumenrt: Emersive Visualization for Architecture and Geodesign, 2017).

Similar to the pathways and in fact oriented in relation to them, Flushing Meadows Corona Park also includes large fountains that are remnants of the former world's fairs. At this time, most of the fountains are nonfunctioning and have not been maintained. The Parks Department has been considering options for how best to steward these historic resources and is now actively considering their adaptive reuse. A preservation professional, architect, or landscape architect might want to show how different adaptive reuse options would fit within the current park context. 3D visualization could be used illustrate how the fountains could be repurposed as new interactive water features for the public. In addition, alternative finishes might be considered and compared with finishes and paints from the fair era. This would require the ability to modify finishes and materials of the fountains and ideally simulate water movements. These use cases were not specifically tested in the generated 3D models.

A Strategic Framework Plan for the Park proposed the daylighting of the Flushing River (Quennell Rothschild & Partners and Smith-Miller + Hawkinson Architects, 2008). The proposed intervention would involve the removal of some of the pathways and fountains from the previous fairs. A preservation professional would also benefit from the ability to model the effects of daylighting the river, such as removal of character-defining features of the landscape. Ideally there would be an ability to show multiple scenarios. For example, a preservationist might focus on scenarios that daylight the river while maintaining as much of the historic cultural landscape as possible. A [design scenario webscene](#) was created to test this ability. For this particular purpose, a webscene could be

generated, but due to the many 3D landscape features, maneuvering around the webscene can be slow.



Screenshot of webscene showing an alignment for daylighting the Flushing River.

Tree Inventories and Other Vegetation Plans

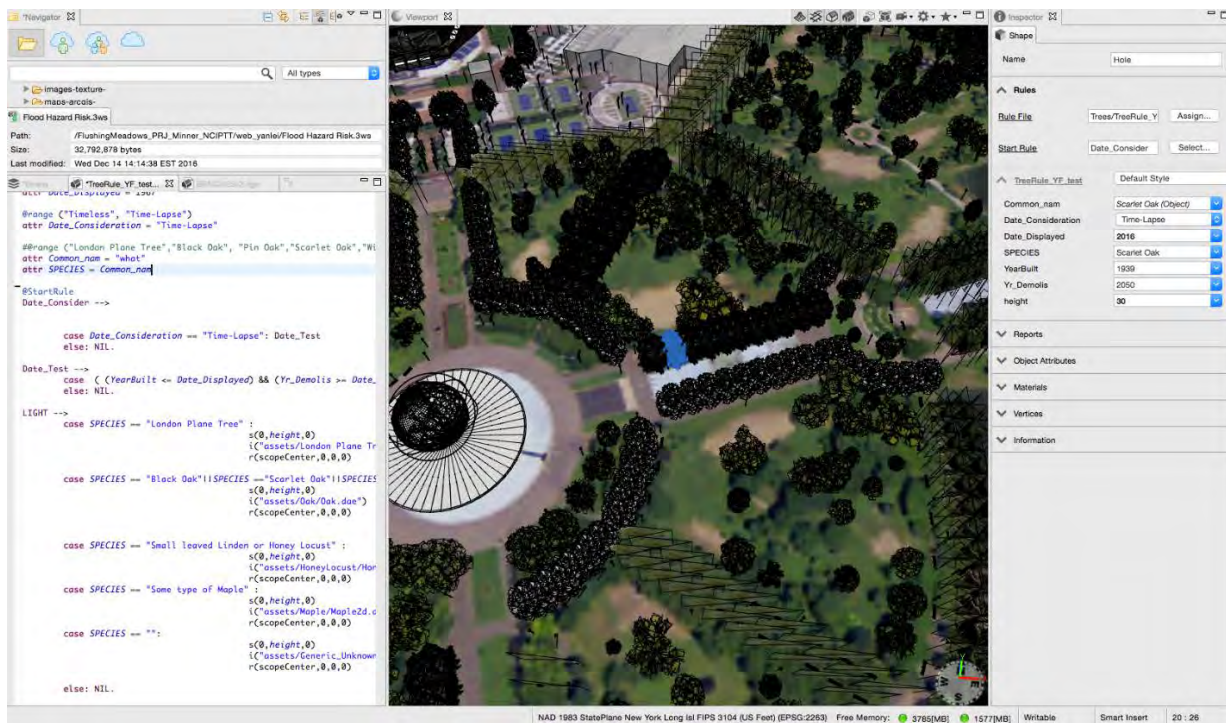
Formal landscaping was an integral part of the 1939-40 and 1964-65 world's fair landscapes (Maloney, 2011). For the 50th anniversary of the 1964 world's fair, some areas, such as flower beds, were replanted with the historic species. A preservation professional would benefit from the ability to explore historic or proposed planting plans, as well as the ability to store information about them. There may also be interest in identifying the provenance of trees planted around the fairgrounds. Preservationists and parks officials would also benefit from the ability to create a detailed inventory of trees on site, including the species, height, health, age, and any cultural/historical information about their plantings. Physical maps and paper records can be used for a tree inventory, or asset management software. A 3D GIS could provide more functionality if information can be stored and queried geographically, along with the capability of displaying and analyzing trees in 3D.

The research team created a preliminary inventory of trees to test this capability. The team produced several 3D models. A detailed description of the process of creating the inventory and incorporating trees into 3D models is in in a separate, following section titled "Mapping and Modeling Trees." The following screenshots show 3D models of trees that have been selected in the desktop version of CityEngine.

The research team noted two major limitations in handling a tree inventory in CityEngine. First, there was a limit to the number of features that can be comfortably navigated in an online webscene. This means that 3D representations online would either need to be less detailed or for smaller, discrete

areas of the park. A second limitation to CityEngine in the desktop application as well as in published webscenes is that there is very limited means of querying information. In a 2D GIS system, it would be easy to select all trees, for instance, within a certain age range. This same query in CityEngine takes custom scripting that is time consuming and increases the probability of user error or frustration. Information reports can be generated in CityEngine, but this also requires custom scripting.

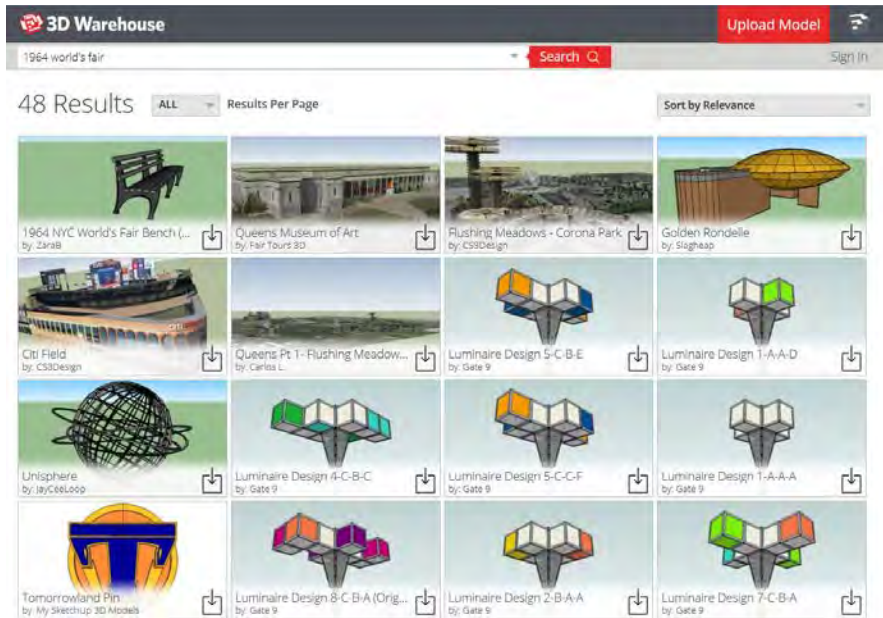
Thus, CityEngine demonstrated potential as a platform for both storing, analyzing, and visualizing vegetation, especially if combined with tools such as LumenRT that enhanced the visualizations. However, CityEngine does not go as far as a GIS in supporting the ability to do queries based on attributes or spatial analysis. This is where further development of a GIS that has built-in capabilities for query and analysis like 2D GIS functionality, could be better supported and integrated with 3D modeling capabilities.



Screenshot showing a selected tree with associated attributes of the tree.

Asset Management of Historic Landscape Features

One of the reasons Flushing Meadows Corona Park is a fascinating test site is that there are have been so many efforts among amateurs to model individual buildings and other aspects of its landscape. Its history as a world's fair site and also as a site of multiple sports stadia has attracted both fair and sports enthusiasts. Some of these enthusiasts have volunteered their time and effort by contributing elements of the Flushing Meadows landscape (past and present) online. This is evident at 3D Warehouse, where users have contributed Sketchup models of historic benches and light fixtures, and fair pavilions.



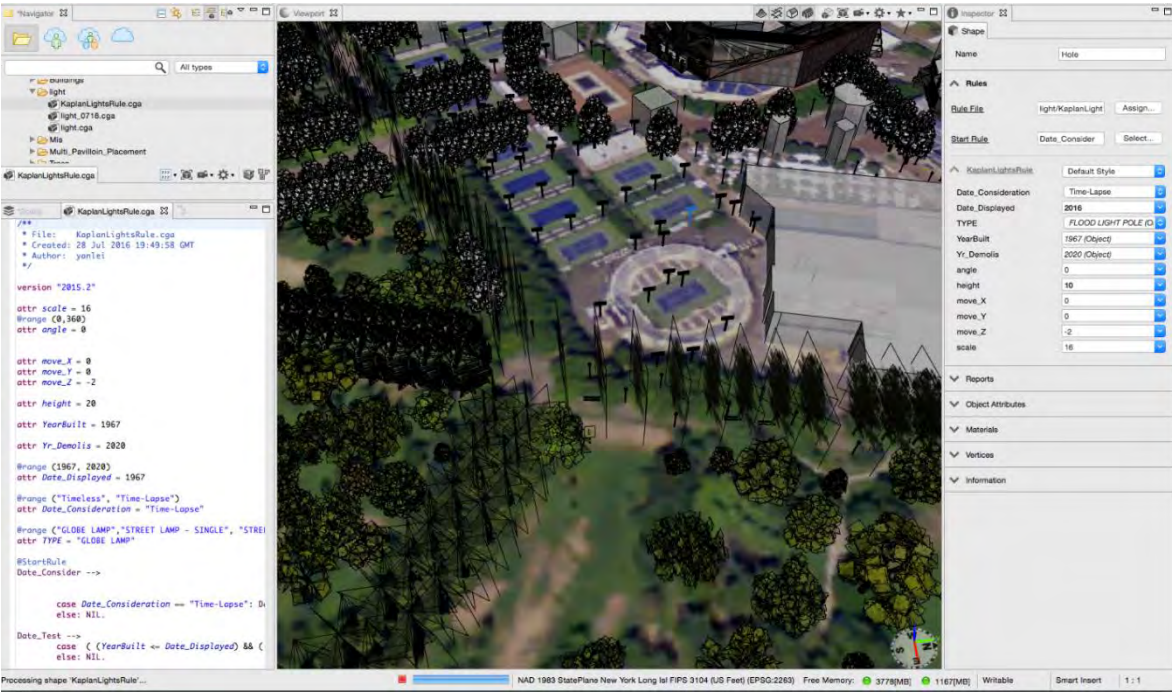
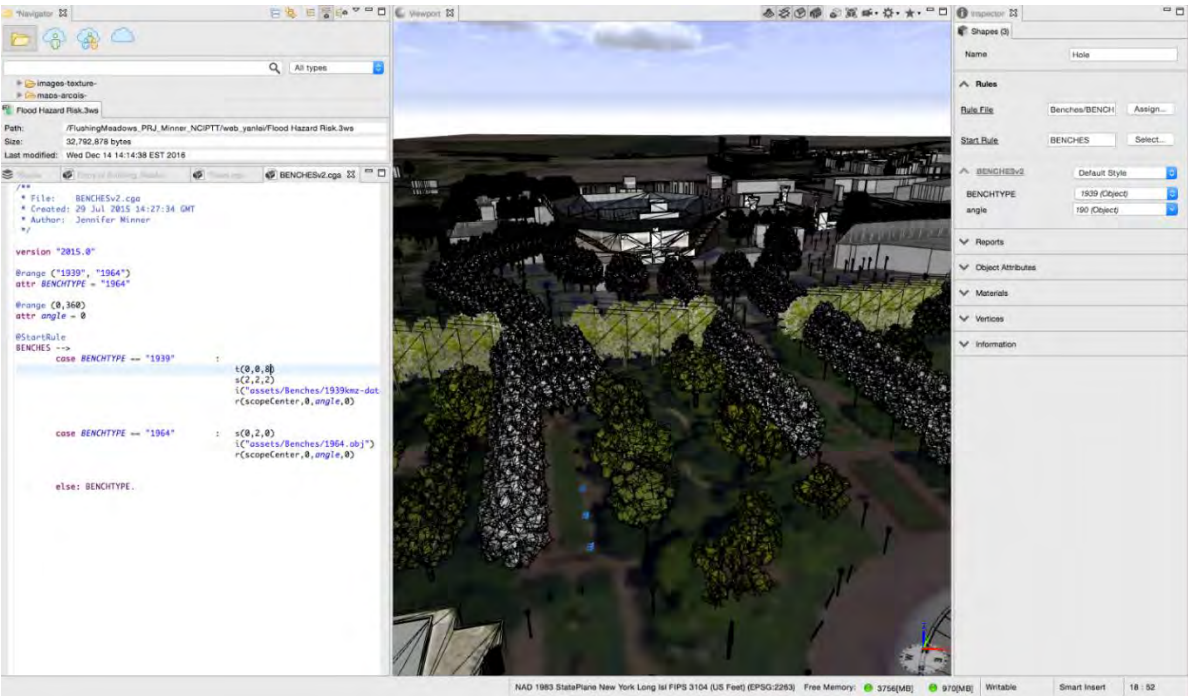
Screenshot from 3D Warehouse showing models of features associated with the 1964 world's fair.

This potential for crowdsourcing elements of the past and present landscapes was recognized by the research team as an important way to get people involved in the stewardship of the landscape. Some of the citizen-generated models were used in the research team's 3D models. Preservation planners and park officials could incorporate 3D modeling in their public outreach plans.²

As the research team explored the contributed 3D models of benches, light fixtures, and buildings from the fairs and the park, it also became apparent that 4D GIS would be an ideal platform for asset management. The team explored these capabilities by adding benches (shown in the screenshots below) as well as light fixtures to scenes. The team then tested the ability of CityEngine to store data associated with them.

As noted in the section on tree inventories, there are aspects of CityEngine that meant limited functionality for storing detailed information about elements of the landscape or exporting detailed landscapes to webscenes. However, the team found that it is relatively easy to set up the capability to interactively populate different 3D models in the Desktop version based on a simple CGA script and important available GIS data on the locations of different kinds of benches and light fixtures.

² In fact, there is already a track record of involving the public in wayfinding and public art activities. A previous project by the Design Trust for Public Space engaged people in the process of designing new public art for the fair, based on the colorful light fixtures that once populated the fairgrounds.



Impact of Future Development in the Park

In the past few years, there have been several proposals to build new facilities in Flushing Meadows Corona Park, either on historic resources, as was the case with a proposed soccer stadium, or on existing parking lots, as is the case of a proposed mall adjacent to Citi Field. 3D visualization is another means of assisting planners, preservationists, parks officials and the public in exploring the potential

impacts of proposed development in the park. The ability to visualize alternative developments involves the placement of proposed buildings into the park landscape.

The process of modeling future development could involve bringing building models that have been created in other platforms, such as SketchUp or Rhino into a model of the park. Thus, interoperability between software used by architects and a geographic and 3D environment would be an important requirement of a 4D GIS system to accommodate this use. In addition, it is important to be able to create building models (from simple representations of building mass to more detailed models) within the platform.

CityEngine does allow for interoperability between some commonly used architectural platforms. However, difficulties were experienced in bringing textured architectural models from Rhino, as well as from Maya, into CityEngine. Textures were frequently stripped from the buildings upon import. Detailed information from building information models (BIM) cannot be imported into CityEngine and the research team agreed that it would be ideal to be able to retain this information in a fully functioning 4D GIS.

Building models can be generated within CityEngine using procedural and hand modeling techniques. CityEngine excels in the ability to generate cityscapes based on repeating rules and especially with regular repeating effects and rectangular shapes. However, the ability to create very detailed models of buildings is limited in CityEngine. The research team also experienced bugs in utilizing CityEngine's 'façade wizard.'

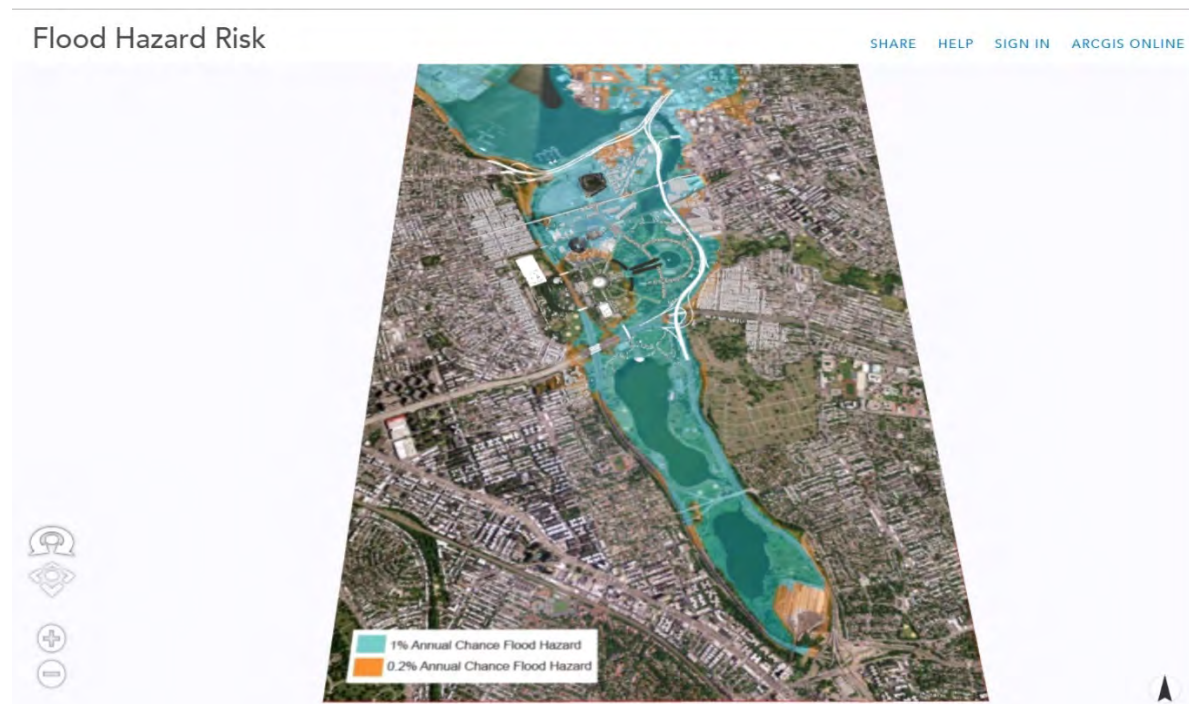
Impact of Future Development around the Park

Planners and preservation professionals would benefit from the ability to visualize and analyze the impacts of changes around the perimeter of the Park. This could involve generating models of development according to "build-out" under current zoning. The modeling of build-out through procedural modeling is one of the key functionalities of CityEngine. The research team did create CGA rules that brought in data from extant property records and extruded them into building volumes. These rules could then be modified to visualize different redevelopment scenarios for individual parcels or for whole neighborhoods. A user-friendly interface to allow the professional to input common zoning criteria, such as building envelopes according to standard setback, FAR, height and other restrictions, would likely benefit many users who do not wish to interact with the model through scripting. Since CityEngine was developed as an engine to easily generate cityscapes, its focus is on visualization. Unlike 2D GIS platforms such as ArcGIS or QGIS, it does not include analytical tools. The creation of 3D spatial analysis tools would be central to a wish list for a fully functioning 4D GIS platform.

Resilience Planning

Flushing Meadows Corona Park can be examined using the concepts of risk, vulnerability, and resilience. For the following models, we overlaid data from National Oceanic and Atmospheric Administration (NOAA) onto 3D models and an aerial image of existing conditions. Select the images below to view in an interactive web viewer. Research Assistants Xiao Shi and Yanlei Feng took the lead on mapping aspects of risk and vulnerability in and around the Park. The following image shows flood hazard risk in terms of a 0.2% or 1% annual flood risk. Additional maps on flood hazard risk can be accessed for Flushing Meadows Corona Park, as well as other coastal communities around the

country using [NOAA's Coastal Flood Exposure Mapper](#). Former pavilions and landscape features, such as historic trees and benches, are rendered in 3D on the map. Thus, the web viewer can be used to discuss threats to the historic features of the cultural landscape.



This image shows Flood Hazard Risk overlaid on a 3D model and aerial of the site. Illustration and 3D model created by Xiao Shi and Yanlei Feng.

In our experiments related to resilience, we observed the following:

- In heritage-focused resilience planning a preservation professional would need to store information about the location and attributes of historic assets in an inventory. Information would need to include detailed information about character-defining features of buildings and cultural landscapes. We found that CityEngine is good at representing repeated features (e.g. benches, trees). However, there are limitations in the number of features that can be displayed on the web viewer and slowness of web viewer and desktop were challenges. It also appears difficult to identify individual elements of a building as character-defining. A fully-functioning 4D GIS system would ideally give one the ability to tag and easily query windows, doors, and other fine-grained details.
- A 4D GIS system would be capable of uniting 2D and 3D data, such as 2D GIS information about vulnerable populations in and around a heritage site. The research team was able to import 2D GIS data on the locations of vulnerable populations. However, once imported into CityEngine, all the data's analytical and querying capabilities were lost.
- Support for deliberating about the vulnerability of historic resources in relation to natural hazards would be important in a 4D GIS. The research team found that 2D layers showing natural hazard risks can be displayed, but not queried or analyzed.

The ability to visualize alternatives for the management of buildings and landscapes is desirable for resilience planning, as well as many other planning processes. With CityEngine, multiple scenarios can be created. However, the research team encountered numerous issues in generating and sharing complex 3D scenes.

A recently published book chapter “Geodesign, Resilience, and the Future of Former Mega-Event sites” in *Planning Support Science for Smart Urban Futures*, fully details the results of our inquiry (Minner, 2017).

The next section consists of an overview of some of the procedures for creating our experimental 4D models in CityEngine and other applications such as AutoCad and ArcMap, which were needed for data preparation purposes.

Step-by-Step Descriptions of Processes Used to Create Aspects of 3D Scenes

The following sections detail how central aspects of our 3D and 4D models were created. These sections are intended to illustrate the complexities of using the software, as well as to aid other researchers or practitioners who might be using CityEngine. These descriptions are not exhaustive, in fact the actual steps of experimenting and troubleshooting in order to test and create scenes would be difficult to document comprehensively. We provide a sample of some of the important processes in developing webscenes. These include the creation of terrain, taking site plans from AutoCad to ArcGIS and into CityEngine, the extrusion of footprints, and the placement of models. Additional notes can be found on our [research blog](#).

Creating Terrain for Flushing Meadows

By Feiyang Sun

This section documents steps that were taken to generate a geo-referenced terrain in CityEngine with DEM data and a Basemap from ArcGIS.

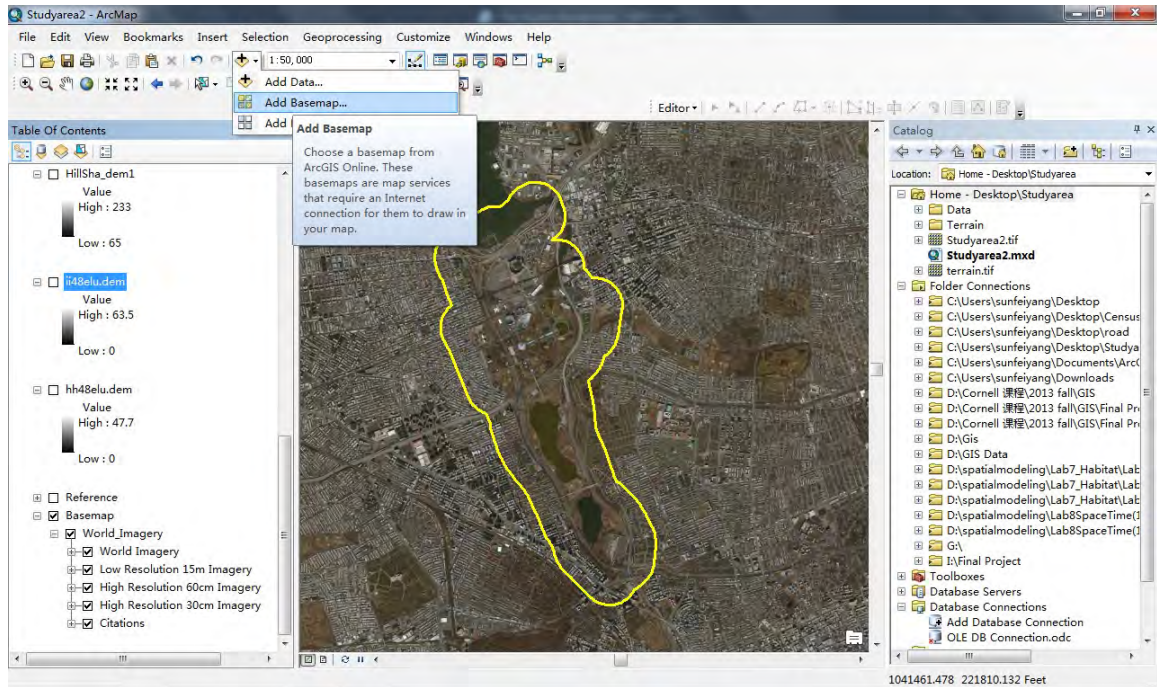
This included the following steps:

- A. Exporting geo-referenced tiff and jpg file from ArcMap
- B. Creating a CityEngine Scene and setting the coordinate system
- C. Creating Terrain from a TIFF
- D. Importing the Geodatabase and Growing a Street Network from shapefile.

These steps require the use of ArcGIS and CityEngine. We obtained a geodatabase from Quennell Rothschild & Partners, LLP and the New York City Parks Department. The geodatabase contained the street file reference below, as well as other datasets, which were created in the process of developing a Flushing Meadows Strategic Framework Plan (Quennell Rothschild & Partners and Smith-Miller + Hawkinson Architects, 2008).

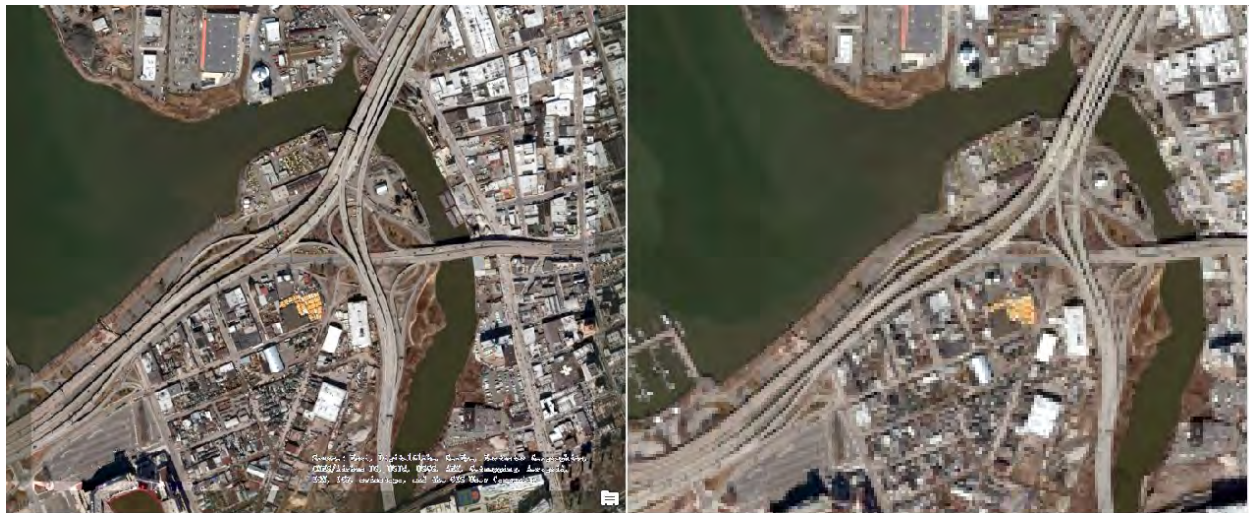
Export geotagged tiff and jpg file from ArcMap

1. The DEM for Queens County was downloaded from the Cornell University Geospatial Information Repository. (Before doing anything, one should always check the coordinate system and make sure every layer is of the same projection.) After the first inspection, we added the basemap from the dropdown menu of the “Add Data” button.



2.

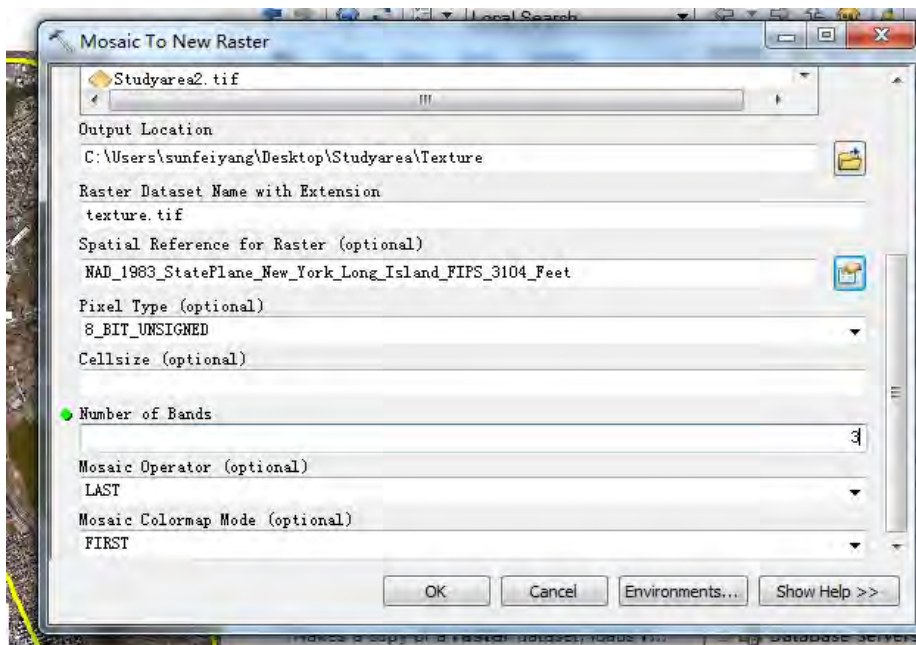
3. The next step was to export the tiff file of both the basemap and the DEM with geoTIFF tags. In order to produce a high-resolution tiff file, we needed to export a small portion of the entire study area, one at a time, until the entire study area was assembled, and then merge them together. The images below show a comparison between tiff files exported this way and a single tiff file exported directly for the entire study area.



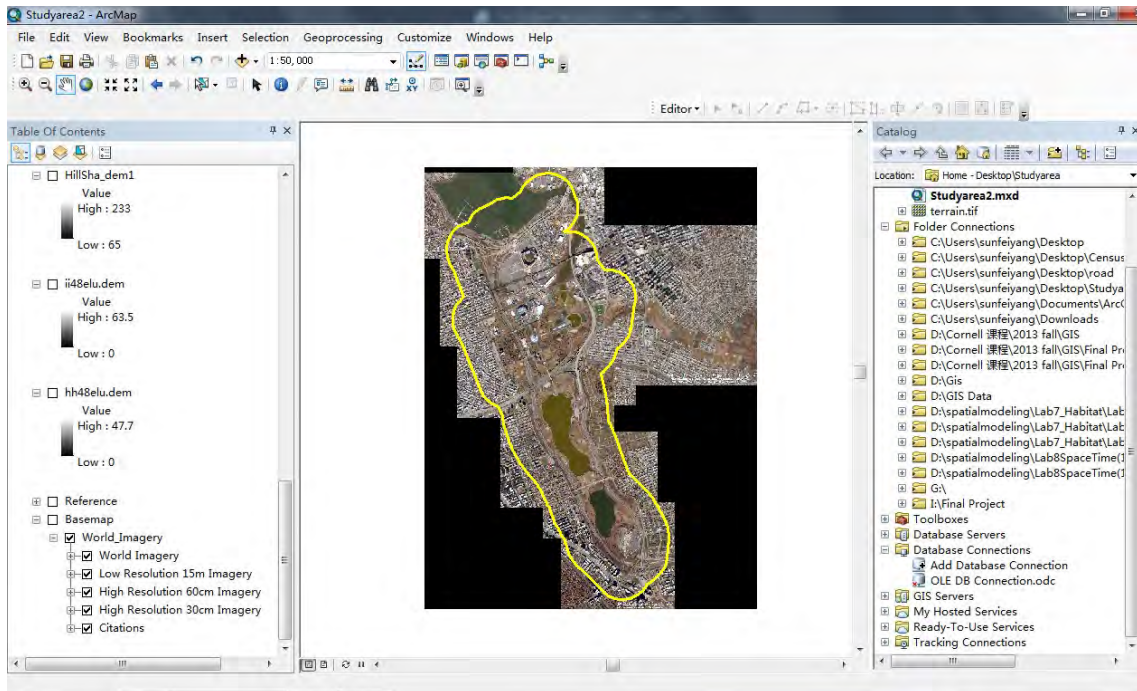
4. In order to produce a high-resolution tiff file, we zoomed in to a reasonable scale and used the "Export" button from the "File" dropdown menu. We selected tiff for the file type to save the file. In addition, in the Options box below, as made sure to enable the "Write World File" option in the General tag and the "Write GeoTIFF Tags" in the Format tag. We added the new tiff files to ArcMap.



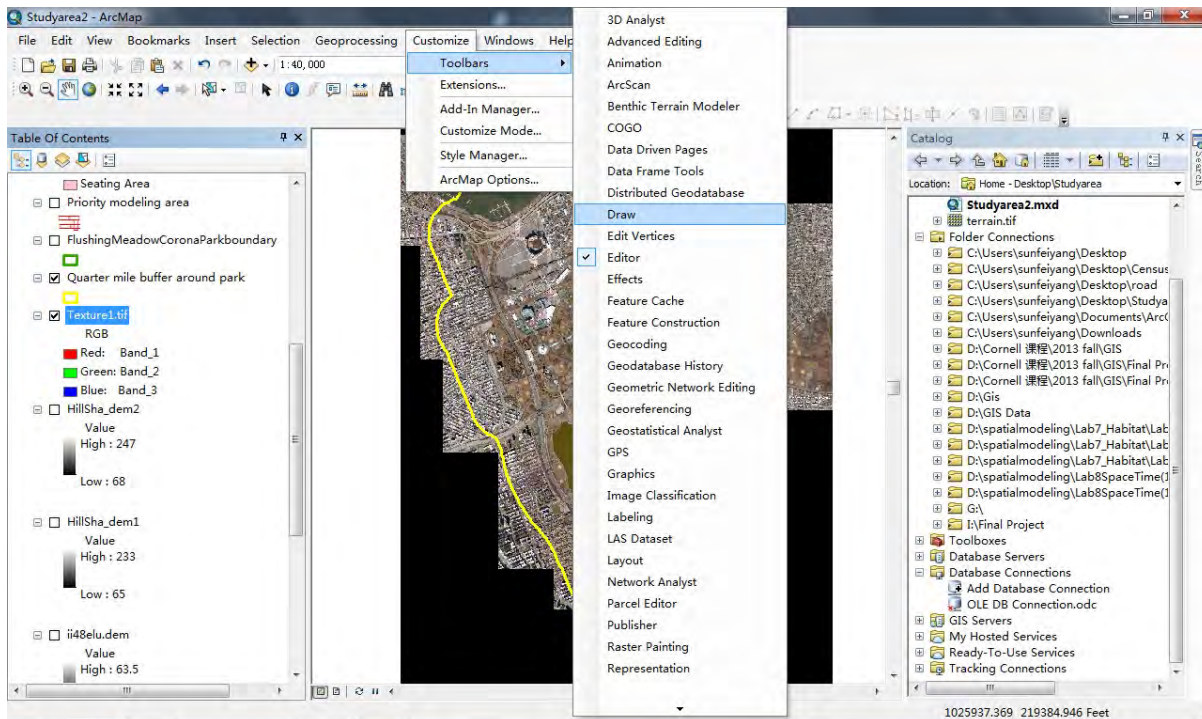
5. We repeated the above operation several times to create enough tiff files to cover the entire study area. We made sure that the adjacent tiff files overlapped each other to avoid blank spaces between tiff files. We organized the tiff files with numbers in order to track them.
6. We used the Mosaic to New Raster function to merge all the tiff files into a single layer. The function can be found through the "Search" function in ArcMap.
7. In the dropdown list of Input Raster, we selected all the tiff files we just produced and added them one by one. The tiff file that is added first appears in the bottom of the new layer and vice versa.
8. In the Output Location, we browsed to the folder to save the file. In the Raster Dataset Name with Extension, we entered the name of the file with .tif to save it as a tiff file. Next, in the Spatial Reference for Raster, we chose the desired coordinate system. Finally, we entered the Pixel_Type and Number of Bands according to the property of the tiff layers we were going to merge with.



After merging the tiff files, we removed the original tiff files we created and just kept the merged tiff file.



- Next, we are divided the merged tiff file into smaller cells in order to export them to CityEngine. We used the Draw tool to draw a square that covers the entire study area. The reason we created square cells is because they are more compatible with CityEngine.

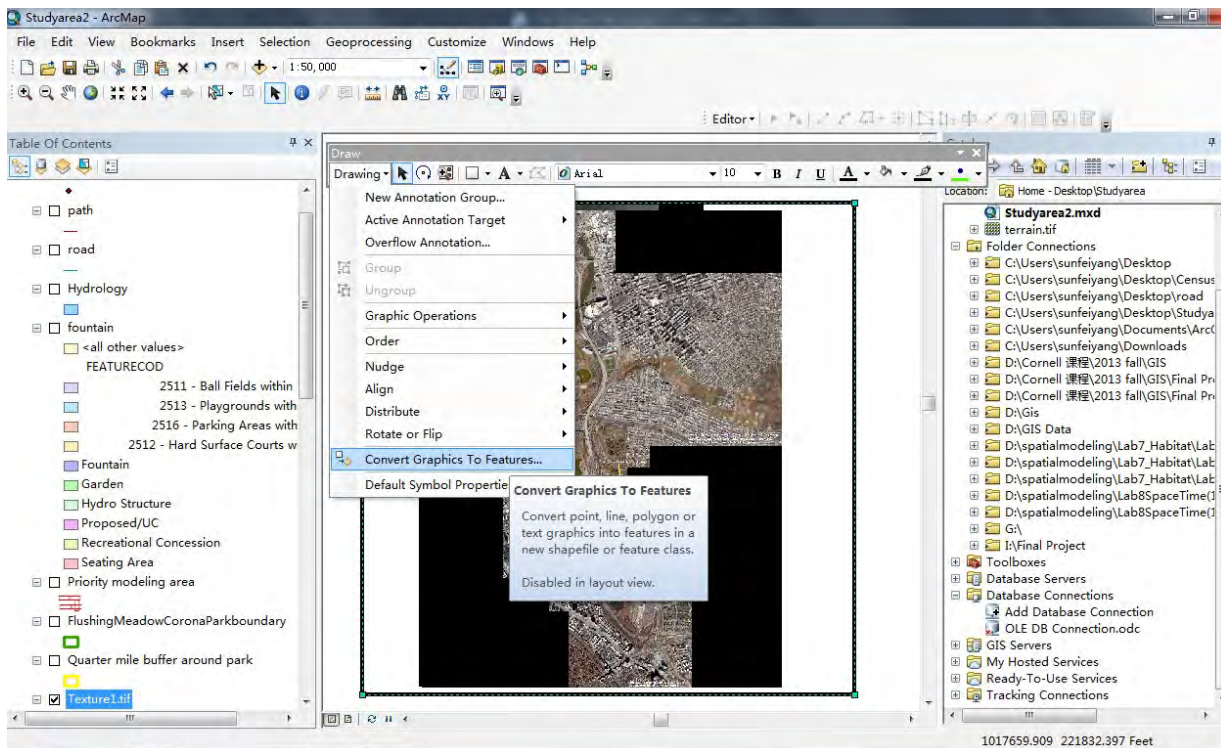


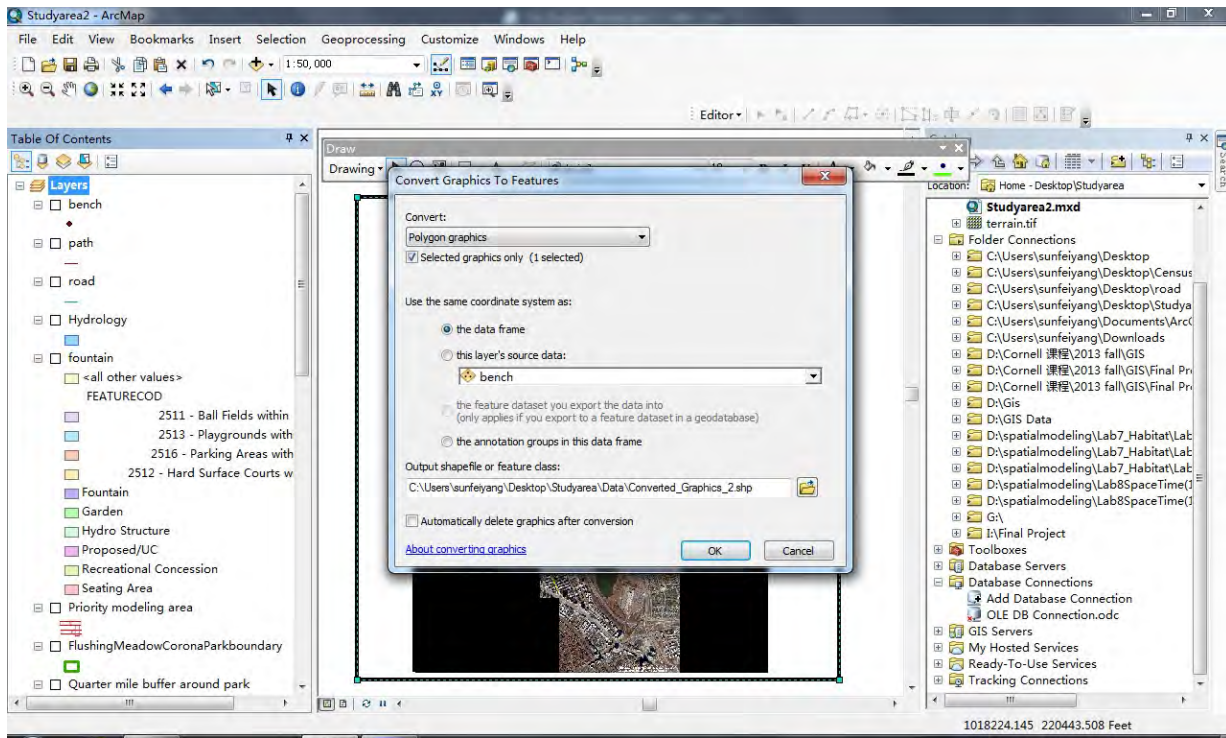
10. We first drew a random rectangle that covered the study area. We right clicked the rectangle to open the “Property” menu. Under the Symbol column, we set the fill color to no color and adjusted the outline so that we could see the content under the square. Under the Size and Position column we copied the value of the Width to the Height and we checked Preserve Aspect Ratio to create a square.



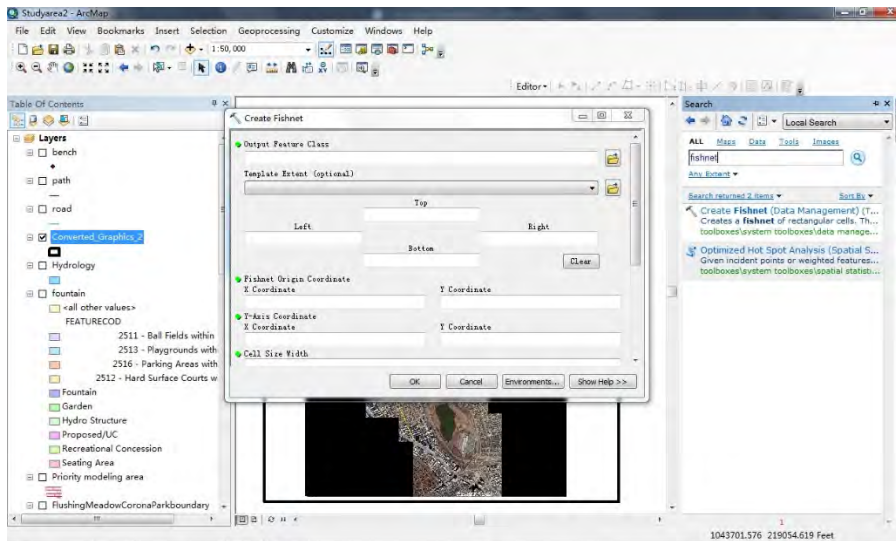
11.

9. We then converted the Graphic we just drew to feature. We saved and added it to layer.

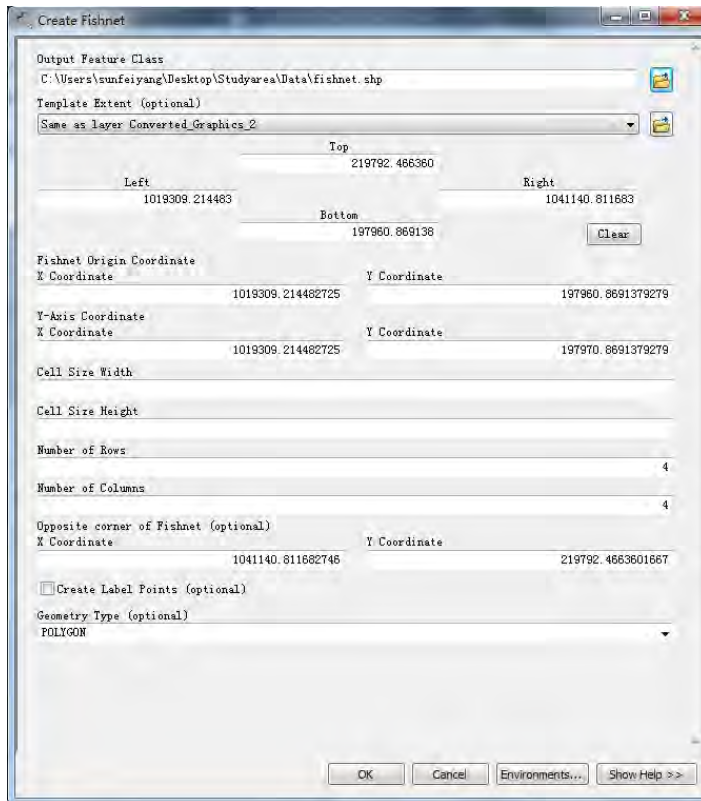




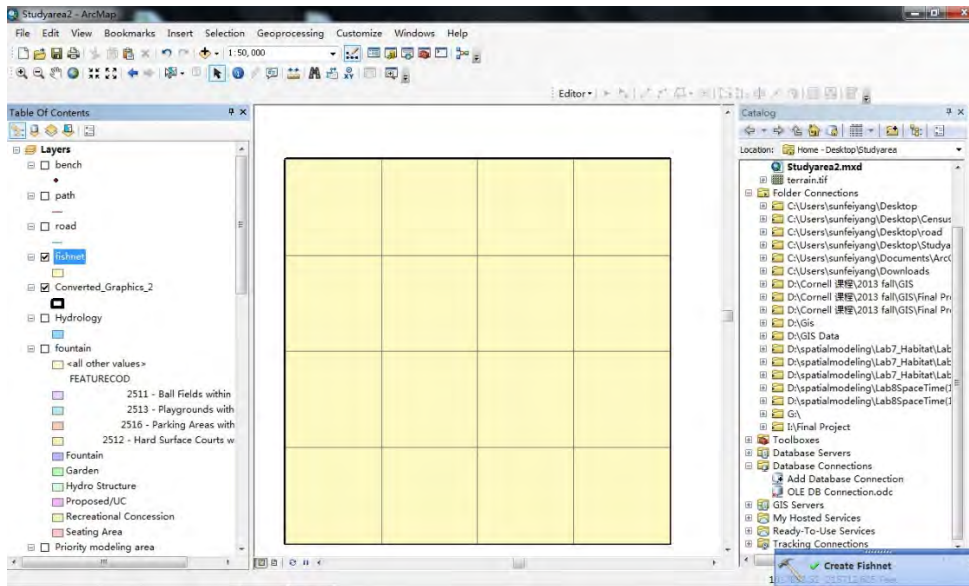
12. We used a Fishnet tool to divide the square we just created into cells. The Fishnet tool can be found through the “Search” function.



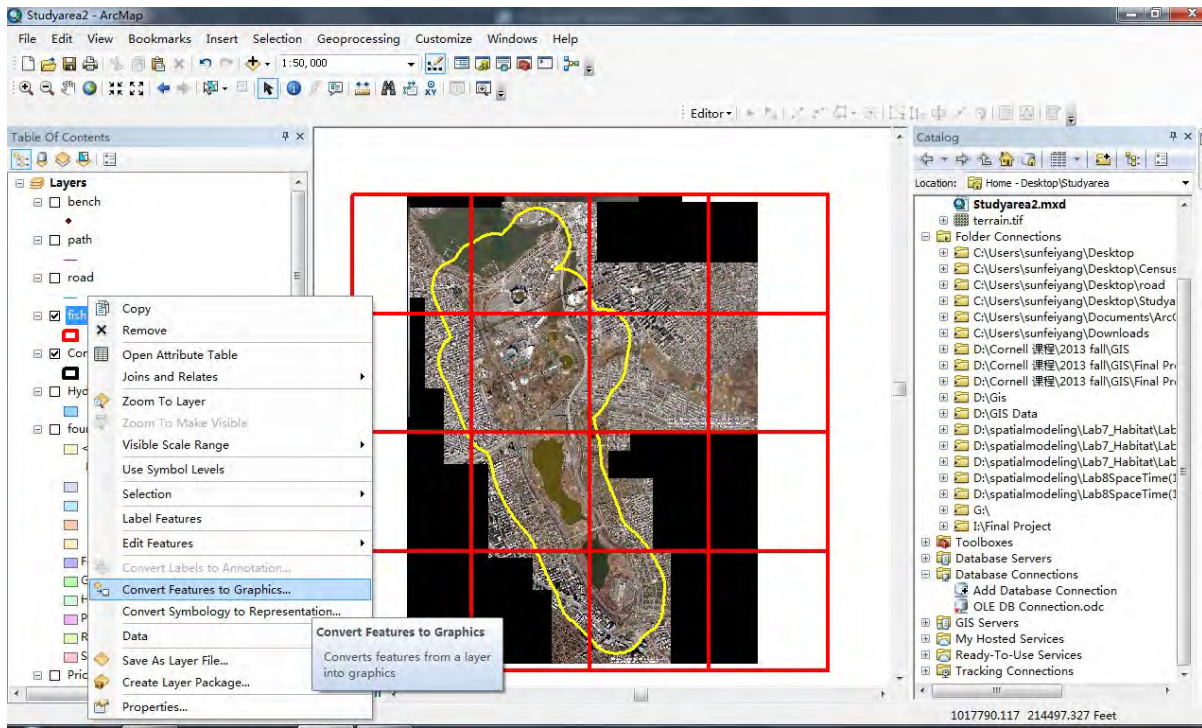
In the set-up menu we selected “Same as layer Converted_Graphic” for the Template Extent. We entered the number of Rows and Columns and unchecked the Create Label Point. The more cells we divided, the higher the resolution we got in CityEngine. Leave the rest as default.



We clicked OK and ArcMap created a new layer called fishnet.

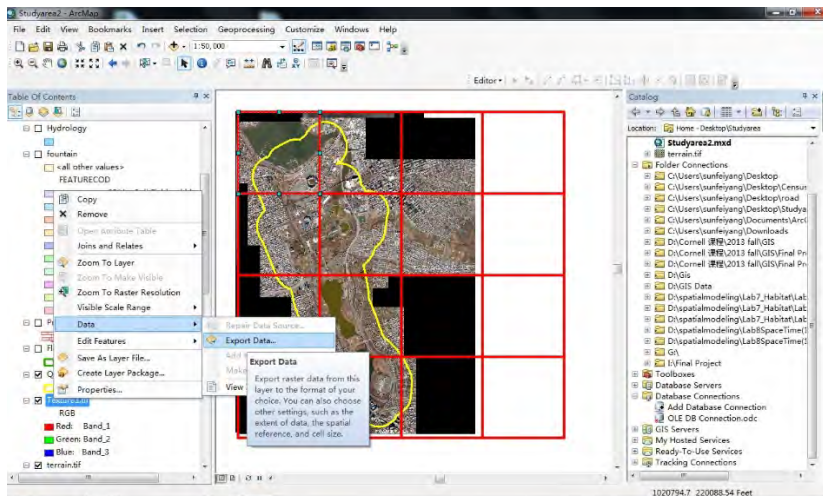


We right clicked the fishnet layer and converted it back to a graphic.

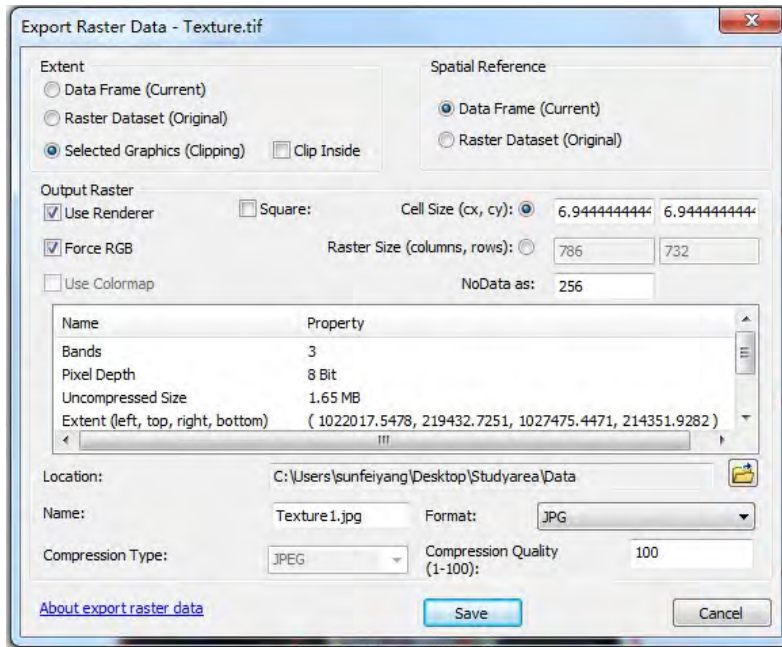


We

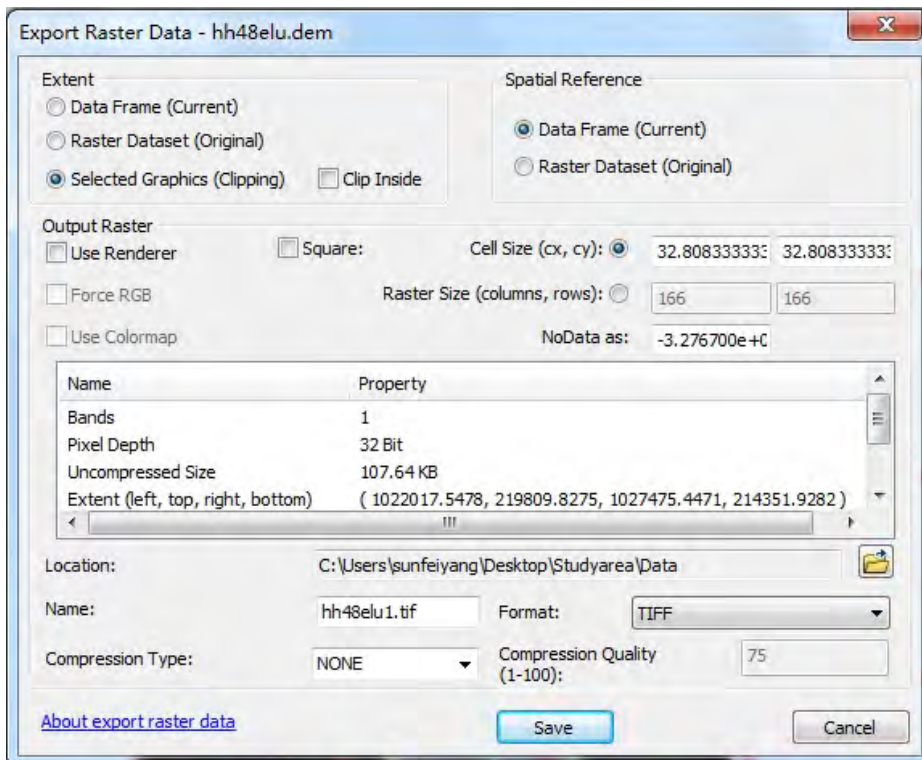
13. We selected one cell at a time and right clicked the merged tiff file to export geo-referenced jpg for the terrain texture.



12. In the set-up menu, we selected Data Frame (Current) for Spatial Reference, selected JPG for Format and 100 for Compression Quality and checked Use Renderer in Output Raster. We left the rest as default. We repeated and exported for each cell. It was unnecessary to export all cells, just covering the entire study area was sufficient. We made sure each JPG file was assigned a proper number in order to track it. The JPG files were used as texture of the terrain in CityEngine.



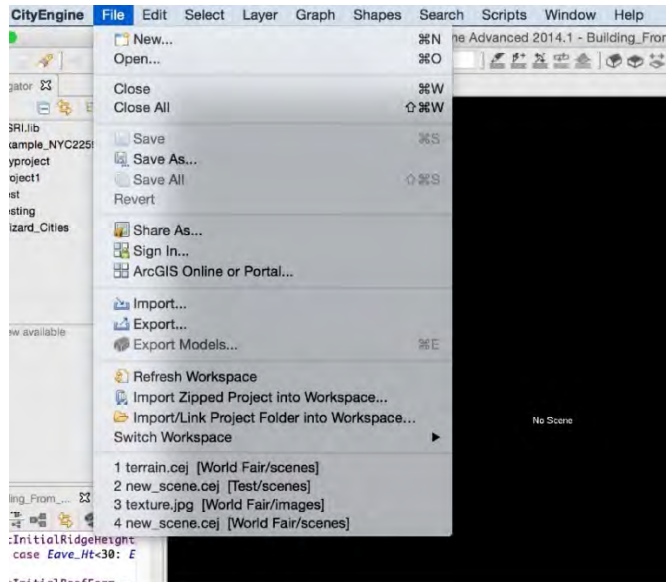
- We repeated the same steps to export the DEM data into geo-referenced tiff files. However, this time we used TIFF for the format and we did not check the Use Renderer options. We kept every exported TIFF file coded in order to track them. The TIFF files were used as height map of the terrain in CityEngine.



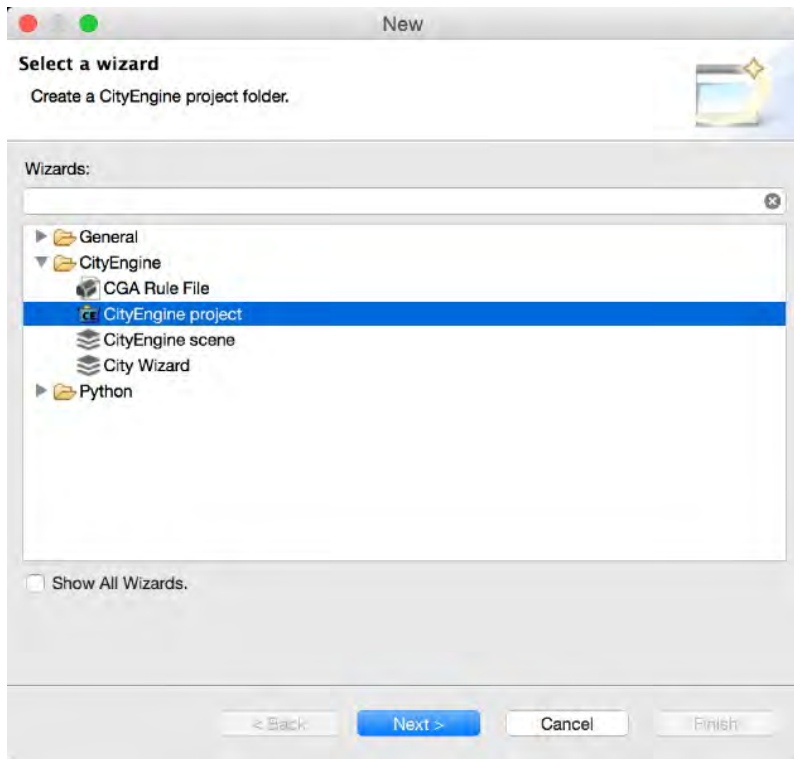
Now, we moved to CityEngine.

Creating a CityEngine Scene and Setting the Coordinate System.

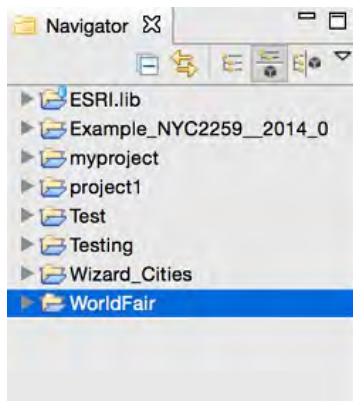
1. First, we needed to create a new CityEngine project. In CityEngine, select 'New' in the File dropdown menu.



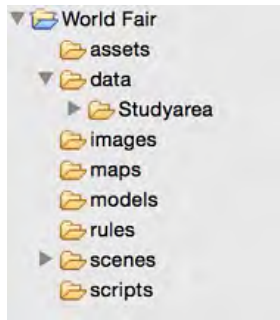
1. We selected CityEngine project and clicked 'Next' and then 'Finish.'



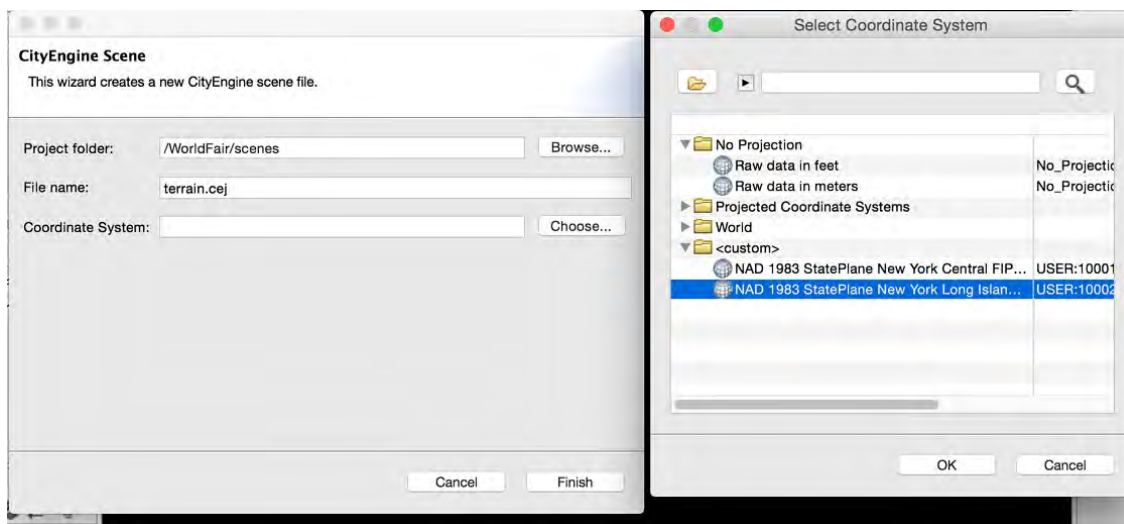
This created a new folder under the Navigator.



2. We expanded the newly created project folder. Each project folder contains 8 folders: assets, data, images, maps, models, rules, scenes and scripts. We dragged the folder that contains the Geo Data Base and all the exported files into the data folder.



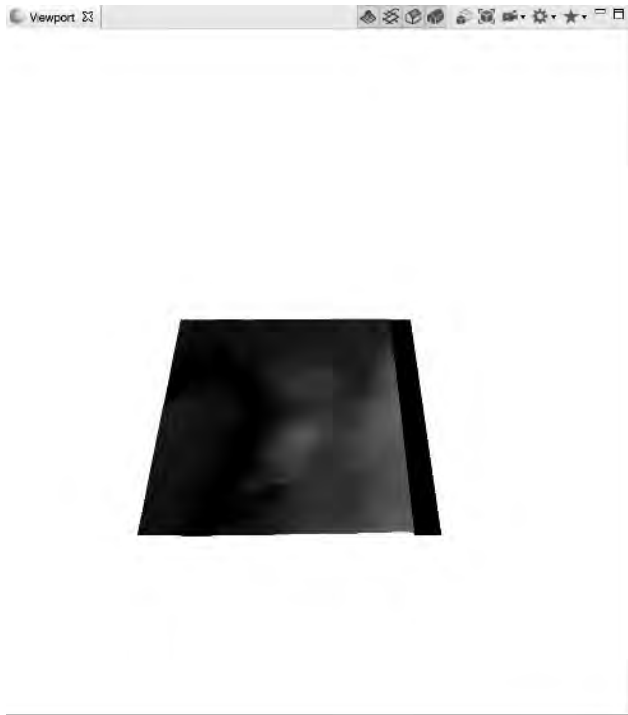
3. We created a CityEngine Scene. We right-clicked the scenes folder and selected 'New' – 'CityEngine Scene.'
4. In the pop-up window, we entered a file name and selected the Coordinate System.



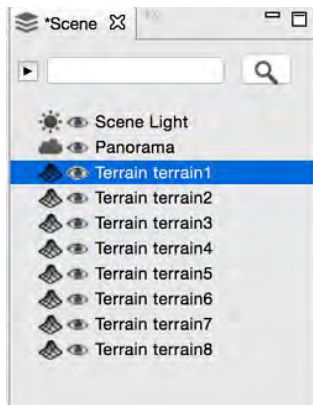
Creating Terrain from TIFF

1. We used the TIFF files exported from ArcMap. In this document, we exported the TIFF file directly to the CityEngine folder. (However, if the TIFF file is moved into the CityEngine folder from another folder, be sure to copy the .tfw file with it in order to keep the georeferencing information. Right click the .tif file and select Import.)
2. We kept everything as default in the popup window and clicked 'Finish.'

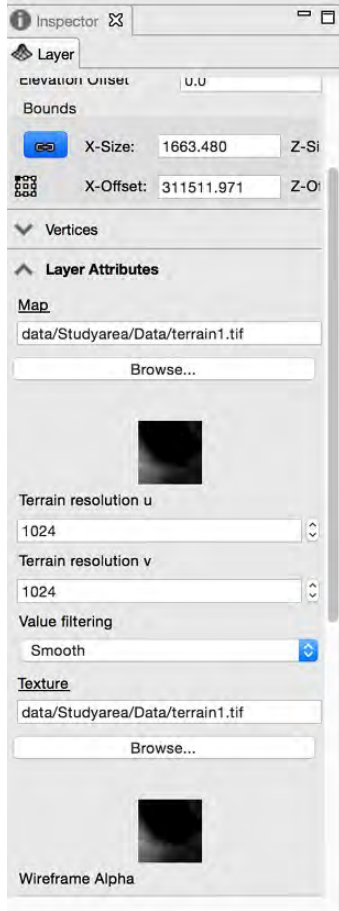
We can see that a block of terrain will be created in Viewpoint window.



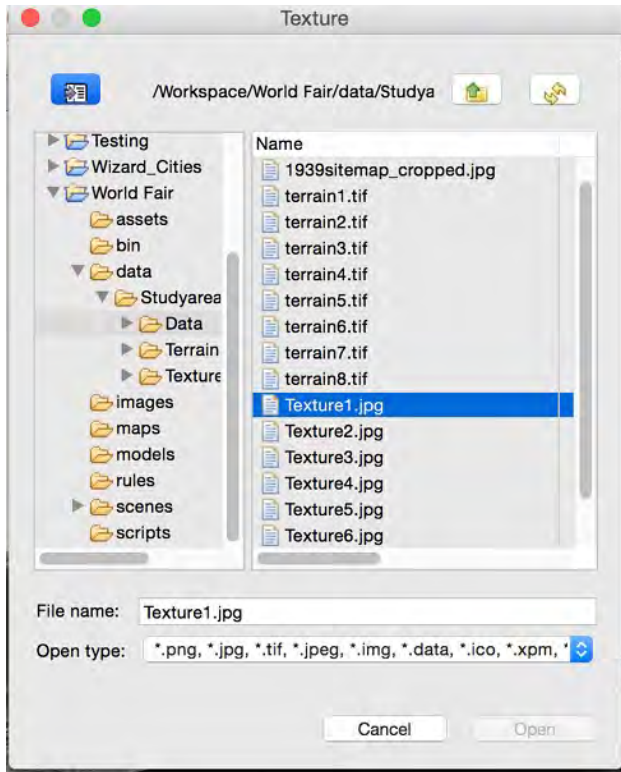
3. We imported every TIFF file into CityEngine. Each of them is treated as a layer in CityEngine and can be selected in the Layer Editor at the bottom left of the screen.



After selecting a Terrain layer, we can see its information and attributes in the Inspector at the top right of the screen.



Under the Texture column, we selected Browse. We selected the corresponding JPG as texture.



Now we have successfully generated the terrain.



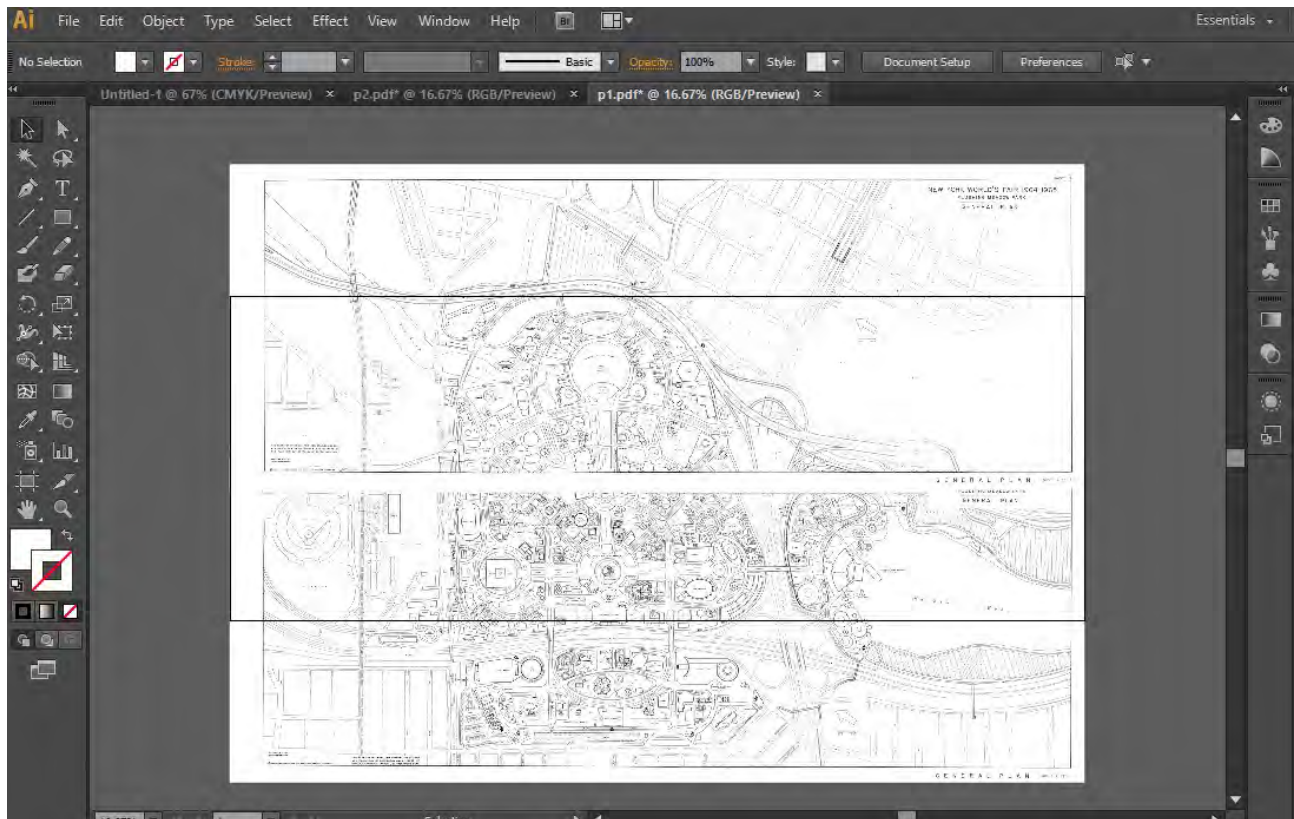
Preparing a Digitized Site Plan of the World's Fair for Import into CityEngine using CAD and ArcGIS

By Taru

AutoCad and ArcGIS were used to create shapefiles representing pavilions, roads, and landscape features from a scanned historical site plan of the 1964-65 World's Fair. These shapefiles were later imported into CityEngine. The following steps provide an overview of the process of going from scanned site map to shapefile ready for import.

Step 1. Merge the jpegs drawing in Adobe Photoshop/Illustrator to create a complete map

The site plan was available in a pdf, presented on two different pages. To create a complete map, the two images had to be merged. This was done by printing each page separately and bringing them to Adobe Photoshop/Illustrator. Since I wanted to create a vector version to line trace, I opened the two files in Illustrator and merged the files by opening them in the same file and aligning them on a page. The image was saved as a pdf.



This step can be skipped and the merging of the line out drawings can also be done in AutoCad. This can be done by importing/inserting the pdf as background and tracing. The line outs can then be scaled appropriately, using the same units and merged by using object snap and move tools.

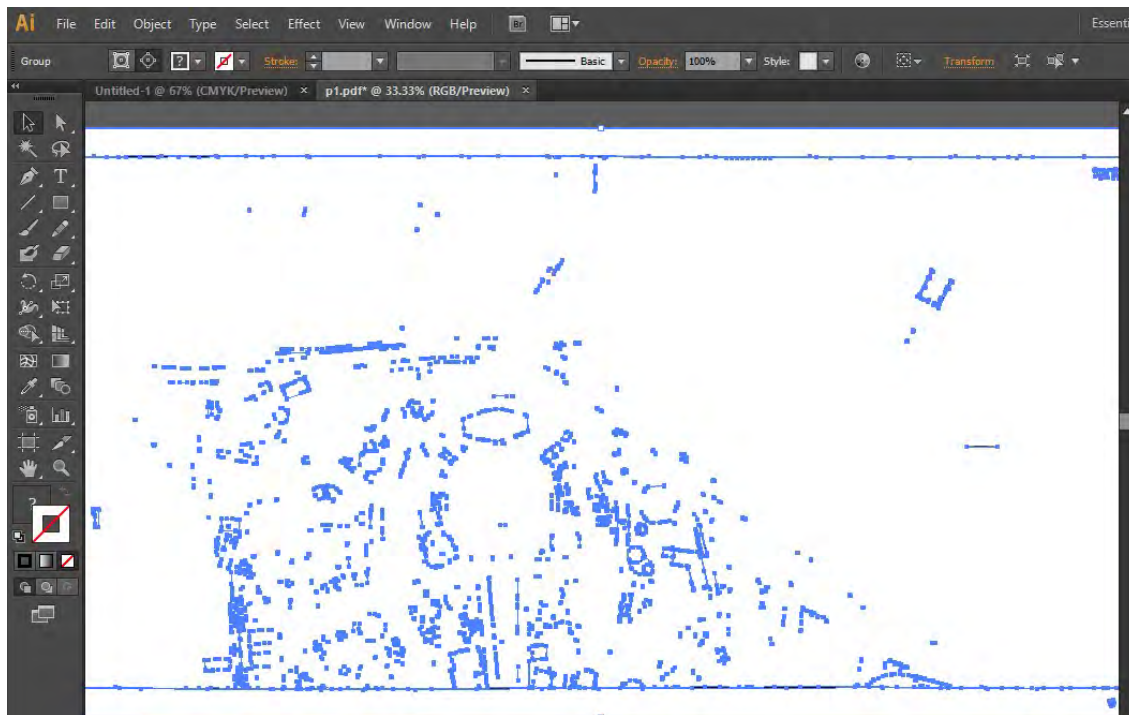
Step 2. Creating a Vector Drawing of the image

A vector drawing of the complete map from 1964 can be useful in recreating the cultural landscape digitally and compare it geospatially with the current day plans.

Process A: Using Illustrator

I imported the image to Illustrator and used the object-image trace option to create a vector version of the drawing. If this had worked, I could have simply taken line tracing to AutoCAD and assigned layers. Ideally, this would be the way to proceed as it would save a lot of time by auto tracing.

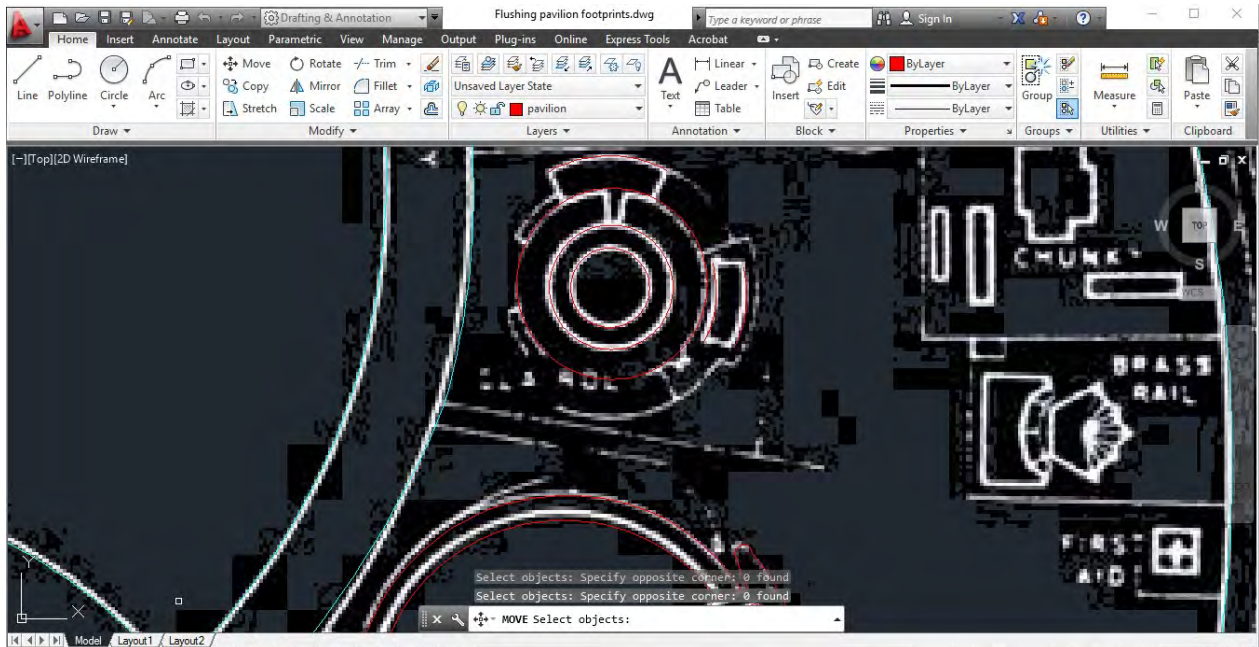
In this case, however, the resolution of the image was low and lines were therefore pixelated. The image trace resulted in a fragmented line out that would not be of any use. It thus became necessary to create a line out manually and AutoCAD is the most useful software to accomplish this.



Process B: Using AutoCad

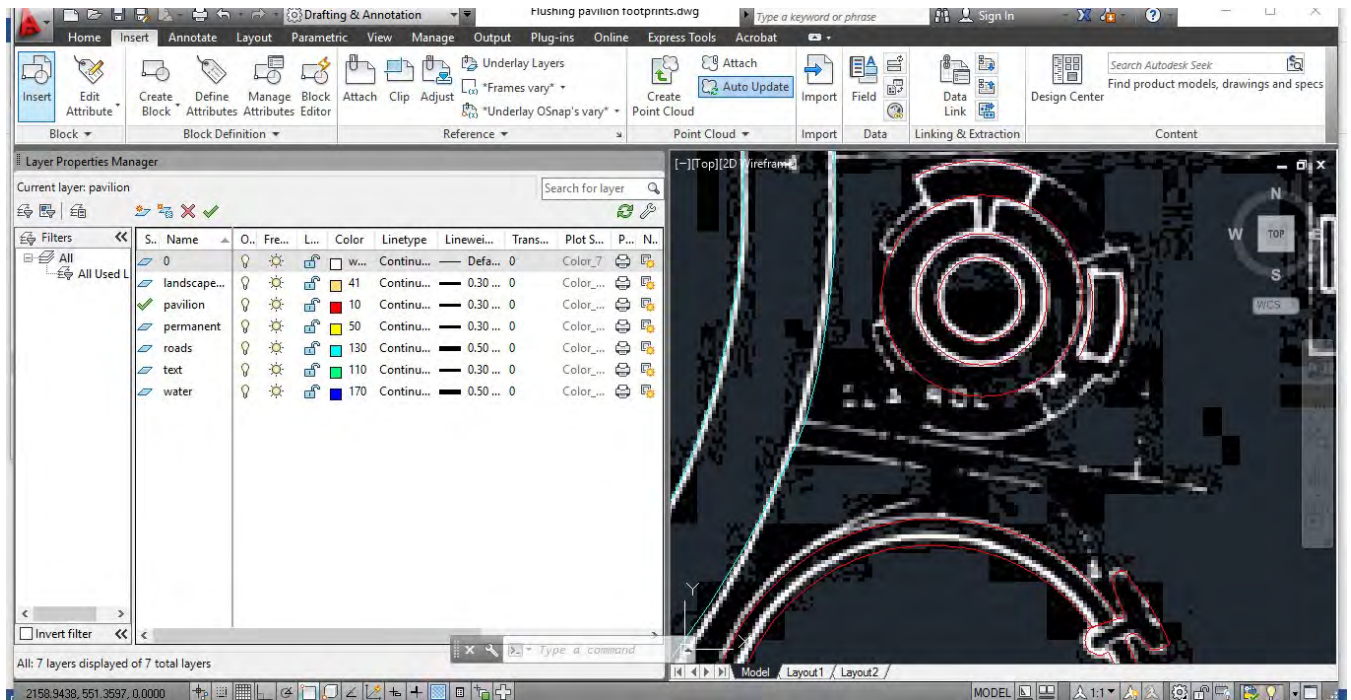
a) Importing the jpeg into AutoCad and scaling it

The combined pdf/jpeg can be used as a background image to create a line out drawing. One can either import a jpeg or link the image as a background image by either using Insert Attach or Insert Import. It is easier to work with Insert Attach as it only links the pdf file and does not bring the entire image in to the CAD drawing. In this case linking the drawing keeps the file from becoming too bulky.



b) Creating Layers

The line drawings needed to be drawn in layers so that they could easily be converted to relevant shapefiles. In this case, one can create relevant layers by the type of physical feature, like pavilion, landscape and roads.



c) Tracing the drawing using polylines

The p-line or sp-line tools are the best tools to use.

d) Things to be Careful About

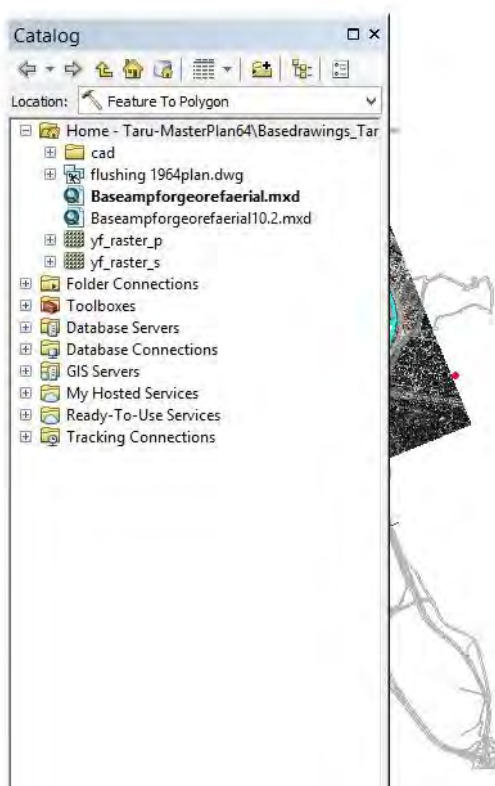
- Assigning geographic coordinates in AutoCad can lead to transitioning issues with GIS. It is best to add them in ArcGIS.
- Using Completed line loops is important or the files will not change to polygon shape files and will therefore require major re-editing during the transition.
- Using the right units and scale (in keeping with the rest of the files) helps the aligning of the project.
- Using the right layers in cad lets us differentiate shapefiles better.

Step 3 Importing into GIS and Aligning with existing Files

a) Import the Cad drawing into ArcMap

In this case, since we had existing shapefiles, we created an ArcMap file where we imported relevant shapefiles existing in other databases. We then open the cad drawing via ArcCatalog in the file.

The file opens with the multiple layers listing type of features (lines, polygons, points etc.)



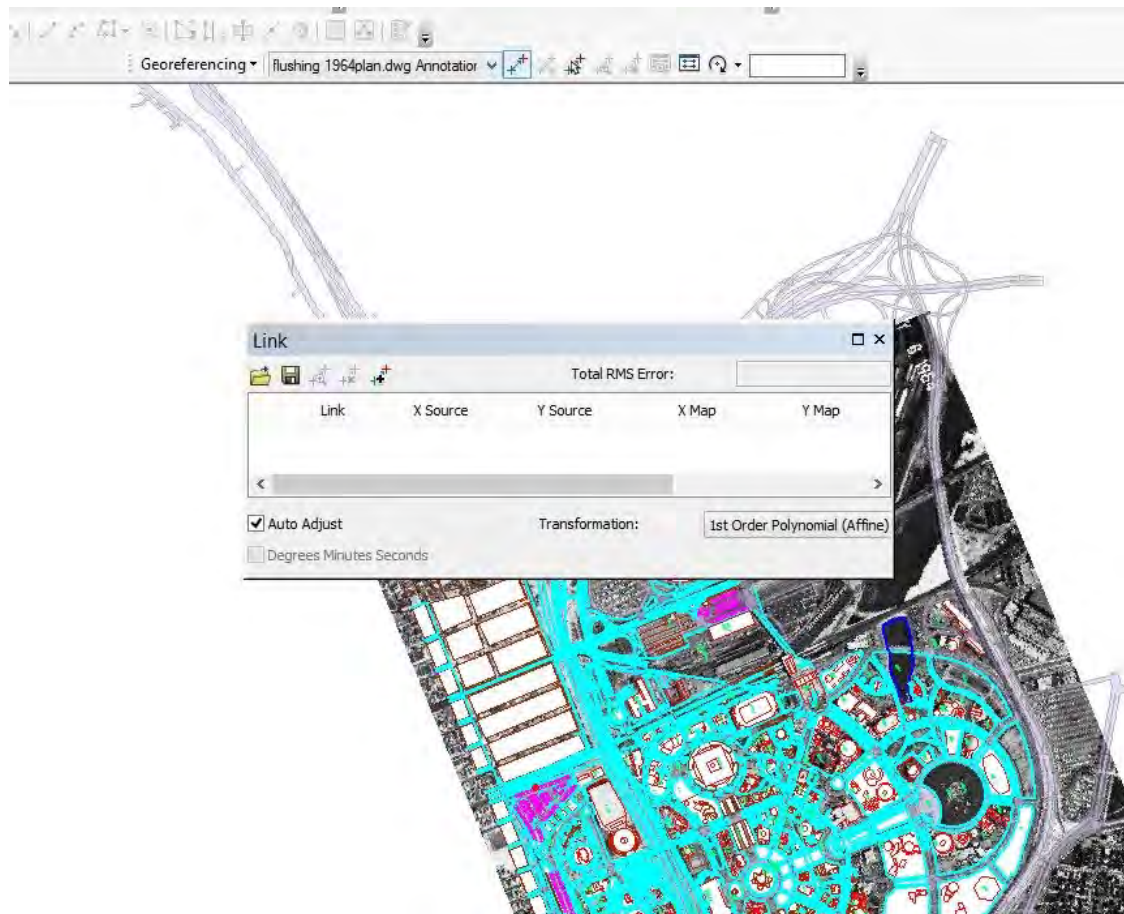
b) Assign Coordinates

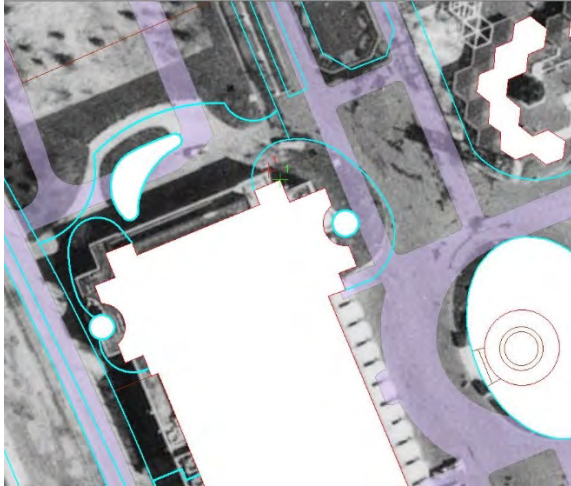
I used the Define Projection tool and assigned the same projection to the CAD file as the other shapefiles for my project. Doing this allowed the file to be spatially located. In this case, the files still did not align.

c) Georeference the File

The CAD drawing needed to be aligned to other shapefiles. Since the data sources for both files were different, geo-referencing was a problem. Consequently, we imported a historic aerial of the 1964 world fair and aligned it first with the existing shape files using the geo-referencing tool.

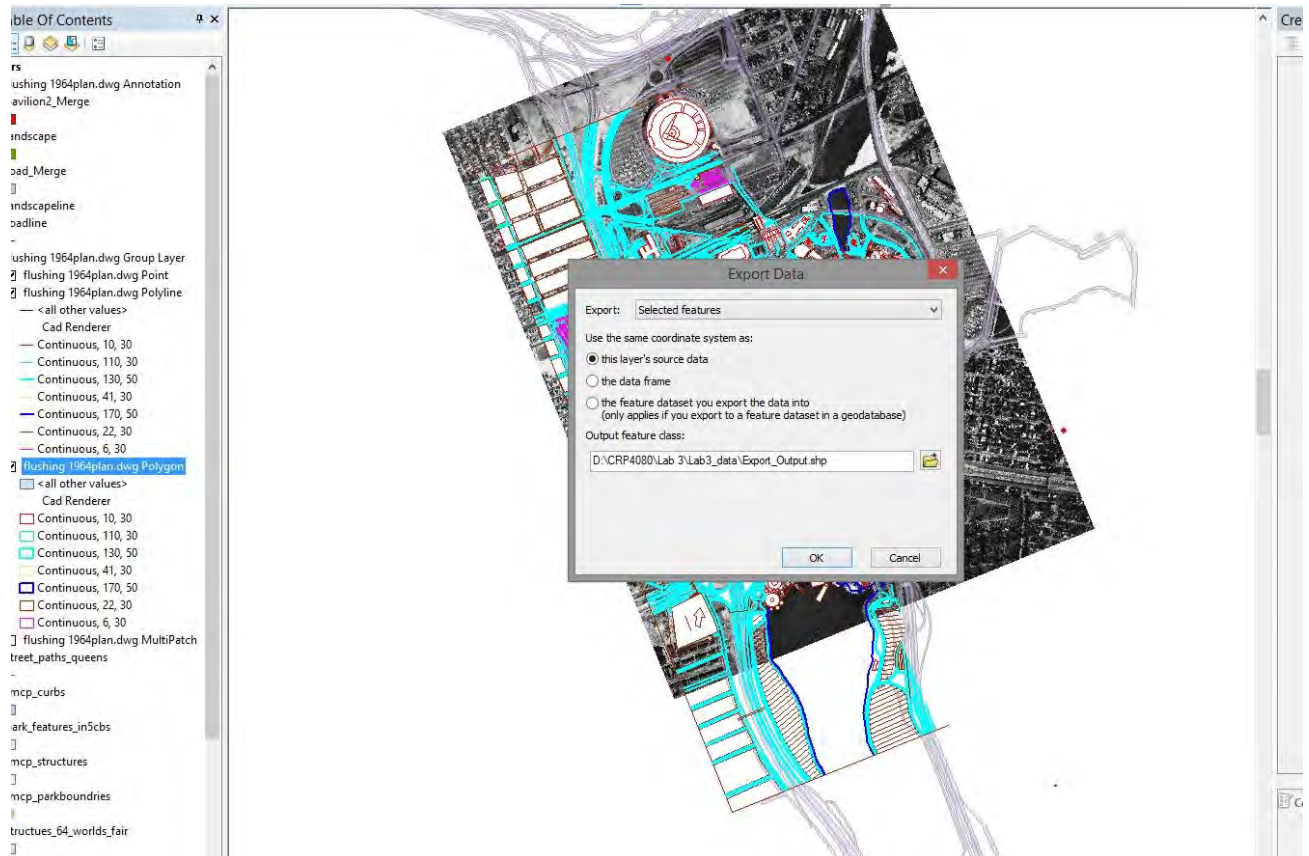
We used four points on the outer edges to orient the plan. We then used the same method using parallel key points like the building edges to align the CAD drawing with the rest of the image.





d) Converting given layers into separate shapefiles

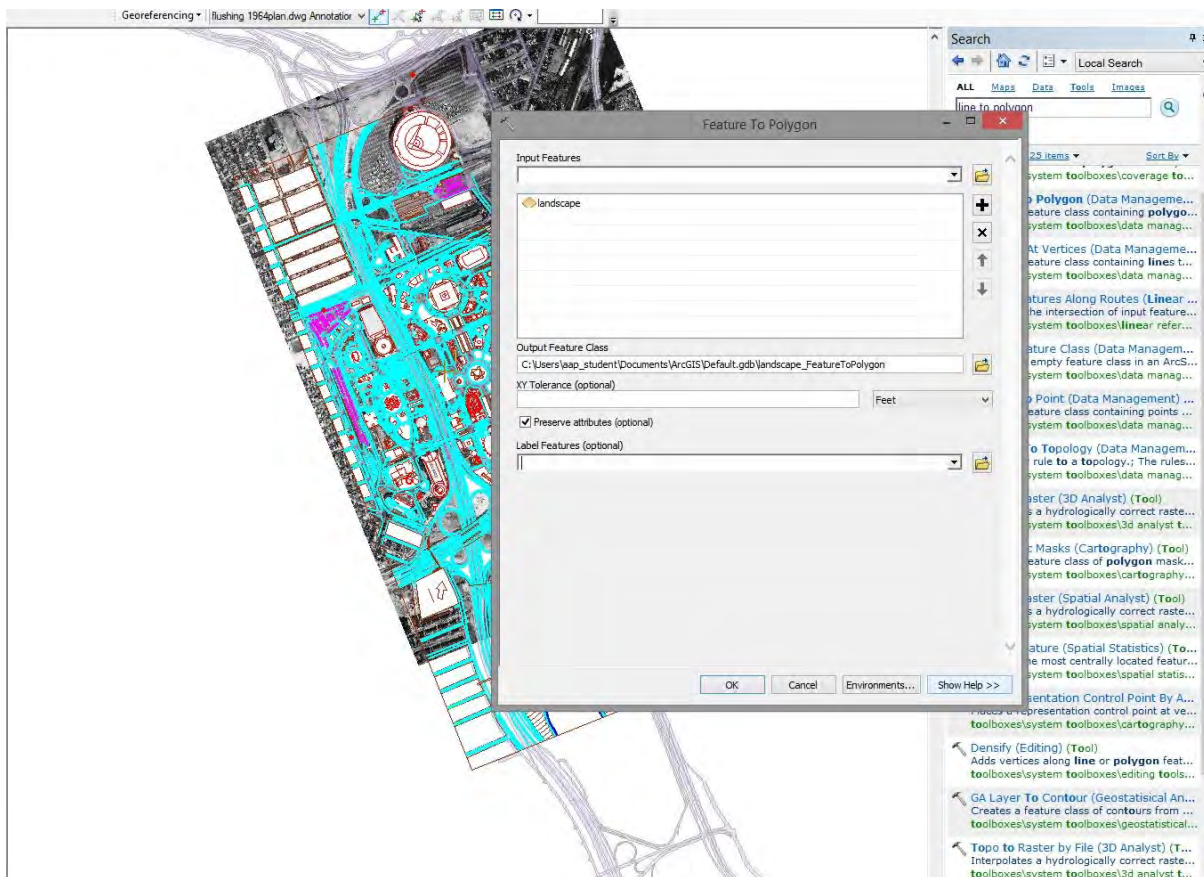
The assigned layers to the files did not manifest directly when the file is imported in ArcMap. The features have to be selected and saved as a shapefile. This can be done by selecting features by attributes. I used the SQL 'Layer=pavilion' to select all attributes drawn as pavilion. I did this for all the drawing features and saved the selected features as a separate shape file using "Export and Save as shp file."



e) Converting separate shapefiles into polygons and merging the files

All line and polygon features needed to be converted to polygon format for the shapefiles to be usable in GIS. The individual layers extracted from the CAD drawing needed to be converted to a polygon format. This was done using the Feature to Polygon tool. Each of the extracted layers needed to be converted to polygon format to be merged.

I then selected various shapefiles and merged them into a single layer. For example, all shapefiles consisting of the landscape features were merged in to a single shapefile. A similar process was repeated for other layers like pavilions.



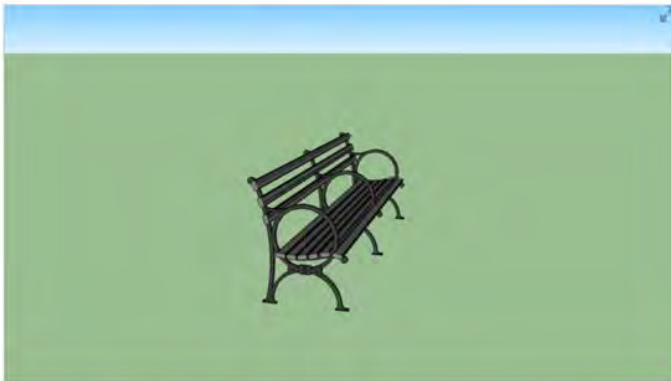
Populating Historic 1939 and 1964 Bench Types with CityEngine: A Short Introduction to CE Rule Script

This section describes how we populated the 3D model with two bench types from the 1939 and 1964 world's fair. These benches are historic resources that are integral to the Flushing Meadows Corona Park landscape.

In order to do this, we needed three main sources of data:

- A GIS shapefile with the locations of bench types as attributes.
- A 3D model of the 1939 bench type. [This was downloaded from Google 3D Warehouse.](#)
- A 3D model of the 1964 bench. This was [downloaded from Google 3D Warehouse.](#) The GIS bench point file is from the NYC Park Department.

NYC 1939 World's Fair Bench



One of NYC's standard benches, first designed and used in the 1939 World's Fair in Flushing Meadows.

Model of the 1939 world's fair bench. Source: 3D Warehouse.



Model of the 1964 world's fair bench. Source 3D warehouse.

We then followed the following steps:

1. Data about landscape features was obtained from the New York City Parks Department and a consultant who worked on a Framework Plan for the Park.



2. A map document called "Park Features" contained a Bench file. The attributes contained data about the Bench type.

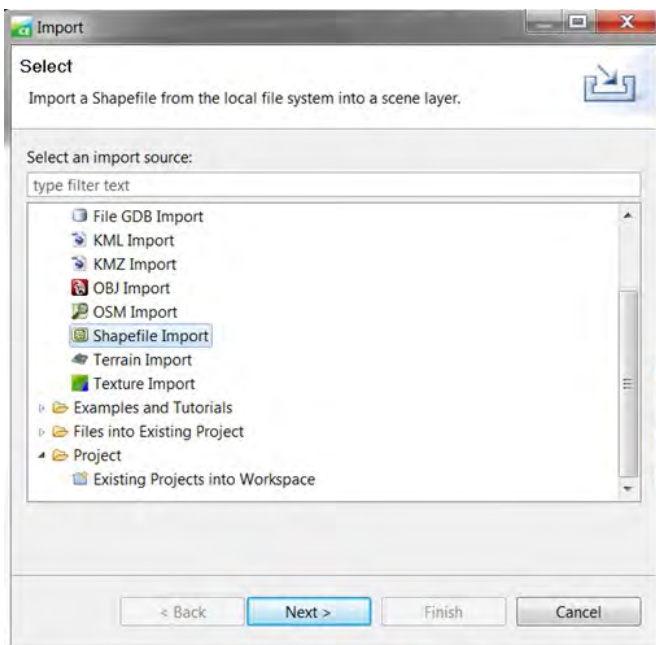
OBJECTID *	Shape *	Id	Units	Type
1	Point	0	1	WFB 64 W. GT 32
2	Point	0	1	WFB 64 31
3	Point	0	1	WFB 64 W. GT 32
12	Point	0	3	WFB 64 31
13	Point	0	5	WFB 64 31
19	Point	0	2	WFB 64 31
22	Point	0	2	WFB 64 31
23	Point	0	2	WFB 64 31
24	Point	0	2	WFB 64 31
25	Point	0	2	WFB 64 31
26	Point	0	3	WFB 64 31
29	Point	0	6	WFB 64 31
35	Point	0	1	WFB 64 31
38	Point	0	1	WFB 64 31
40	Point	0	5	WFB 64 31
62	Point	0	3	WFB 64 31
77	Point	0	2	WFB 64 31
78	Point	0	2	WFB 64 31
79	Point	0	2	WFB 64 31
861	Point	<Null>	2	WFB 64 31
862	Point	<Null>	2	WFB 64 31
863	Point	<Null>	2	WFB 64 31
875	Point	<Null>	2	WFB 64 30 (backless)
878	Point	<Null>	1	WFB 64 31
879	Point	<Null>	1	WFB 64 31

3. I copied the Bench layer and created a new shapefile with my initials, so that I could distinguish between original data and a modified shapefile.

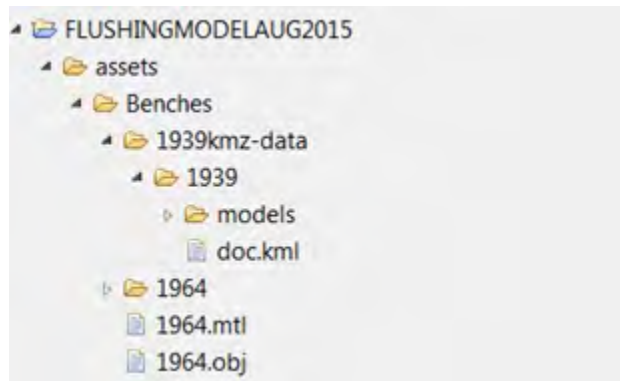
4. I added an Attribute field called “BenchType” that translated the Types in the Parks Database into a more easily understood field that I could use in CityEngine.

FID	Shape *	OBJECTID	Id	Units	Type	BENCHTYPE
547	Point	809	0	1	TYPE A 20	1939
548	Point	810	0	1	TYPE A 20	1939
549	Point	811	0	1	TYPE A 20	1939
554	Point	815	0	1	TYPE A 20	1939
555	Point	817	0	1	TYPE A 20	1939
556	Point	818	0	1	TYPE A 20	1939
557	Point	819	0	1	TYPE A 20	1939
558	Point	820	0	1	TYPE A 20	1939
559	Point	821	0	1	TYPE A 20	1939
560	Point	822	0	1	TYPE A 20	1939
561	Point	823	0	1	TYPE A 20	1939
562	Point	824	0	1	TYPE A 20	1939
563	Point	825	0	1	TYPE A 20	1939
564	Point	826	0	1	TYPE A 20	1939
565	Point	827	0	1	TYPE A 20	1939
566	Point	828	0	1	TYPE A 20	1939
567	Point	829	0	1	TYPE A 20	1939
568	Point	830	0	1	TYPE A 20	1939
569	Point	831	0	1	TYPE A 20	1939
570	Point	832	0	1	TYPE A 20	1939
571	Point	833	0	1	TYPE A 20	1939
572	Point	834	0	1	TYPE A 20	1939
573	Point	835	0	1	TYPE A 20	1939
574	Point	836	0	1	TYPE A 20	1939
575	Point	837	0	1	TYPE A 20	1939

5. I imported the shapefile into the scene.



6. In the Assets folder of my Project, I copied the 1939 and 1964 bench models:



7. I created a new rule file by right clicking the "rule" folder on the left column and clicking new rule file.

```
BENCHESv2.cga
/**
 * File:    BENCHESv2.cga
 * Created: 29 Jul 2015 14:27:34 GMT
 * Author:  Jennifer Minner
 */

version "2015.0"

@range ("1939", "1964")
attr BENCHTYPE = "1964"

@range (0,360)
attr angle = 0

@StartRule
BENCHES -->
    case BENCHTYPE == "1939"      :
        s(0,2,0)
        i("assets/Benches/1939kmz-data/1939/models/untitled.dae")
        r(scopeCenter,0,angle,0)

    case BENCHTYPE == "1964"     :
        s(0,2,0)
        i("assets/Benches/1964.obj")
        r(scopeCenter,0,angle,0)

    else: BENCHTYPE.
```

Note: Since CityEngine has a large collection of rule scripts from both their own developers and users, we can always refer to their rule scripts rather than write our own script from scratch.

The CityEngine rule file is based on Python scripting. However, it has its own grammar that is sometimes quite different from standard Python. In the following part, I will explain the bench rule we used to place the benches line by line.

(The ** mark means comments and explanations to the script)

version "2015.0"

**This is the version of CityEngine used to create the rule.

@range ("1939", "1964")

Attr BENCHTYPE = "1964"

** The key word "attr" will define a variable or attribute that we can refer to and adjust in our model. This code basically indicates that there are two attributes under BENCHTYPE that CityEngine should pay attention to when populating models in the scene. These are 1939 and 1964. There are other bench types in the shapefile, but they will be ignored if they have attributes other than 1939 and 1964. 1964 is defined as the default value.

attr angle = 0

** For this one, I created an attribute called angle which is later used to define the orientation of the benches. The attribute created here will also appear in the inspector which will allow us to change value for each single model generated by this rule. Here we just define the angle to a default value of 0. However, we change the value of angle for any single bench later and rotate the bench models in order to make them face the correct way.

See <http://cehelp.esri.com/help/index.jsp> for example and more explanation.

@StartRule

** This marks the start of the real rule. This indicates that we are getting down to business after defining attributes. Code from here on, tells CityEngine what should happen with the attributes.

BENCHES ->

** This is the name of this rule. Sometimes there are multiple sub-rules in a rule set. Each sub-rule is started with a "->" mark which is unique in CityEngine.

case BENCHTYPE == "1939" :

s(0,2,0)

i("assets/Benches/1939kmz-data/1939/models/untitled.dae")

r(scopeCenter,0,angle,0)

**"case" tells the computer to populate the scene with the 1939 model located here: assets/Benches/1939kmz-data/1939/models/untitled.dae, if the attribute BENCHTYPE = 1939.

s(0,2,0)

** The s(float xSize, ySize, zSize) operation sets the size vector.

** See <http://cehelp.esri.com/help/index.jsp> for example and more explanation.

i(...)

** The i(geometry path) operation inserts the model of the geometry asset.

r(scopeCenter,0,angle,0)

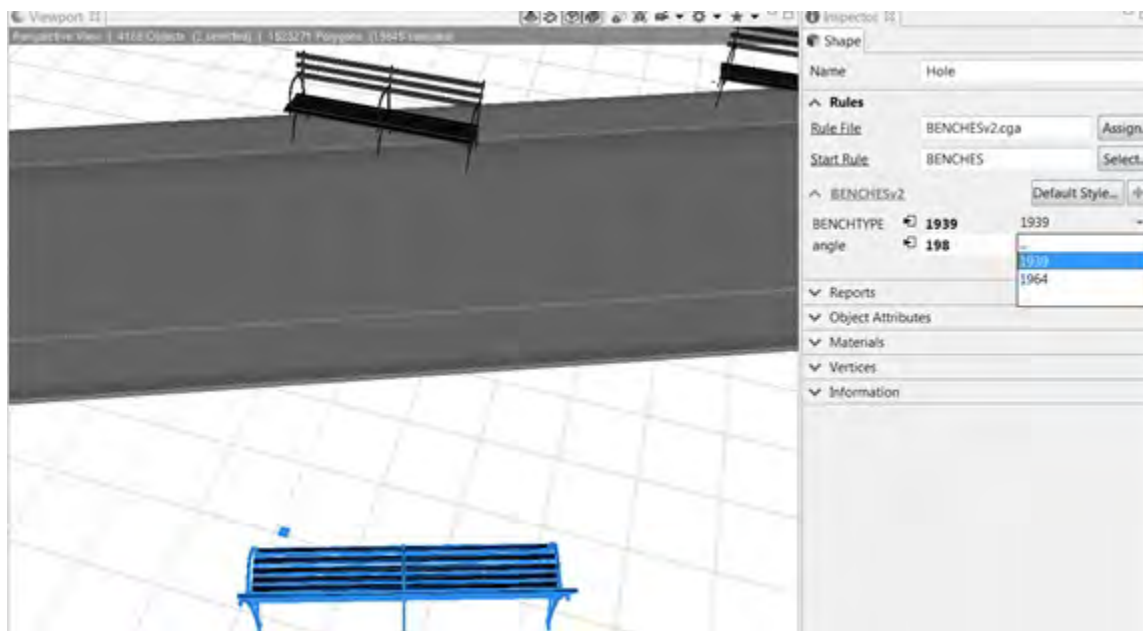
** The rotate operation rotates the model around the scope center. Parameters "0, angle, 0" are angles in degrees to rotate about each axis.

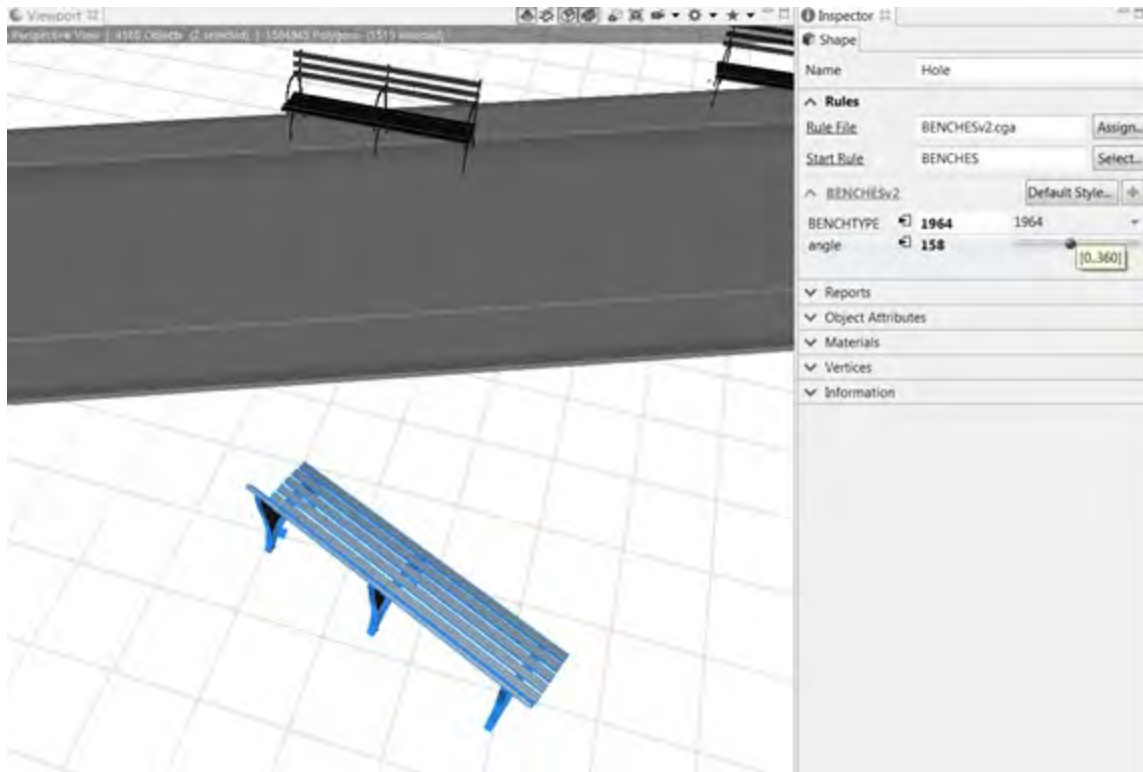
See <http://cehelp.esri.com/help/index.jsp> for example and more explanation.

** This is the end of this rule file.

The above is an introduction to some basics of CE rule file. After creating your own rule file, you just need to right click the layer you want to apply the rule and select apply rule.

Once the rule is applied, I can select individual benches and modify either the bench type or the angle.



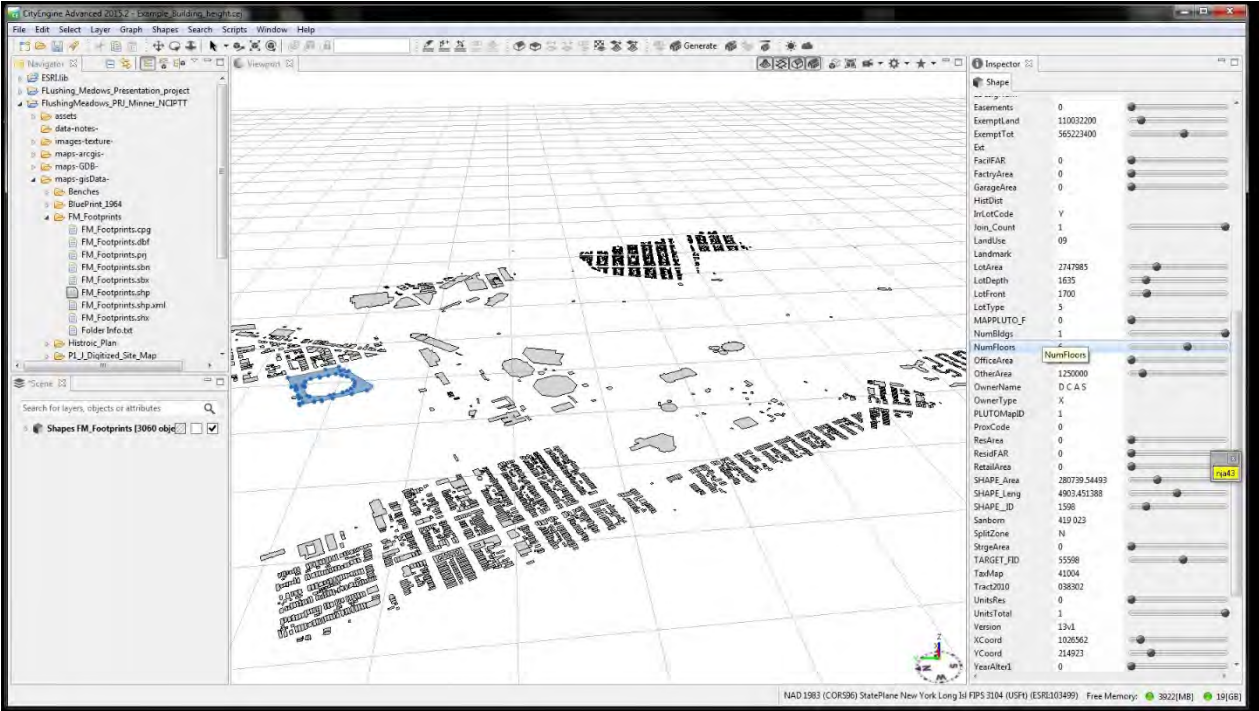


If I find or create a better 3D model for either type of bench, I can copy and paste into my “Asset” folder and regenerate all of the models.

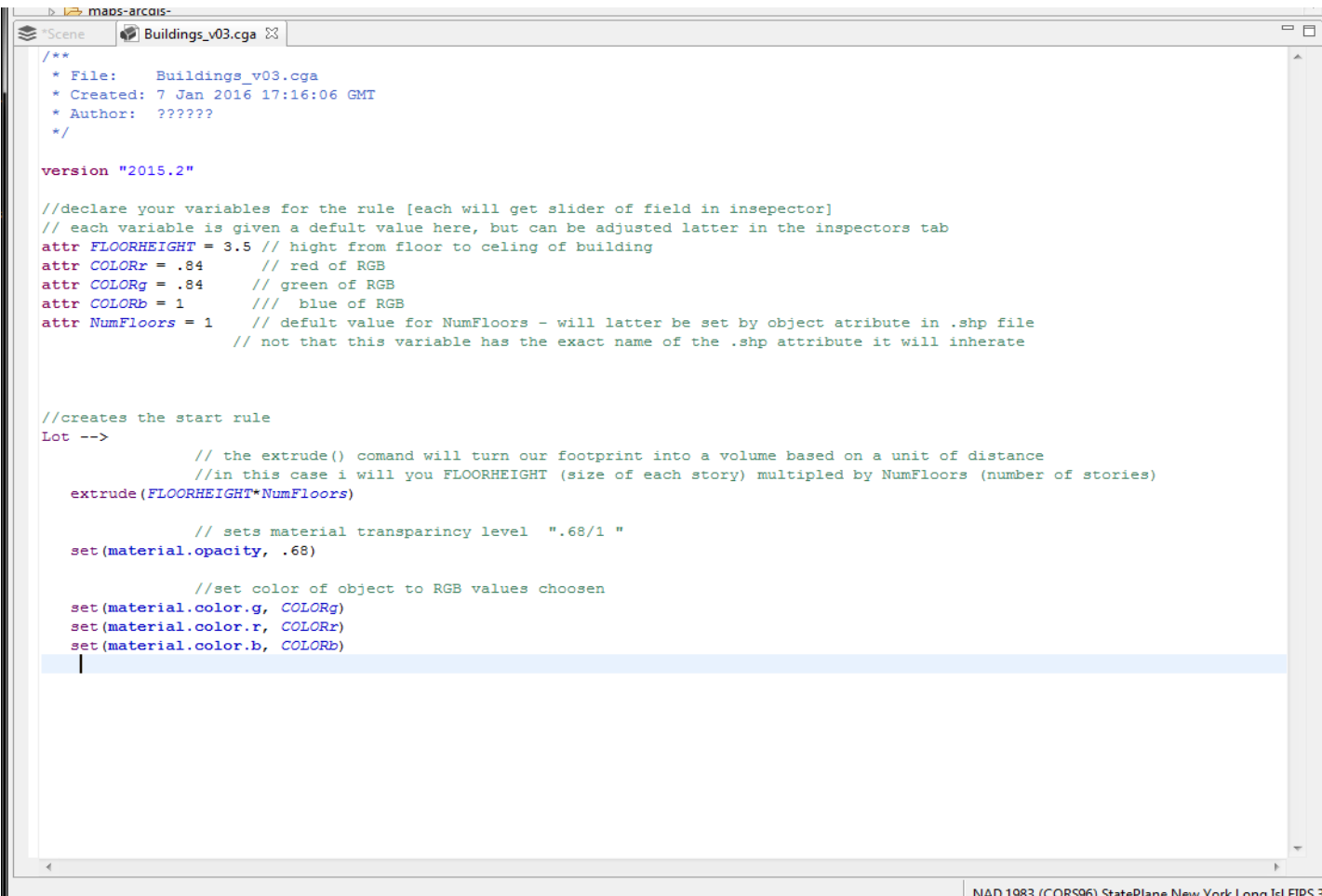
Extrusion of Building Shapes

By Nico Azel

A shapefile was created with outlines of buildings from multiple time periods. Each feature in the shapefile was coded with the year built and year demolished. The shapefile was added to a CityEngine Scene.



2. A new .CGA rule file was created, in this case, it allows for color and floor height to be specified and takes the number of floors to be placed from the shapefile (.shp) data.



```
maps-arcais-
Scene Buildings_v03.cga
/**
 * File: Buildings_v03.cga
 * Created: 7 Jan 2016 17:16:06 GMT
 * Author: ??????
 */

version "2015.2"

//declare your variables for the rule [each will get slider of field in insepector]
// each variable is given a default value here, but can be adjusted latter in the inspectors tab
attr FLOORHEIGHT = 3.5 // hight from floor to celing of building
attr COLORr = .84 // red of RGB
attr COLORg = .84 // green of RGB
attr COLORb = 1 // blue of RGB
attr NumFloors = 1 // defult value for NumFloors - will latter be set by object attribute in .shp file
// not that this variable has the exact name of the .shp attribute it will inherate

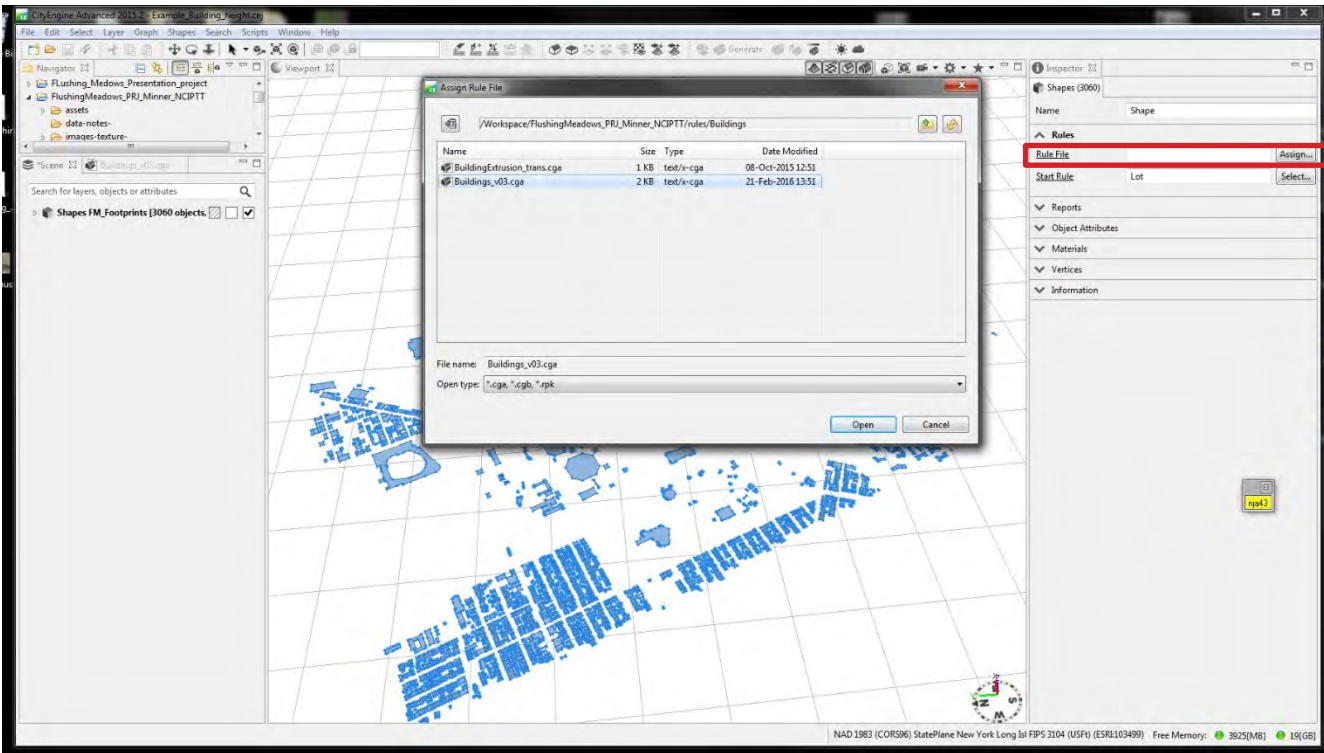
//creates the start rule
Lot -->
    // the extrude() comand will turn our footprint into a volume based on a unit of distance
    //in this case i will you FLOORHEIGHT (size of each story) multiplied by NumFloors (number of stories)
    extrude(FLOORHEIGHT*NumFloors)

    // sets material transparancy level ".68/1 "
    set(material.opacity, .68)

    //set color of object to RGB values choosen
    set(material.color.g, COLORg)
    set(material.color.r, COLORr)
    set(material.color.b, COLORb)
```

NAD 1983 (CORS96) StatePlane New York Long Id FIPS 3

3. All objects imported from the .shp are selected and assigned the new rule.



4. The declared 'attr' variables appeared within the inspector window under the heading of the rule's name.



a. this will be in the inspector for any shapes that have had the rule applied to them

b. We can then use these sliders to adjust the value for any selected shapes

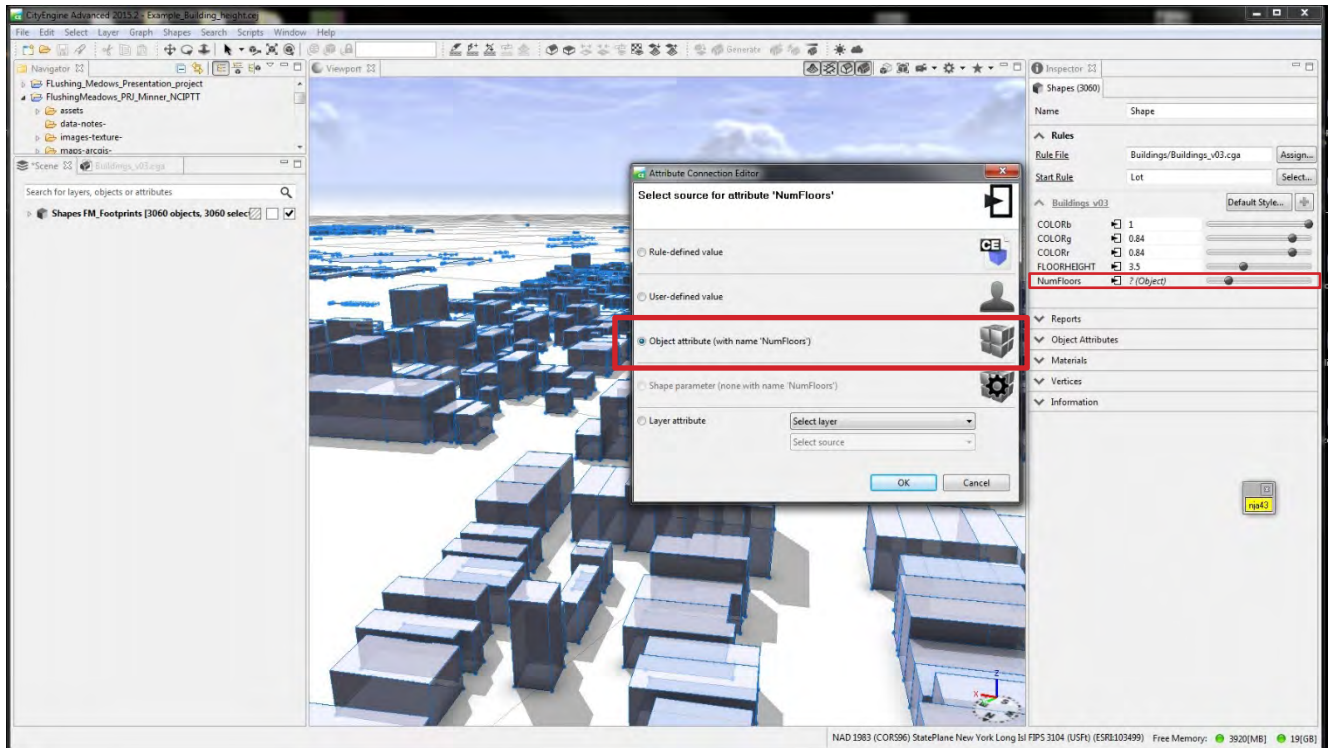
c. We click the generate button at the top of the screen to visualize the results of applying the rule

5. We ensured that the 'attr' variables link to .shp attributes for given shape

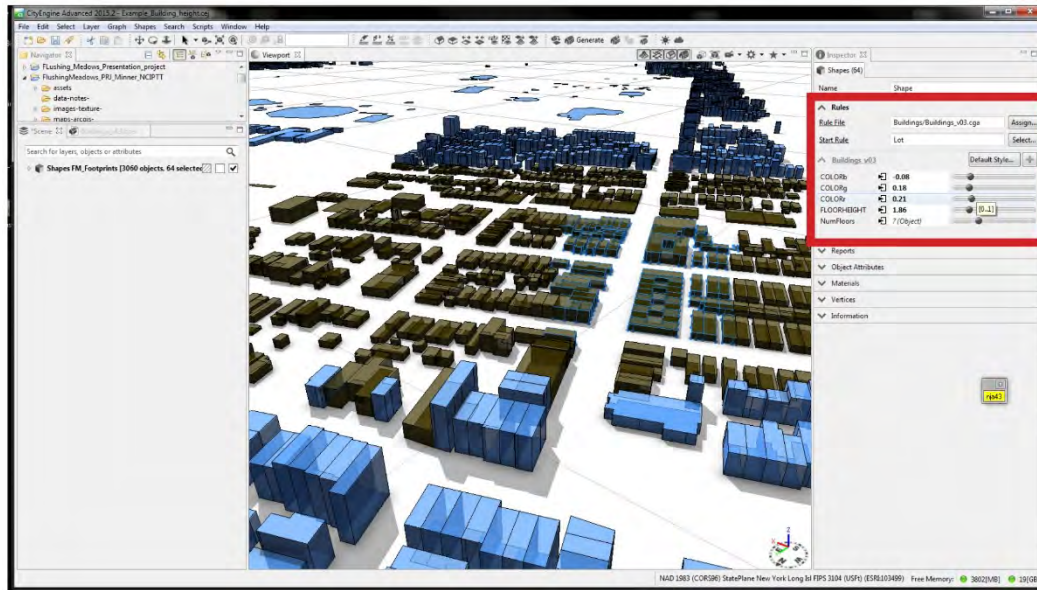
a. next to the 'NumFloors' variable listed with the rule's other attributes and Sliders, we clicked the button with a black triangle pointing to a white box between the label and the slider.

b. we choose the option "Object attribute (with name 'NumFloors') and hit 'ok'

c. We re-generated selected layers.



6. The user can then adjust the 'attr' sliders and see the effect.



See Appendix C for a CityEngine script example.

Time-based Generation of 3D Models and Building Footprints

By Jennifer Minner, Nico Azel, and Yanlei Feng

A 'Pavilion Placement Rule' was created for placement of 3D models of buildings and extruding footprints to create the building envelope or massing of buildings. Although it is called the "Pavilion Placement Rule," this set of rules was used to display all buildings in Flushing Meadows Corona Park or in proximity to it (not just world's fair pavilions). According to the rule, 3D models appear or building footprints are extruded (if there is no available 3D model) according to a display date that can be set.

A shapefile with the footprints of all known buildings in and around the park was created. Building construction and demolition dates, as well as height are attributes in the shapefile. The shapefile was created by merging multiple sources, including a database of building footprints for the pavilions from the 1939-40 and 1964-65 world's fairs as well as from MapPluto, a database of all New York City land records.

The resulting rule produced a CityEngine Desktop display that looks like the image to the right. See Appendix C for the CGA rules. By selecting all building footprints imported into CityEngine, 3D models and extruded building footprints appear according to the underlying attributes in the shapefile. Additional rules created controls to help position and scale 3D models dynamically.

Creation of the rule was a demonstration of 4D functionality in CityEngine. Unfortunately, the rules only work in the desktop version of CityEngine and not in webscenes. See Appendix D for the underlying CGA rules.



Controls created for time-based display of building footprints

Mapping and Modeling Trees

By Geslin George and Jennifer Minner

Trees may be significant historic resources and are often integral to taking a cultural landscapes approach to preservation and planning. Historic trees dating to the 1939 world's fair remain a significant part of the contemporary landscape of Flushing Meadows Corona Park. We set out to include trees in our landscape analyses and 3D modeling efforts.



Photo of 1939 world's fair landscape showing how formal plantings of trees related to fountains, sculptures and buildings. Image from Thomas Campanella's collection.

A report entitled *Preparation of the Site for the World's Fair 1964-65. Supplementary Report 1 (1964)* states:

The trees within the lease area, particularly those in formal rows, are of great value to the park and should prove of value to the Fair. They have grown for over twenty years on the site and hence are mature: they could not be replaced at their present sizes. We recommend that a contract be let for the replacement of trees that have died and have been removed: this refers to those in formal rows. The replacements should be as large as practicable. The contract should provide for having the trees selected and root-pruned, so they may develop

new roots over two growing seasons, before moving them to the Fair site. ***It is recommended that the Fair Corporate make use of all of the trees on the site that were planted for the 1939-40 Fair.*** Where they are situated informally in open areas it may be necessary to move a number out of the way of proposed structures. ***The trees along walks and roads should be retained in their present location. No large trees should be destroyed without permission from the Department of Parks.*** [Emphases added.]

All existing trees are shown on the aerial photograph on page 6 of the report.

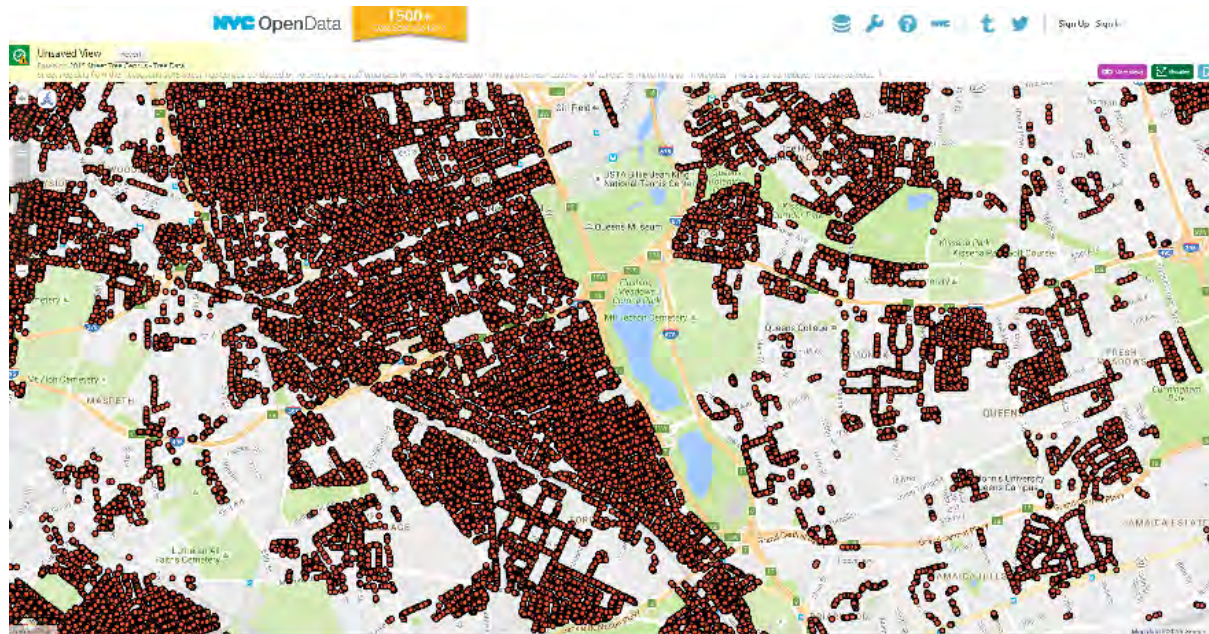


This photograph of the 1964 world's fair shows a variety of tree sizes, indicating both new plantings and areas with larger, mature trees leftover from plantings from the earlier fair. Image from Thomas Campanella's collection.

Unfortunately, the aerial photograph referenced in the site preparation report was missing. We did have a large stock of images from Thomas Campanella's collection of world's fair photographs, as well as the thousands of online and archival images of the 1939 and 1964 world's fairs that could be used for tree identification. However, with photographs, it is difficult to pinpoint the exact geographic location of remaining trees with any amount of precision, although building volumes of former world's fair pavilions did help in creating relative approximations.

We checked for an existing tree inventory for the park. The New York City Parks Department did not have GIS data for tree points or detailed records in other formats that could be shared with us. We then checked the New York City GIS portal for available open data on trees. We found that street trees were mapped for areas all around Flushing Meadows Corona Park, but not within the park

boundaries. An additional GIS dataset was available for reforestation planting areas and included polygons showing areas where new trees were planted. However, these were not locations in the historic core of Flushing Meadows and they did not show individual tree locations, only the general area of plantings.



Screen Shot of 'Census of Street Trees 2015' on NYC Open Data Portal.

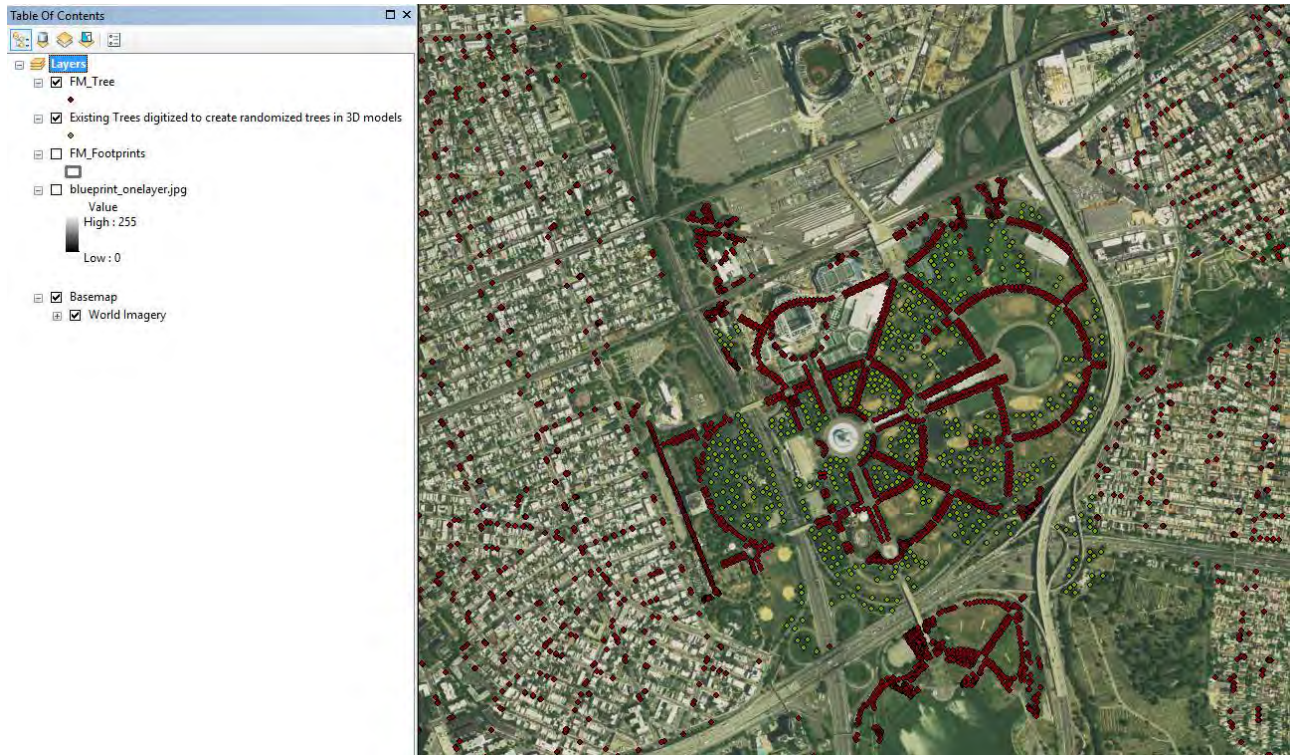
A shapefile was created containing data collected from maps, site plans, aerial photos and the field visit described below. First we used the NYC Open data portal with street tree data in neighborhoods surrounding the park. By starting with this dataset, we ensured that the shapefile had the attributes common to the street tree census, although most of these columns of information are blank for trees in Flushing Meadows. The second set of data was from a Demolition Grading Plan of 1965, which we georeferenced and used to add points to the map. We also used additional site maps with plantings that were found in the New York Public Library Archives.

We conducted additional background research into the types of trees that are common to New York City Parks and likely to be on site. This includes the London Plane Tree or *Platanus Acerifolia*. The New York City Department of Parks and Recreation has identified the London plane tree as the most common street tree in New York. The London plane tree is exceptionally resistant to disease and tolerant of urban conditions (e.g., soil compaction, air pollution). The London plane tree may be of hybrid origin, representing crosses between the American sycamore and Oriental plane tree (*Platanus orientalis*). The symbol of the Parks department is a cross between the leaf of the London plane and a maple leaf. It is prominently featured on signs and buildings in public parks across the city. The London plane tree is on the NYC Parks Department's list of restricted use species of street tree planting because it constitutes more than 10% of all street trees. As a side note: London plane trees (and other *Platanus* species) are sometimes referred to as itchy ball trees. During the winter and early spring, the tree's ball like clusters of fruits begin to break apart, releasing hairs that can be an irritant if they come into contact with skin or are breathed in. The hairs on young leaves can be similarly irritating.

On July 23, 2016, the research team visited Flushing Meadows to gather data on trees and light fixtures. Many trees were initially identified using the mobile app 'leafsnap,' which is an electronic field guide for tree and plant species in NYC and Washington DC. Their online website is www.leafsnap.com. The team took notes on paper maps showing digitized tree points.



Geslin George appreciating the trees during the data collection field trip.



Screenshot of Dataset in ArcGIS. Dataset created by Geslin George and Xiao Shi.

The shapefile was then imported into CityEngine. Models of specific tree species were downloaded and generated at appropriate points.

In addition, another dataset was created that shows the approximate location of trees, rather than exact locations or species. In the image above, this dataset is called 'Existing trees used to create randomized trees in 3D models.' Using procedural modeling, trees were filled in based on an observed species mix, but the points are not exact.

Results and Discussion

The process of evaluating CityEngine resulted in the creation of multiple webscenes. The webscenes can be accessed via links from this document as well as our research blog at <http://blogs.cornell.edu/3dgis/>. In addition, very large project files were created in CityEngine that contain collections of 3D models and 2D GIS data.

Through this process we critiqued CityEngine as a 4D design tool for preservation. The following are some key issues:

- CityEngine is not intuitive. Its graphical interface seemed only marginally so, even for the graduate research assistants working with it who had substantial 3D modeling experience with other software packages.
- CityEngine loses many of the functionalities of a 2D GIS. The most important and desired aspects of these functionalities concern the collection of 2D and 3D data, the ability to easily query attributes of the 2D data and 3D models, and standard spatial analysis tools available in 2D GIS.
- There is not a well-developed way to create an underlying database that includes user-defined attributes beyond basic aspects of the objects in CityEngine. It would be ideal for a preservation professional to be able to store user-defined information (string or text as defined by the user) and associate it not just with individual buildings, but with individual building parts (e.g. information attached to each column in the New York State Pavilion with information about its condition.)
- Attributes associated with objects in CityEngine apparently cannot be queried without custom scripting in CGA.
- Basic calculations, such as volume, building area, dimensions, etc. are not built in. This also requires scripting in desired tools, rather than functionalities that GIS users have come to expect.
- When bringing data from 2D GIS datasets or models from 3D applications, manual adjustments have to be made to align features such as buildings and landscape features with the terrain.
- Bringing in textured models from other applications such as SketchUp and Maya is not intuitive. Additional sessions were required to learn how to bring already textured models into CityEngine in such a way that their details were not stripped.
- Scaling from a relatively large area to a zone in the park requires separate models. Keeping aerials at a high resolution takes extra steps in ArcGIS in which many tiles must be mosaicked.
- Users must have substantial knowledge of other systems, including AutoCAD and ArcGIS. Creating a scene requires substantial use of these other tools.

Conclusions

In our evaluation of CityEngine at Flushing Meadows Corona Park, we had the opportunity to bring together spatial and temporal data in new ways, using new tools and methods. This was an exciting opportunity and the ability to bring together university and high school students, faculty, and professional planners was an important benefit to the project. In the project, we were able to think reflectively and critically about available 3D and GIS technology. We generated new GIS datasets and 3D scenes that can be used by other researchers and preservationists for Flushing Meadows Corona Park, as well as other heritage sites. We also documented CGA code that can be repurposed. We thought expansively about use cases in the context of cultural landscapes and historic districts.

Ultimately, we concluded that a fully functional 4D GIS platform that brings together the analytical capabilities of 2D GIS with new and enhanced abilities for 3D and temporal analysis remains a vision for the future. A platform that integrates interdisciplinary knowledge and the disparate methods that can inform preservation efforts will take additional development. Our intent is to encourage the field of preservation to articulate its needs, so that it can inform information technology related to geographic information systems, asset management, and building information modeling.

Acknowledgments

We would like to thank the National Center for Preservation and Training for generously supporting this research project.

Many thanks to the research assistants for this project: Xiao Shi, Yanlei Feng, Nicolas Azel, Feiyang Sun, Geslin George, Malcolm Cariddi, Ethan Rhee, Daniel Kenough. Thanks to all of the dedicated students in an urban design workshop and who informed our use cases. This includes Brian Byrd, Michael Catsos, Hector Chang, Rashmi Gajare, Gabriel Halili, Irene Hung, Daniel McKenna-Foster, Christine Ma, Isaac Robb, Robert Rivera, Rachel Shindman, and Taru.



We would also like to acknowledge members of the research advisory team: Thomas J. Campanella, Andre Hafner, and Michael A. Tomlan. Technical assistance was provided by Eric Brady, Todd Heckaman, and Nick Carrington of Bergmann Associates.

Thanks also to people who have shared their knowledge of Flushing Meadows Corona Park who includes, but not limited to: Matthew Silva, Lori Walters, Bob Balder, Sam Holleran, John Krawchuk, Marit Larson, Kathleen McCarthy, and Janice Melnick.

This report was developed under a grant from the National Center for Preservation Technology and Training, a unit of the National Park Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official position or policies of the National Park Service or the National Center for Preservation Technology and Training.

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Appendix A: List of Related Websites, Publications, Presentations

Research Blog

A World's Fair Landscape in Time. (2017) <http://blogs.cornell.edu/3dgis/>

Also, another course blog from a previous workshop that informed our use cases (2015): <http://blogs.cornell.edu/modernfootprints/>

Peer-reviewed Publications

Minner, Jennifer and Jeffrey Chusid. (2016) "Time, Architecture, and Geography: Modeling the Past and Future of Cultural Landscapes," *APT Bulletin* 47(2-3): 49-58.

Minner, Jennifer. (2017) Geodesign, Resilience and the Future of Former Mega-Event Sites. *Planning Support Science for Smarter Urban Futures*, Chapter: 8, Editors: Stan Geertman, Andrew Allan, John Stillwell, Chris Pettit. Springer: 135-152.

Presentations

Minner, Jennifer. (2017, forthcoming) Geodesign, Resilience, and the Future of Former Mega-event Sites. Computers in Urban Planning and Urban Management, Adelaide, Australia.

Minner, Jennifer and Jeffrey Chusid. (2015) *3D GIS and the Modeling of the Past and Future of Historic Districts and Cultural Landscapes*. Association for Preservation Technology, Kansas City, MO.

Additional Mention in:

Shapiro, Gideon Fink. (2015) "How Mount Vernon's HBIM Is Helping to Change Historic Preservation." in *Architect: The Journal of the American Institute of Architects*. Online version available: http://www.architectmagazine.com/technology/how-mount-vernons-hbim-is-helping-to-change-historic-preservation_o. Last accessed June 13, 2015.

Appendix B: Table 4. Additional Notes about Select 3D Modeling Tools

Application	Topography Notes	File Type/ Extensions	Interoperability (Transferability) of native file type to another file type	File types can be imported into application	Ability to import files into CityEngine	Crowdsourcing opportunity
CityEngine	<p>Can import DEM, but have to use values associated with color cells rather than actual values.</p> <p>Have to manually enter the minimum and maximum values that have calculated in ArcGIS by processing DEM</p>	<p>.cej</p> <p>3ws</p>	<p>Projects created in CityEngine are not easily exported outside of the ArcGIS Suite.</p> <p>Scenes may be exported as image captures in standard image file formats</p> <p>Various file types can be imported into a CityEngine project. This includes CAD renders and data in different formats</p>	<p>.dae .dxf .fbx .gdb .kml .kmz .obj .osm .shp</p>	<p>Yes - native file</p>	<p>CityEngine models can be directly uploaded online to ArcGIS Online and the CityEngine Web Viewer to be shared and viewed by the public and decision makers</p> <p>Viewers can manipulate the model by applying different conditions, turning on/off different layers, and running different scenarios</p>
AutoCad	<p>AutoCAD is not well suited to model and draw natural environments and landscapes.</p> <p>However drawings and models created in AutoCAD can be exported to other programs in which landscapes can be added.</p>	<p>.dwg (native file format for autocad) .dxf (interchange file format) .dwf</p>	<p>.dxf and .dwg are considered the standard file types for CAD drawings and models. As such they are supported by almost all CAD programs. However, files exported from AutoCAD may have certain features that are not supported in other platforms. In such instances drawings and models must be edited to remove incompatible features. Additionally, the complexity and number of 3D features in the drawing will further complicate the export and import of any CAD file.</p>	<p>AutoCAD allows the import of most file types from popular CAD programs. However, just like exporting AutoCAD files, certain features from other programs may not be supported by AutoCAD and such files may need editing.</p>	<p>Yes</p>	<p>Limited crowdsourcing opportunities among the public as licenses are required and expensive. The tools that are the strengths of the software are meant for use by professionals.</p> <p>More viable crowdsourcing opportunities among trained professionals particularly for peer editing and team projects</p>

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ArcGIS 10.3	<p>ArcGIS specializes in topographic modeling. Ranging from geographic usages such as analyzing the climate change by mapping and analyzing natural environments to population analytics through ArcGIS created city maps. The program can be utilized to created 2D or 3D models and maps that are interactive with associated datasets creating powerful simulations that collect additional data.</p> <p>3D maps can reach building and street level precision with some amount of detail. Individual buildings can be represented on the city scale but will not be as visually detailed as a CAD produced rendition. Additionally, CAD produced renditions may be imported by ArcGIS for incorporation into a specific map or project. In a geologic application features such as rivers, rock formations, and can be recreated with a high level of detail of information and data.</p>	<p>*.shp (shapefiles) are an umbrella term for different files types that store vector based geometric and attribute information of geographic features</p> <p>Shapefiles are constructed by combinations of the file types listed below: -.shp -.aih -.shx -.cpg -.dbf -.xml -.sbn -.prj -.sbx -.mxd -.fbi -.ixs -.fbx -.atx -.ain</p> <p>ArcGIS utilizes a geodatabase that stores spatial data, in particular files in the shapefile format. With the geodatabase entire projects may be stored in a single location. Doing so allows spatial features to remain tied to their respective attributes and data sets.</p>	<p>While shapefiles and the other file types utilized in ArcGIS are commonly found in other GIS programs, exportation of projects created in ArcGIS can be difficult due to the sheer volume of files that is found in most projects. The ArcGIS Data Interoperability extension may be used to facilitate the exportation of projects. However, at \$2500 the extension may be pricey for an independent user.</p> <p>Projects and maps may be simplified for exportation but in doing so some datasets and attributes may have to be exported separately in different file formats.</p> <p>ArcGIS Online offers a simpler format to create projects that are easier to work with and share with others.</p>	<p>ArcGIS allows for the import of datasets and text from other programs. The commonly imported file formats are GPX files and other shapefiles. Data is usually imported as CSV data.</p>	<p>Yes</p>	<p>Parameters may be set on maps and datasets that allow access to certain functions and information as defined by an administrator.</p> <p>ArcGIS offers ready-to-use basic features such as base maps that can be edited and manipulated by less experienced users.</p> <p>ArcGIS offers a wide range of apps that each perform different functions. These apps can range from helping to perform simple tasks such as adding a data point or specific point of interest to a preexisting map to more complex tasks such as creating an entire map or working with large datasets. All of the apps are compatible with one another allowing for integration of data and information between various users.</p>

Appendix B: Table 4. Additional Notes about Select 3D Modeling Tools

Application	Topography Notes	File Type/ Extensions	Interoperability (Transferability) of native file type to another file type	File types can be imported into application	Ability to import files into CityEngine	Crowdsourcing opportunity
ArcGlobe	<p>As a program specializing in topographical analysis there are a wide assortment of tools and features unique to ArcGlobe.</p> <p>Topography can be further analyzed from a variety of angles and perspectives under different conditions.</p> <p>The animations created in ArcGlobe can also be used to visual physical topographical changes, as well as changes in data related to topography based in the form of 3D models and graphs.</p>	<p>.3dd</p> <p>3D views in ArcGlobe can be captured as 2D images that can be exported in standard image formats e.g.</p> <p>.emf .jpg .eps .png .ai .tif .pdf .gif .svg .bmp</p> <p>.aga (ArcGlobe Animation)</p>	<p>.3dd is exclusively used within ArcGIS and its extensions.</p> <p>The aforementioned image formats are commonly used in many different programs</p>	<p>ArcGlobe manipulates data imported from the same geodatabase as ArcGIS utilizing shapefiles, raster data and vector data of varying formats.</p>	<p>Not tested</p>	<p>Similar to ArcGIS, ArcGlobe's datasets can be altered by anyone with access to the specific file. In doing so those with access can add data points to create an expansive dataset that adds further depth to many projects.</p>

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ArcScene	<p>ArcScene is specifically used to capture and render topographical features. Geographic topographical features ranging from elevation to magnetic fields can be accurately modeled with through input datasets to create basemaps and various layers.</p> <p>Raster data can be uploaded into a project as a unique layer and superimposed on basemaps to add further detailed visuals.</p> <p>For urban scenes 3D renders of buildings created in CAD programs can be uploaded to produce a new layer specifically consisting of buildings and other 3D polygons which is then superimposed on a basemap.</p> <p>Particularly useful for rendering subsurface data and volumes</p>	<p>.sxd</p> <p>ArcScene.exe</p> <p>3D views in ArcScene can be captured as 2D images that can be exported in standard image formats e.g.</p> <p>.emf .jpg .eps .png .ai .tif .pdf .gif .svg .bmp</p>	<p>Both extensions are exclusively used by ArcScene and cannot be exported easily to other programs</p> <p>The aforementioned image formats are commonly used in many different programs</p>	<p>ArcScene manipulates data imported from the same geodatabase as ArcGIS utilizing shapefiles, raster data and vector data of varying formats.</p>	<p>Not tested</p>	<p>Limited to none.</p>
ArcGIS Pro	<p>3D scenes can display topology (similar to ArcScene and ArcGlobe).</p>	<p>.aprx is the equivalent of a map document file in ArcMap.</p>	<p>Cannot export the .aprx to .lyr, .lpk, .mxd, .sxd, or .3dd (commonly used in other ArcGIS apps).</p>	<p>Commonly used GIS formats.</p>	<p>Not tested</p>	<p>Not fully evaluated.</p>

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Google Earth	Comprehensive data and images in 3D and 2D of most if not all surfaces on the planet	-kmz	<p>Google Earth Pro has the capacity to directly import most GIS data</p> <p>There are other tools available to convert GIS data to KML for use in Google Earth</p>	<p>-KML</p> <p>-GIS Data, both vector and raster</p> <p>-ESRI Shape files in the .prj format</p> <p>-GEO TIFF's Tiff World File, .tfw</p> <p>-GPS files/data, i.e. .gpx</p> <p>-DEM(Digital Elevation Model) file types</p> <p>-Sketchup files</p>	Yes-geotagged snapshots of a selected region	<p>As a standalone program Google Earth is useful for presentations</p> <p>Most useful when use is combined with other programs</p>

<p>Maya</p>	<p>May be used to model topographical features, however not the most efficient or appropriate program for this use</p>	<p>-The default file type for rendered images is the Maya Image File Format (Maya IFF)</p> <p>-Maya can also save images in standard image formats for easy exportation</p> <p>- .ma, .mb</p> <p>- .tif, .gif, .bmp</p> <p>-While the Maya defaults are .ma and .mb, projects may be saved in the standard file type for each respective project type (e.g. CAD, 3D image, animation, Raster, bitmap, vector)</p>	<p>.ma and .mb files must be converted to more common, universal file types for interoperability with most programs</p>	<p>Maya allows for the import of a wide variety of file types. Extensions allowed for importation:</p> <ul style="list-style-type: none"> -ma (Maya ASCII) -eps -mb (Maya Binary) -ai (Adobe Illustrator) -mel -dfx -obj -iges -editMA -editMB -mov <p>Plug-ins called translators may be downloaded to expand the library of files that can be opened, saved, imported and exported through Maya. File types allowed imported through the use of translators:</p> <ul style="list-style-type: none"> -fbx -wire -stl -dae -jt -prt -abc -prt -wire -model -stp -cat-product -sldprt 	<p>Files must be converted into a supported format -most likely .obj or .dxf</p>	<p>Limited to none.</p>
-------------	--	---	---	--	--	-------------------------

-ipt -iv
-anim -csb
-apf -flt

Appendix B: Table 4. Additional Notes about Select 3D Modeling Tools

Application	Topography Notes	File Type/ Extensions	Interoperability (Transferability) of native file type to another file type	File types can be imported into application	Ability to import files into CityEngine	Crowdsourcing opportunity
Revit (BIM)	Capacity to create basic topography surrounding a building	.rvt -supports and utilizes most CAD and image file types -e.g. DGN, DWF, DWG, DXF, IFC, SAT and SKP	-rvt is a BIM/CAD file type exclusive to Revit -projects may be exported in standard image or CAD file formats	-Most standard CAD and image file types can be imported -Other importable file types include: -ODBC, HTML, TXT, MDB, XLS, gbXML	No - must export as obj	Limited to none.
Rhinoceros 3D (Rhino)	Rhino can be used to create realistic and incredibly detailed 3D topographies, however, the accuracy of the models will be based on the users input and is not backed by data	Rhino operates with most standard CAD and image file types Native format is .3dm	.3dm files are native and exclusive to Rhino -projects may be exported in standard image or CAD file formats	-Most standard CAD and image file types can be imported	.3dm files cannot be imported by CityEngine -files must be exported as .obj	Limited to none.

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Application	Topography Notes	File Type/ Extensions	Interoperability (Transferability) of native file type to another file type	File types can be imported into application	Ability to import files into CityEngine	Crowdsourcing opportunity
Sketchup	Topographical features can be created in SketchUp, however the level of detail is limited compared to other more robust CAD software and is not supported with data such as topographical models created via GIS	Native format is .skp Google Earth terrain .dwg and .dxf files can only be exported with Sketchup Pro	-skp is exclusive to Google Sketchup, however files can be directly exported to Google Earth	-Most standard CAD and image file types can be imported to Sketchup	Files may be exported from sketch up as .obj files, however, this is a Sketchup Pro only feature	Sketchup is an excellent program for crowdsourcing ideas and plans. Presentations are easy to make that display the intricacies of a project via animated walk throughs and flyovers Sketchup's ease of use and accessibility to the public encourages hands on public participation in projects
Tygron Engine	Not fully evaluated.	Project	Unknown	Shapefiles that have been converted to GeoJSON or uploaded to ArcGIS Online.	No	Originally created in the mold of an online multiplayer videogame, Tygron engine is intended for crowdsourcing as the community works together to improve and build models using GIS data to simulate and solve planning challenges in a virtual environment

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Application	Topography Notes	File Type/ Extensions	Interoperability (Transferability) of native file type to another file type	File types can be imported into application	Ability to import files into CityEngine	Crowdsourcing opportunity
Unity	<p>Topographical features can be created in great detail in Unity in a manner similar to other 3D modeling software, however these models are not like GIS based models and are not necessarily backed by hard data (although models can be used to visualize data, the program itself does not interact with the raw data) and are often times instead the designer/users personal designs or virtual models of real sites for the purpose of visual presentation and game environments, not research</p>	Not evaluated.	Not evaluated.	<p>Files from popular 3D modeling programs such as Maya and Blender.</p> <p>This is true for any 3D modeling software that is integrated with the FBX plugin on Windows systems</p>		Limited to none.

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Application	Topography Notes	File Type/ Extensions	Interoperability (Transferability) of native file type to another file type	File types can be imported into application	Ability to import files into CityEngine	Crowdsourcing opportunity
3D Max	Can create very detailed landscapes	.3ds, .max	.3ds can be imported into sketchup, solidworks, .max unity	large about of files can be imported into 3ds max (http://knowledge.autodesk.com/support/3ds-max/learn-explore/caas/CloudHelp/cloudhelp/2015/ENU/3DSMax/files/GUID-566E59EE-8221-4AC6-824B-5062C5AE0B32-htm.html)	No, not directly	Licensing is free for students, otherwise very expensive.
Minecraft	topography can be done, but to a 1m3 scale	.schematic (map/object file)	.schematic is exclusive to minecraft	.schematic	No	Huge crowdsourcing possibilities. Base maps can be laid out and multiple people can build on the server (by hand) at a time. Cameras can be setup to record time-lapse of the creation process.

Appendix C: CityEngine Script Example for Building Extrusion

```
/**  
  
File: Buildings_v03.cga  
  
Created: 7 Jan 2016 17:16:06 GMT  
  
Author: Nico Azel  
  
*/  
  
version "2015.2"  
  
//Declare your variables for the rule [each will get slider of field in inspector]  
  
// Each variable is given a default value here, but can be adjusted latter in the inspectors tab attr  
FLOORHEIGHT = 3.5 // height from floor to ceiling of building  
  
attr COLORr = .84 //red of RGB  
  
attr COLORg = .84 // green of RGB  
  
attr COLORb = 1 // blue of RGB  
  
attr NumFloors = 1 // default value for NumFloors - will later be set by object attribute in .shp file  
// note that this variable has the exact name of the .shp attribute it will inherit  
  
//creates the start rule Lot -->  
  
Lot -->  
  
extrude (FLOORHEIGHT*NumFloors)  
  
// the extrude() command will turn our footprint into a volume based on a  
unit of distance  
  
//in this case I will use FLOORHEIGHT (size of each story) multiplied by  
NumFloors (number of stories) to extrude (FLOORHEIGHT*NumFloors)  
  
set (material.opacity, .68)  
  
// sets material transparency level ".68/1 "  
  
set color of object to RGB values chosen  
  
//set(material.color.g,COLORg)
```

```
//set(material.color.r,COLORr)
```

```
//set(material.color.b, COLORb)
```

Appendix D: Pavilion Placement Rule

/*

* File: 3dPavilion_Placement.cga

* Created: 20 Feb 2016 15:25:49 GMT

* Authors: Nicolas Azel, Jennifer Minner, Yanlei Feng

*/

version "2015.2"

//gen Options

#@range(GEN, Extrude)

attr *GenOrExtru* = "Extrude"

@range("Gen-Model", "Extrude")

attr *_1_genType* = "Extrude"

@range("Extrude", "Extrude_Stories")

attr *_1_Extrude_Type* = "Extrude"

@range ("Relative", "Absolute", "Original", "Percent")

attr *_2_Scale_Type* = "Percent"

@range ("True", "False")

attr *_3_NU_Scale* = "False"

//Never Built refers to features in a shapefile that were never built, but were considered at one point. This enables the display of hypothetical past buildings.

@range ("True", "False")

attr *_4_Show_Nvr_Built* = "False"

attr *NvrBuilt* = 0

//Show_Neigh_cont was developed to allow the user to turn on or off the surrounding neighborhood context around the park. Some features in the shapefile were coded with an attribute indicating that they are buildings outside the park.

@range ("True", "False")

attr *_4_Show_Neigh_cont* = "True"

attr *Neigh_cont* = 0

//Two options were created – to show all buildings at one regardless of time or to enable “Time-Lapse,” where a specific date displayed is specified.

@range ("Timeless", "Time-Lapse")

attr *_4_Date_Consideration* = ("Time-Lapse")

attr *_4_Date_Displayed* = 2015

#attr *_4_Date_Build* = 1934

#attr *_4_Date_Destroy* = 2050

//@range("destroyed", "not-destroyed")

//attr *_4_Destroyed_Yet* = "not-destroyed"

attr *YearBuilt* = 0

attr *_4_Date_Build* = *YearBuilt*

attr *Yr_Demolis* = 0

attr *_4_Date_Destroy* = *Yr_Demolis*

attr *Model_Path* = "Model path populates here for individual building footprints where there is a 3D model"

#attr *Model_Path* = "0"

//model Source

attr *_4_source_loc* = (*Model_Path*)

attr *Move_X* = 0

```
attr Move_Y = 0
attr Move_Z = 0
attr Angle = 0
attr Scale = 0
attr _6_move_X = (Move_X)
attr _6_move_Y = (Move_Y)
attr _6_move_Z = (Move_Z)
attr _6_angle = (Angle)
attr _7_Scale = (Scale)
//extrude Options
attr NumFloors = 1
attr _5_Height = 20
attr _5_color_R = .84
attr _5_color_G = .84
attr _5_color_B = 0.84
attr _5_opacity = .68
//Model Location Options
#@range (0,360)
#attr _6_angle = 0
#@range (-200,200)
#attr _6_move_X = 0
#@range (-200,200)
#attr _6_move_Y = 0
#@range (-10,10)
#attr _6_move_Z = -2
```

```

//Model Scale Options
#attr_7_Scale = 1
attr_7_Scale_X = 1
attr_7_Scale_Z = 1
attr_7_Scale_Y = 1

@StartRule

Lot -->

    case Neigh_cont == 1: Show_Neigh_Cont_Test

    case Neigh_cont == 0: Nvr_Build_Test

    else: PAVILION.

Show_Neigh_Cont_Test -->

    case _4_Show_Neigh_cont == "True": Nvr_Build_Test

    else: PAVILION.

Nvr_Build_Test -->

    case NvrBuilt == 1: Nvr_Built_Display_Toggle

    case NvrBuilt == 0: Date_Considerations

    else: PAVILION.

Nvr_Built_Display_Toggle -->

    case _4_Show_Nvr_Built == "True" : Date_Considerations

    else: PAVILION.

Date_Considerations -->

    #Gen_Type_Test

    case _4_Date_Consideration == "Timeless" : Gen_Type_Test

    case _4_Date_Consideration == "Time-Lapse": Destroy_test

    else: PAVILION.

```

```

//Lot -->

//          #Gen_Type_Test
//          case _4_Date_Consideration == "Timeless" : Gen_Type_Test
//          case _4_Date_Consideration == "Time-Lapse": Destroy_test
//          else: PAVILION.

#@StartRule

#Lot -->

#case _1_genType == "Extrude": extrude( _5_Height )

#set(material.opacity, _5_opacity)

#set(material.color.g, _5_color_G)

#set(material.color.r, _5_color_R)

#set(material.color.b, _5_color_B)

#case _1_genType == "Gen-Model" :

#           //report("zscale =", scaleZ)

#           Scale_Type_Test

#     else: PAVILION.

// if destroyed

//Destroy_test -->

//          case ("true" == "true"): Destroy_Assign
//          case (_4_Destroyed_Yet == "not-destroyed"): Date_Test_one
//          case (_4_Destroyed_Yet == "destroyed"): Date_Test_two
//          else: PAVILION.

```

Destroy_test -->

```
case (Yr_Demolis == 0): Date_Test_one
```

```
case (Yr_Demolis > 1) : Date_Test_two
```

```
else: PAVILION.
```

Date_Test_one -->

```
case (_4_Date_Build <= _4_Date_Displayed) : Gen_Type_Test
```

```
else: PAVILION.
```

Date_Test_two -->

```
case ( (_4_Date_Build <= _4_Date_Displayed) && (_4_Date_Destroy >= _4_Date_Displayed) ) :  
Gen_Type_Test
```

```
else: PAVILION.
```

Gen_Type_Test -->

```
case GenOrExtru == "GEN" || GenOrExtru == "Gen": Scale_Type_Test
```

```
case GenOrExtru == "Extrude": Extrude_type_test
```

```
else: PAVILION.
```

#Gen_Type_Test -->

```
# case _1_genType == "Extrude": Extrude_type_test
```

```
# case _1_genType == "Gen-Model" :
```

```
# //report("zscale =", scaleZ)
```

```
# Scale_Type_Test
```

```
# else: PAVILION.
```

Extrude_type_test -->

```

case _1_Extrude_Type == "Extrude" :          extrude(_5_Height )

                                                set(material.opacity,_5_opacity)

                                                set(material.color.g,_5_color_G)

                                                set(material.color.r,_5_color_R)

                                                set(material.color.b,_5_color_B)

case _1_Extrude_Type == "Extrude_Stories" : extrude(_5_Height*NumFloors)

                                                set(material.opacity,_5_opacity)

                                                set(material.color.g,_5_color_G)

                                                set(material.color.r,_5_color_R)

                                                set(material.color.b,_5_color_B)

else: PAVILION.

```

Scale_Type_Test -->

```

case _2_Scale_Type == "Original" : ModelMaker_Original

case _2_Scale_Type == "Absolute" : ModelMaker_Absolute

case _2_Scale_Type == "Relative" : ModelMaker_Relative

case _2_Scale_Type == "Percent" : ModelMaker_Percent

else: PAVILION.

```

ModelMaker_Original -->

```

case _4_source_loc != "" : //exactly the size of the model

                                //s(scope.sx,scope.sz,scope.sy)

                                //s('1','1','1')

                                s(0,0,0)

```

```
i(_4_source_loc)
r(scopeCenter, 0, _6_angle, 0)
t(_6_move_X, _6_move_Z, _6_move_Y)
```

else: PAVILION.

ModelMaker_Absolute --> //must set absolute size for all directions

case _3_NU_Scale == "True" :

```
s(_7_Scale_X, _7_Scale_Z, _7_Scale_Y)
i(_4_source_loc)
r(scopeCenter, 0, _6_angle, 0)
t(_6_move_X, _6_move_Z, _6_move_Y)
```

case _3_NU_Scale == "False" : //model size for xy and absolute size for z

```
s( 0, 0, 0)
i(_4_source_loc)
r(scopeCenter, 0, _6_angle, 0)
t(_6_move_X, _6_move_Z, _6_move_Y)
s( scope.sx, _7_Scale_Z, scope.sz)
```

else: PAVILION.

ModelMaker_Relative -->

case _3_NU_Scale == "False" : //model size + universal scale in all directions

```
s(0,0,0)
i(_4_source_loc)
```

```

r(scopeCenter,0,_6_angle,0)
t(_6_move_X,_6_move_Z,_6_move_Y)
s( scope.sx + _7_Scale , scope.sy + _7_Scale ,scope.sz + _7_Scale)

case _3_NU_Scale == "True" :           //model size + value per directoin
s(0, 0, 0)
i(_4_source_loc)
r(scopeCenter,0,_6_angle,0)
t(_6_move_X,_6_move_Z,_6_move_Y)
s( scope.sx + _7_Scale_X , scope.sy +_7_Scale_Z , scope.sz +
_7_Scale_Y)
else: PAVILION.

```

ModelMaker_Percent -->

```

case _3_NU_Scale == "False" :       //model size* unversal scale
s(0,0,0)
i(_4_source_loc)
r(scopeCenter,0,_6_angle,0)
t(_6_move_X,_6_move_Z,_6_move_Y)
s( scope.sx * _7_Scale , scope.sy * _7_Scale , scope.sz * _7_Scale)

case _3_NU_Scale == "True" :       //model size * value per direction
s(0, 0, 0)
i(_4_source_loc)

```

r(scopeCenter,0,_6_angle,0)

t(_6_move_X,_6_move_Z,_6_move_Y)

s(**scope.sx** * _7_Scale_X, **scope.sy** * _7_Scale_Z, **scope.sz** * _7_Scale_Y)

else: PAVILION