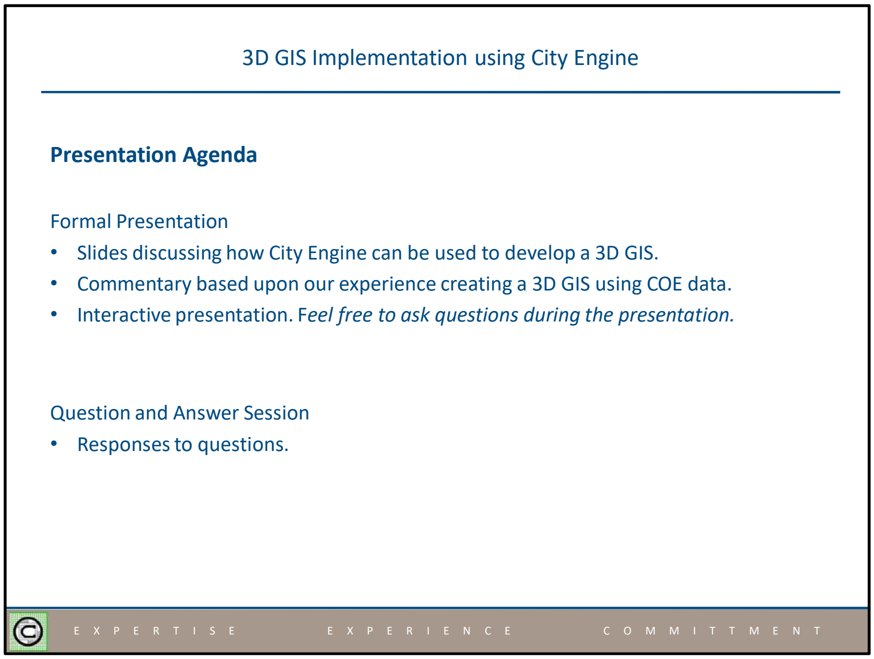
The following presentation describes using Esri's City Engine software to develop a 3D GIS from 2D GIS. The presentation begins with a few background slides on creating a 3D GIS and its applicability, while the remaining slides discuss the process that was used in creating the 3D model.



During the presentation we encourage questions being asked. This leads to a more interactive presentation. So feel free to ask questions at any time.

3D GIS Implementation using City Engine

Typical Questions

How do we get to this?

How long does it take?

How difficult?

How much?

E X P E R T I S E E X P E R I E N C E C O M M I T T M E N T

Let’s begin by showing an image of what we want to achieve. That is, a realistic 3D image of our GIS. As we go through the presentation we will explain each of the components comprising this image. In reviewing the image typical questions most people ask are shown in the slide. Hopefully by the end of the presentation we will have addressed these questions. For those interested, the south end of the image is the intersection of Broadway and 15th.

3D GIS Implementation using City Engine

Before starting the 3D development, the first Question to be Answered is:

How much detail is to be displayed in the 3D GIS?

The less detail to be displayed, the less time and less cost to create the model.

The greater the detail, the more time and cost to create the model.

As the level of detail increases the more realistic the model appears.

Model implies an **approximation**, not an exactness.

EXPERTISE EXPERIENCE COMMITTMENT

The first thing to keep in mind in developing a 3D GIS is the more detail you desire, the more time intensive and expensive the model building effort will be. Additionally, one word that you will hear a lot with a 3D GIS is "model". This is important because model implies an approximation, not an exactness.

3D GIS Implementation using City Engine

Level of Detail (LOD) Definition as defined by Esri

Level of Detail	1	2	3	4
Definition:	3D Extrusion	3D Extrusion with Roof Form or Building Shell	High Detail 3D Building Models	Interior Spaces and Floors
Data Required:				
Building Footprints	# of Stories or Total Height & or Usage	# of Stories or Total Height or Usage & if available Roof Height	3D Building Shell with Fine details (Textured or Untextured)	3D Building Shell Interior Spaces (CAD or BIM)
Streets	Street Centerlines	Street Centerlines with Width attributed	Detailed Streets (CAD)	Street Furniture, Stop Lights, Signage, Infrastructure lines (GIS/CAD)

E X P E R T I S E E X P E R I E N C E C O M M I T T M E N T

Here's an Esri slide that illustrates the 4 levels of detail that Esri associates with a 3D GIS. As you can see, as you move up in level the more information that is included in the model. This also has the effect of the more realistic the 3D GIS becomes. So when creating a 3D GIS, consideration should be given as to what level of detail is the 3D GIS to fall into.

3D GIS Implementation using City Engine

Applications of a 3D GIS

Realistic Visualizations.

Comprehensive City Planning Activities such as:

- Flood Modeling.
- Visibility Analysis of New Developments.
- Line of Sight analysis.
- Redevelopment Scenarios

Once the decision has been made to develop a 3D GIS the visualization benefits that are available can not be understated. Here is an image from the Philadelphia Example which is available for download from the City Engine gallery. As a matter of fact, there are a number of examples that are available for download from the City Engine gallery. The rules in these samples can be used as is or modified in other 3D models, if desired.

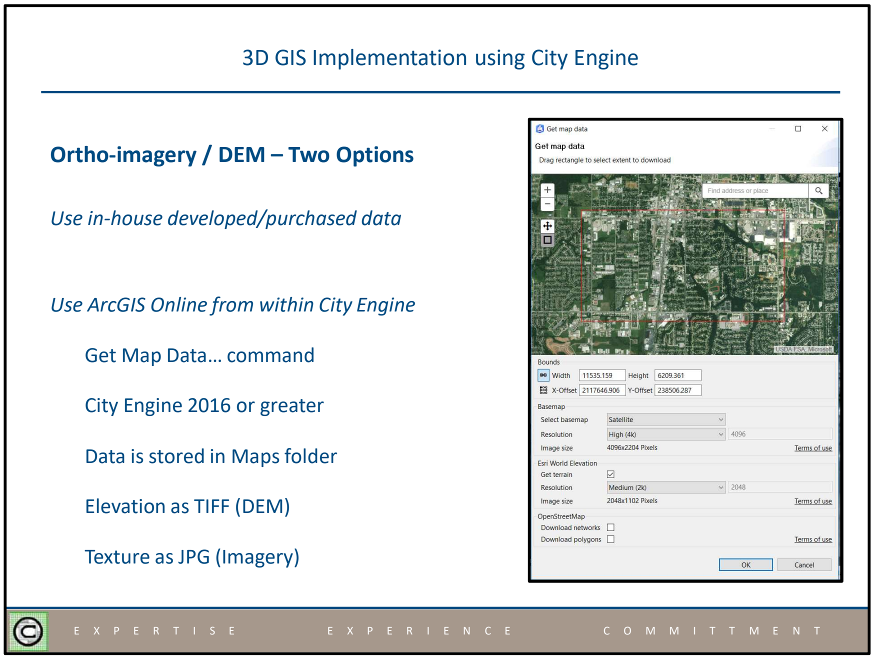
3D GIS Implementation using City Engine

The following datasets are typically used in creating a 3D GIS:

• Ortho-imagery,	Basemap Image
• Digital Terrain Model - DTM,	3D Ground Surface Layer
• Digital Surface Model - DSM,	3D Surface Layer
• Normalized Digital Surface Model - nDSM,	Difference between Ground and Surface
• Street Centerlines,	Road centerlines with pavement width
• Building Footprints,	Outlines of building footprints
• Parcel Data,	Parcel boundaries
• Vegetation Data,	Point locations of vegetation features
• Zoning/Land Use Data,	Zoning/Land Use delineations
• Land Cover Data.	Land Cover delineations

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

The first step in building the 3D GIS is determining which datasets are to be included. The list shown are typical datasets people utilize. Obviously other datasets may be desired such as utilities, such as, sewer, water, storm water, electric, street signs, street lights, etc.



Regarding the basemap there are a couple options. The first is using an in-house ortho-image or cartographic basemap. Now this basemap could be 2D or 3D. That is to say, the basemap may or may not contain elevation information. The second option involves using ArcGIS Online. As can be seen from the slide, using the ArcGIS Online option allows the user to define the area of interest by defining a rectangle. We'll discuss this further in a subsequent slide.

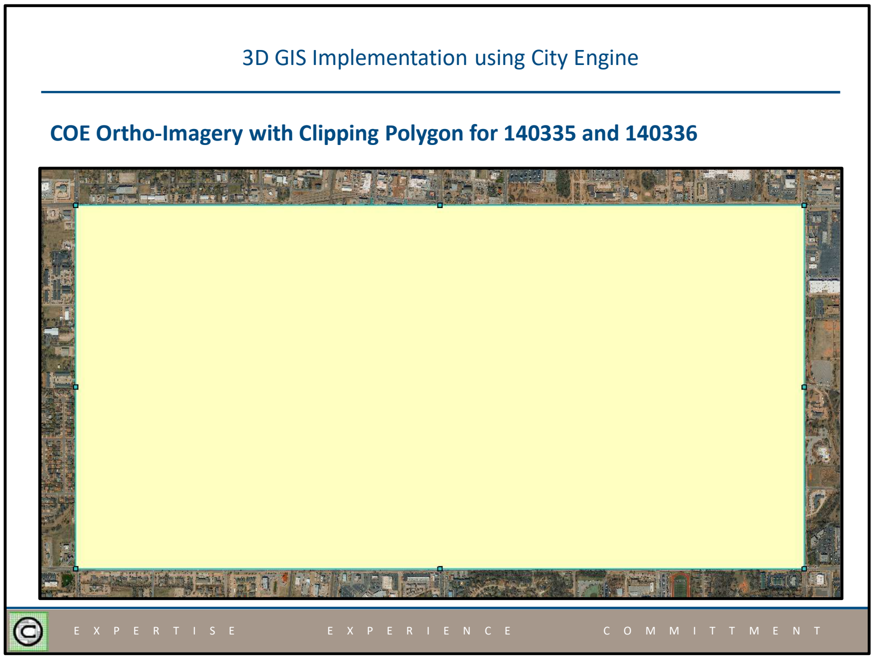
3D GIS Implementation using City Engine

Option 1

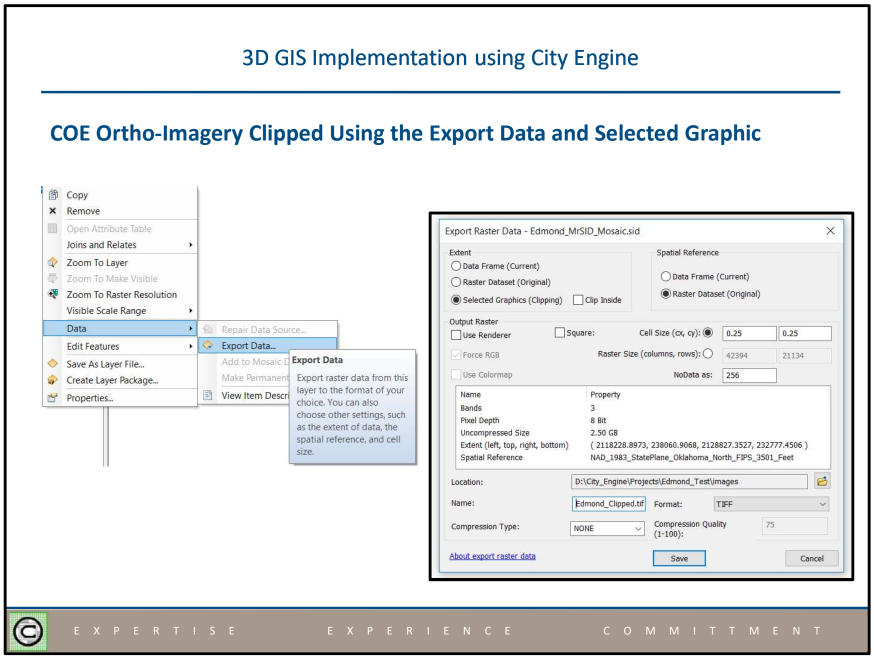
Use in-house developed or purchased Ortho-imagery

E X P E R T I S E　　E X P E R I E N C E　　C O M M I T T M E N T

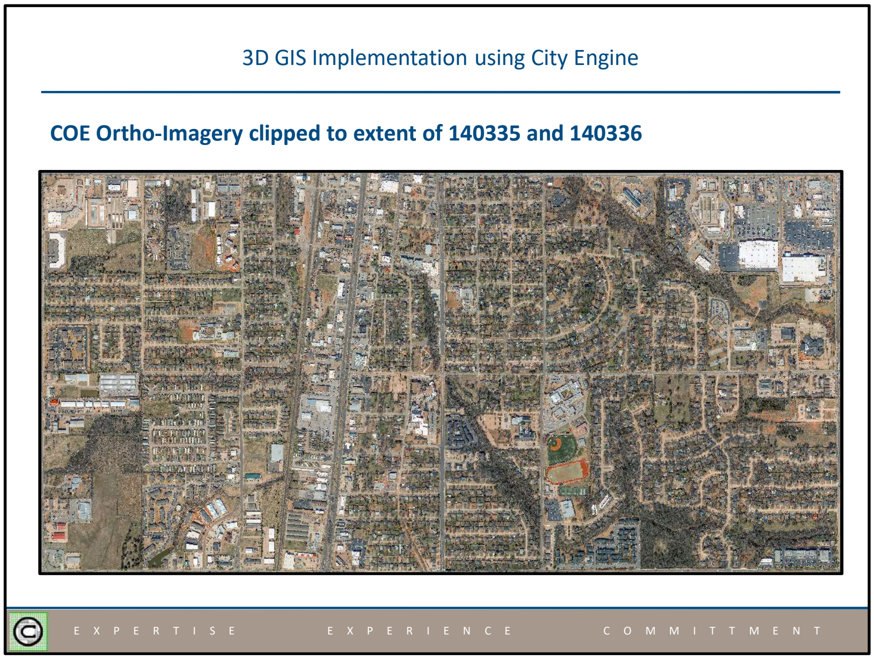
Let’s examine the first option where in-house basemap information is to be used.



Typically a 3D GIS is a subset of the overall 2D GIS. As such, we will want to clip the overall basemap to the desired area of interest. This can be accomplished by defining a rectangle covering the desired area. Note that this rectangle is a graphic that the user interactively creates within ArcMap.



Using the Export Data command the user is able to generate a bitmap representing the area of interest.



In this example we have clipped the overall City ortho-imagery to the extents of sections 140335 and 140336.

3D GIS Implementation using City Engine

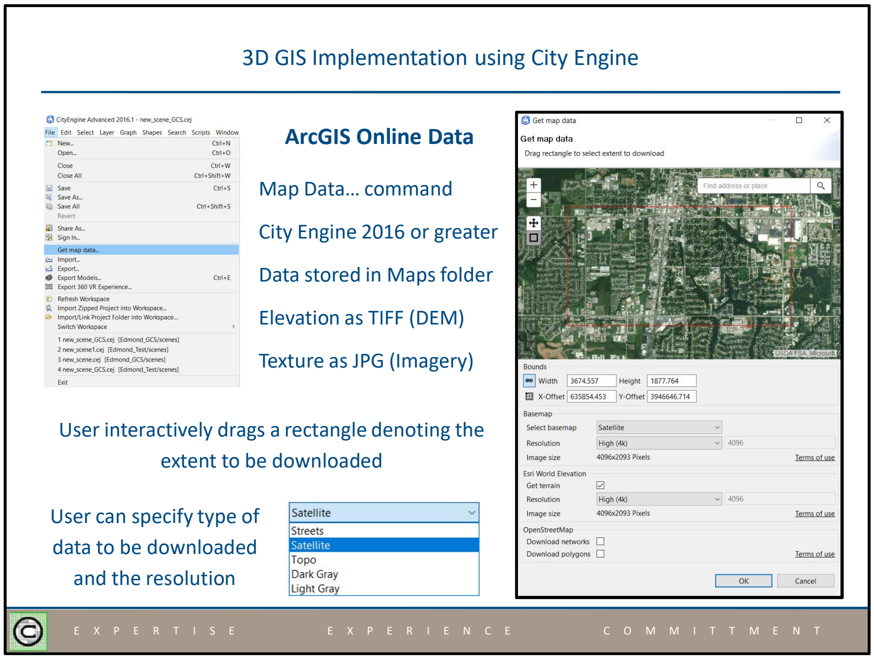
Option 2

Use ArcGIS Online from within City Engine

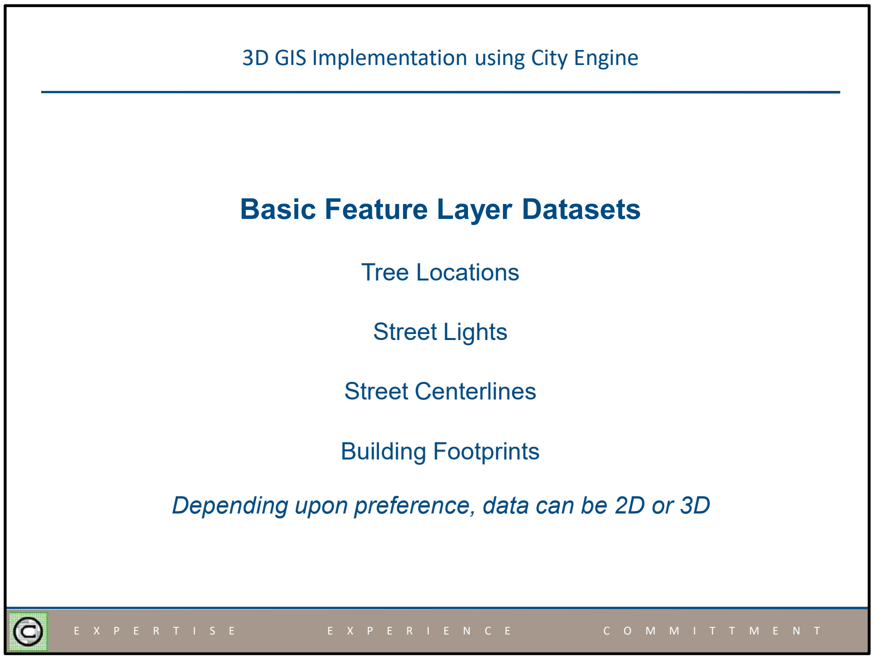
to obtain Ortho-imagery and DSM

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

Now, if there is no existing basemap information in-house or if the user desires to use ArcGIS Online, the second option previously mentioned is available.



In this mode of operation, the basemap can be obtained directly from within City Engine using the Get map data… command. The end result will be the same as with the first option. That is, a clipped rectangular image representing the area of interest. Note that generally speaking, in-house developed imagery will probably be more current and of higher resolution than that provided by Esri. However, if there is no existing basemap, this is an excellent resource for obtaining basemap data.



As mentioned previously, there are a number of datasets that can be imported into the 3D GIS. During this presentation we will concentrate on trees, street lights, street centerlines, and building footprints. Additionally, the user will want to consider whether 2D or 3D feature data is to be imported into City Engine.

3D GIS Implementation using City Engine

Tree Layer Considerations

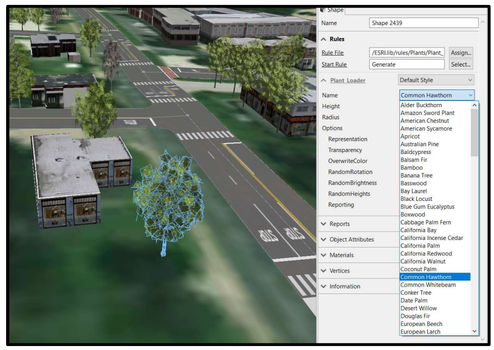
Point features denoting approximate center of tree

Use the Esri Out of the Box Rule File /ESRI.lib/rules/Plants/Plant_Loader.cga

The Rule File contains a robust list of Tree Types

Attributes for facilitating generation of Trees

- RULEFILE
- STARTRULE
- Name
- Height
- Radius



E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

The easiest dataset to convert into a 3D GIS is the Tree Layer. City Engine comes with a very robust Rule File which contains a lengthy list of various tree types. Facilitating the conversion will be the addition of the above mentioned attributes in the Tree Layer. If these attributes are present with the appropriate values, generation of the 3D trees can occur upon import into City Engine.

3D GIS Implementation using City Engine

Street Light Layer Considerations

Point features denoting approximate center of street light

Use the Rule File for Rendering Street Lights from the City of Philadelphia Example /rules/Street Furniture.cga

Rule Contains a Variety of Street Lights

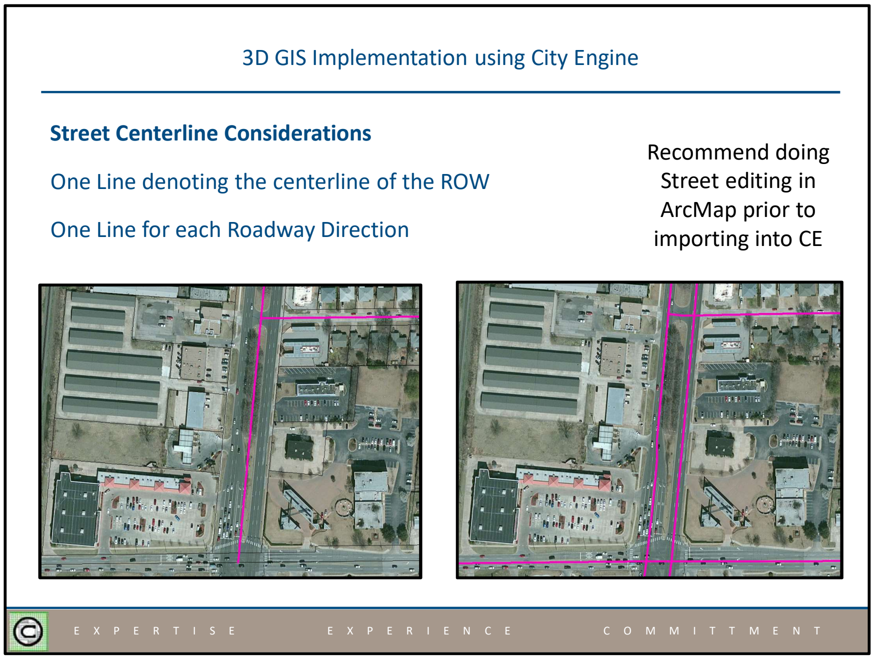
360Bulb	Globe
LightwFlag	Split and Tall

Attributes for facilitating generation of Street Lights (case sensitive)

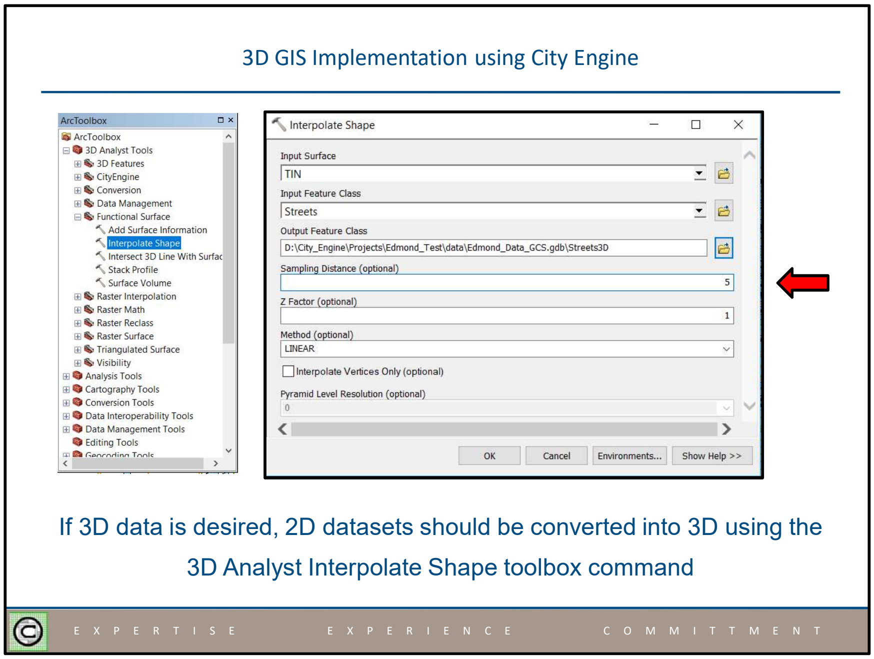
- RULEFILE
- STARTRULE
- TYPE
- SPECIFIC
- SIZE
- ROTATION

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

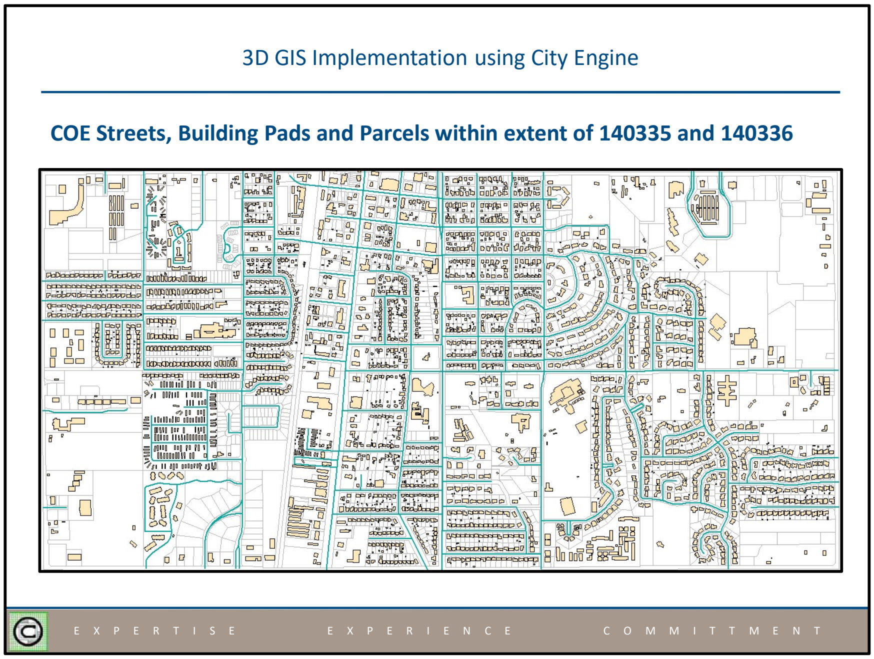
Like the trees, street lights can be imported into City Engine. The attribute assignment can be done within City Engine or the underlying database can be modified to incorporate the Rule's pertinent attributes.



It should be noted that prior to importing street centerline data, consideration should be given as to how the centerlines are to be represented. City Engine does offer the ability to model medians. As such, it may be appropriate to create a centerline that splits the street ROW rather than having two lines representing the road direction. In either case, the editing of the street centerline data will be easier in an ArcMap environment.



If 3D feature data is desired then the Interpolate Shape command can be used to convert 2D feature data into 3D feature data. Note the input surface, TIN. The TIN dataset was created using the 3D Analyst extension from the DSM that was downloaded from ArcGIS Online. Furthermore, note the Sampling Distance parameter. Since there is no draping functionality in City Engine, it is important that the 3D feature data contains enough intermediate vertices to properly reflect the surface of the terrain.



So summarizing, we are going to take the above ArcMap datasets, trees, street lights, streets, building footprints, parcels, and import them into City Engine to create a 3D GIS.

3D GIS Implementation using City Engine

3D Development assisted by GIS Featureclasses containing pertinent Data

Streets

Pavement Width

Lane Width

Building Footprints

Total Height

Number of Floors

Floor Height

A File GeoDatabase was established containing the various featureclasses.

Depending upon the City Engine Rule the pertinent data will vary.

The attributes shown here are the most basic and pertinent.

City Engine is a Rule Based Modeler comprised of a Rule File and a Start Rule which can be stored as attributes in the featureclass.

A City Engine Rule can be defined to extract a parameter's value from a feature's attribute value. All numeric values are in meters, not feet.

E X P E R T I S E　　E X P E R I E N C E　　C O M M I T T M E N T

In developing the 3D GIS, the development process can be assisted by incorporating modeling information into the ArcMap featureclasses. That is to say, by adding certain attributes and populating them with the appropriate values the time to generate the 3D GIS can be greatly reduced.

3D GIS Implementation using City Engine

The Attribute Name must match the Variable Name in the Rule File

Complete_Street.cga Rule File

- Lane_Width : double in meters
- LOD_Setting : text value equal to High, Moderate, Low

3D_City_Design_Rules/Building Construction.cga Rule File

- Floor_Count_Min : integer value > 0
- Floor_Count_Max : integer value >= Floor_Count_Min

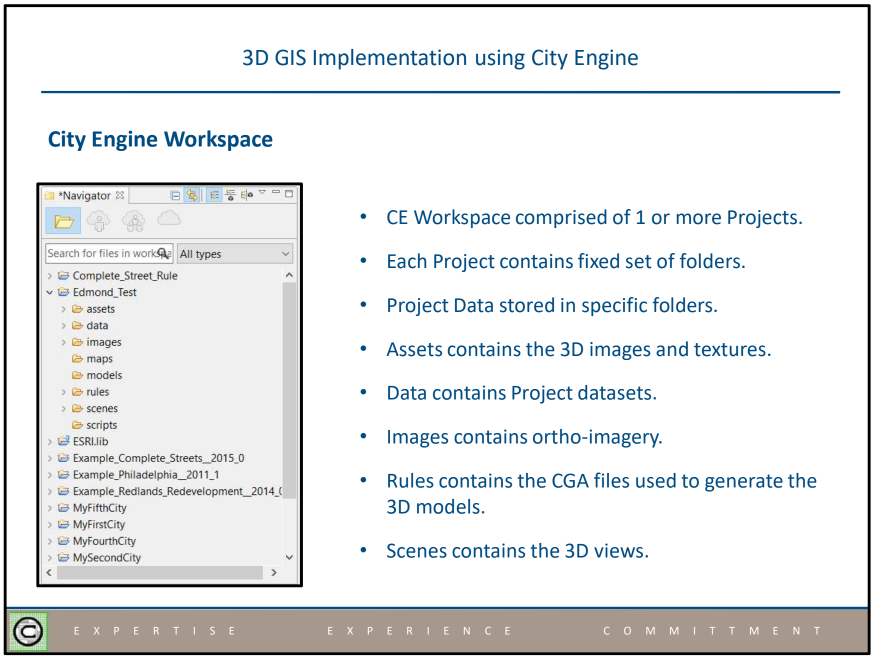
Rule File and Start Rule Attribute Names

- RULEFILE : Rule File name attribute
- STARTRULE : Start Rule name attribute

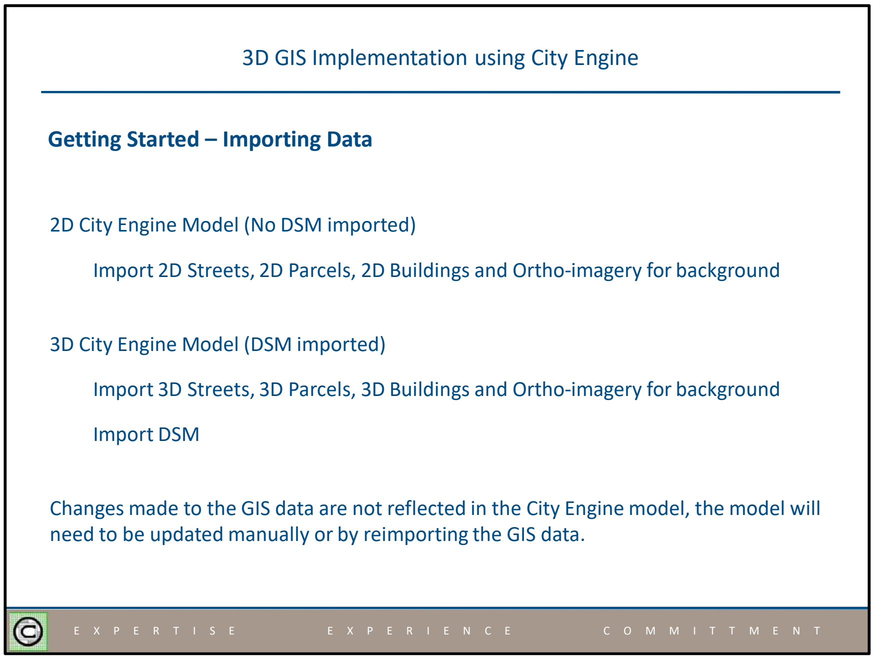
Variable Names in a Rule File are Case Sensitive

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

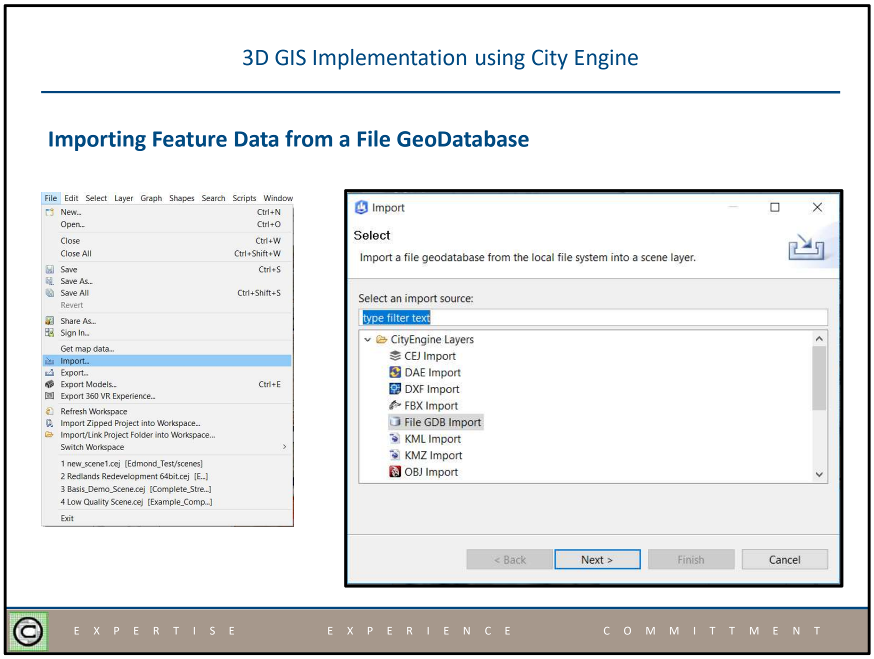
Here are just a few attribute names that can appear for the Complete_Street and Building Construction Rule Files. Note the LOD_Setting attribute. This indicates how detail the texturing will be when rendering a feature. The higher the texture level the more memory that is needed. This has a major effect on the performance of City Engine. Finally, it is possible to store the Rule File and Start Rule values under the RULEFILE and STARTRULE attribute names.



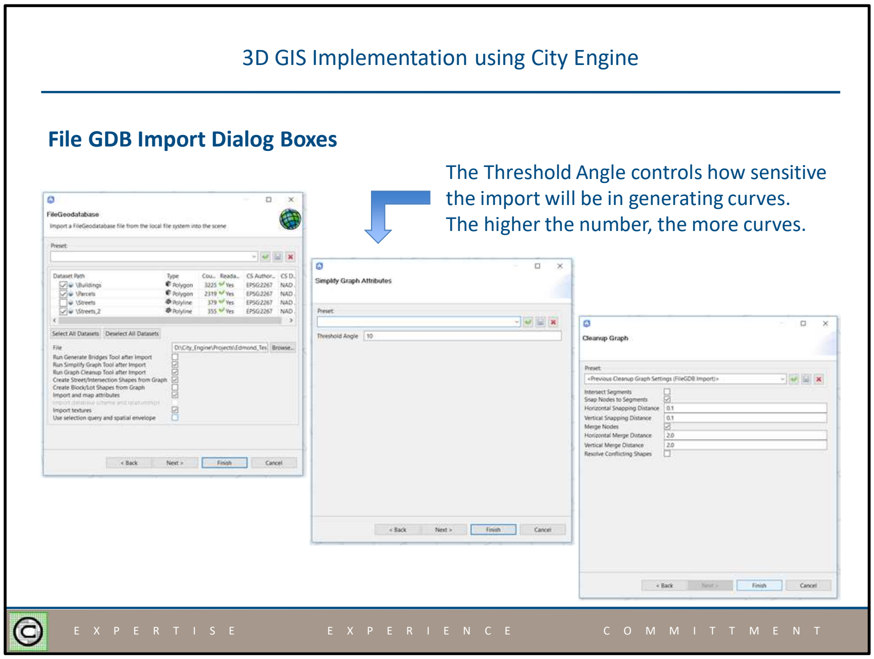
Those familiar with ArcMap's desktop interface will find City Engine's interface a little different. First of all, City Engine operates in a workspace, which is nothing more than a folder on a hard drive. Within the workspace, there can be one or more projects. Again, projects are nothing more than folders within the workspace folder. Each project is comprised of a fixed set of folders containing specific types of information. Note that it is possible for projects to reference information/data in other projects. For example, rules created in Project A can be accessed in Project B. In so doing duplicate information is avoided.



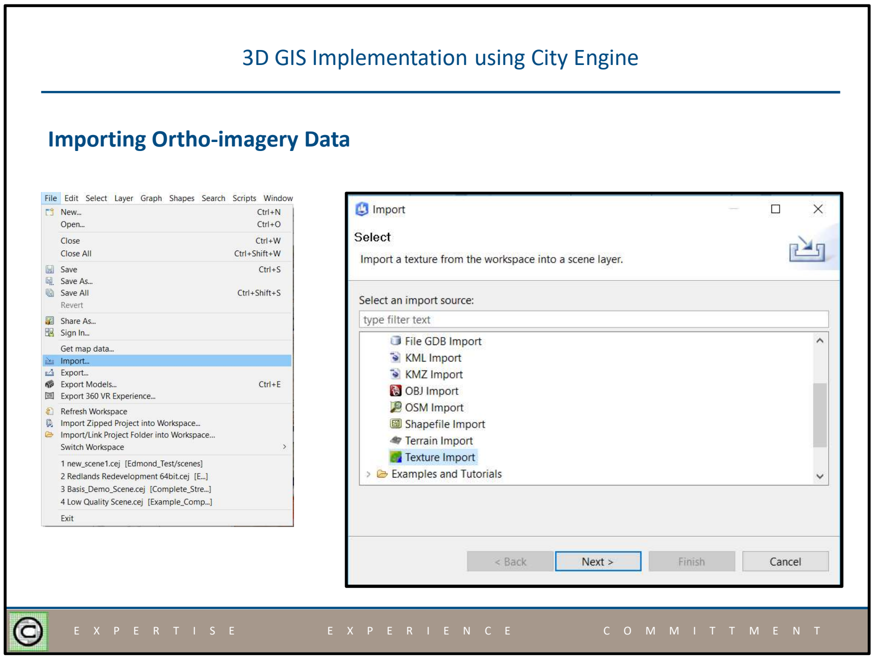
How ArcMap data is imported into City Engine will depend on whether 2D or 3D feature data is to be processed and if a DSM is involved. If a DSM is to be used, 2D or 3D feature data can be processed. If a DSM is not to be used, 2D feature data and ortho-imagery can be imported. Note the comment at the bottom of the slide, if the GIS changes, the City Engine model will need to be updated manually or by reimporting the data.



Regardless if 2D or 3D feature data is to be imported, the Import command will be used to get ArcMap data into City Engine. Depending upon the ArcMap source, the appropriate command should be selected. In our example, we will use the File GDB Import command since our information is stored in a File GeoDatabase.



In importing File GeoDatabase featureclasses, the user has the option of importing one or more featureclass at a time. There are also a number of options that can be activated during the import. The settings of these parameters has a tremendous effect on the import process. So be prepared to try a few variations to determine the proper values.



To import ortho-imagery, the Texture Import command should be selected.

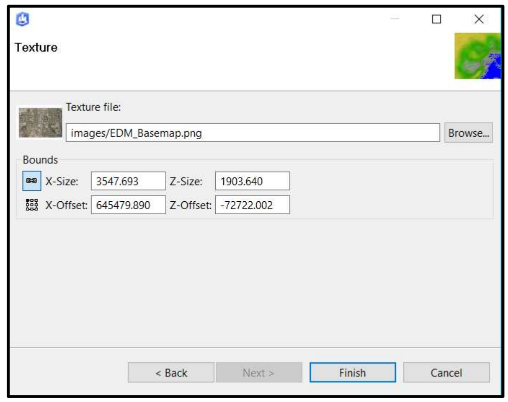
3D GIS Implementation using City Engine

Importing Ortho-imagery Data – Zero Elevation Based

Dialog box for importing the clipped ortho-imagery discussed earlier.

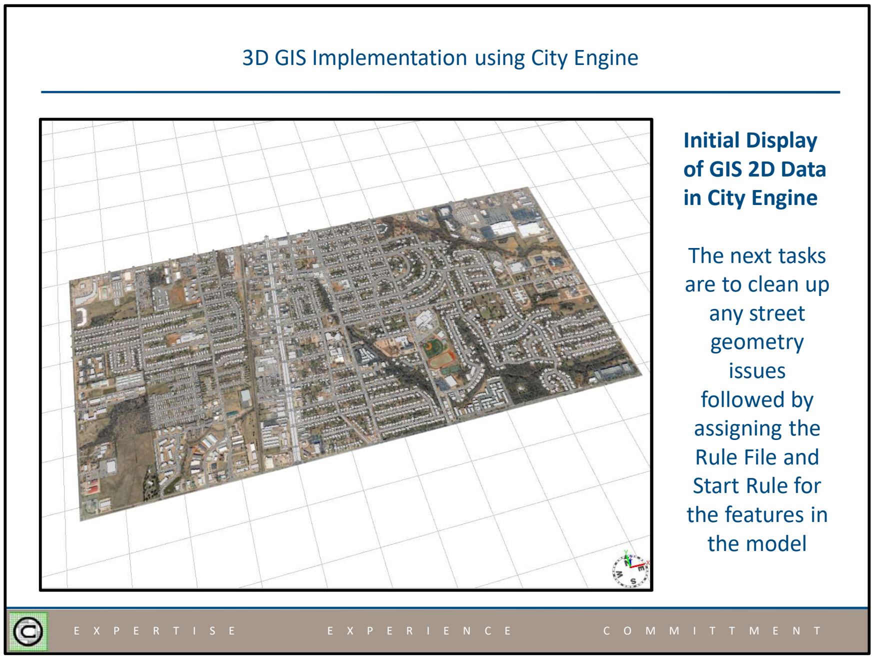
No elevation information is associated with this dataset.

Used solely for visual purposes.



E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

In our example we simply specify the clipped ortho-imagery file that was created using the Export Data command in ArcMap.



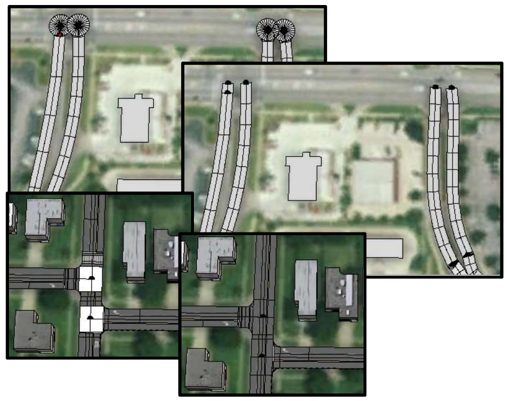
Once the datasets have been imported this is what the display will look like. In this example there is no DSM so all of the data resides at elevation 0. The next step will be to clean up any geometry issues and there more than likely will be issues. Following this step, the user can then go through the process of assigning rules to the features. It is the rules that make the 3D images appear.

3D GIS Implementation using City Engine

Street Geometry Issues/Post-processing in City Engine

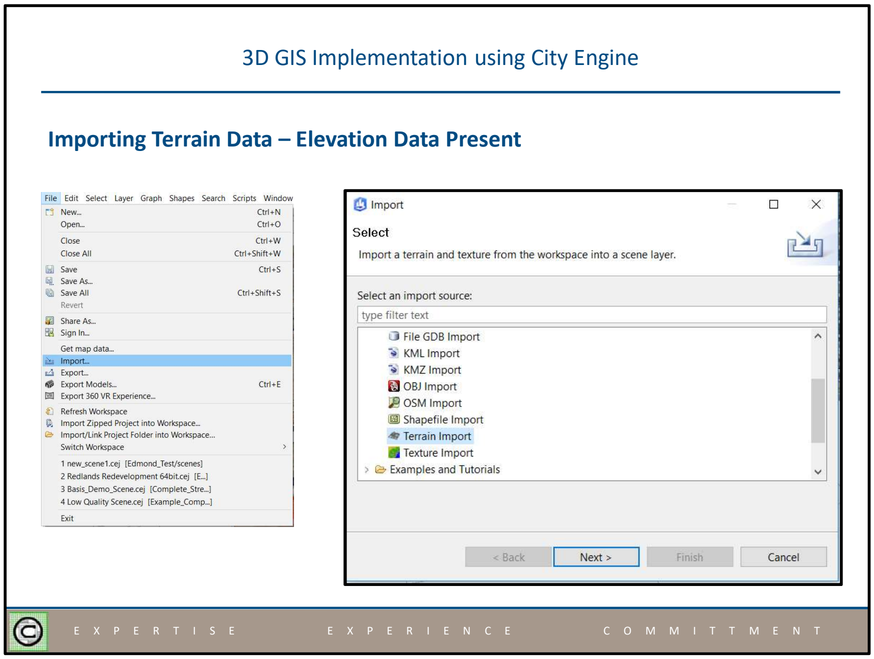
Dead end streets will have cul-de-sacs introduced. *Change Intersection Type for the node from Smart to Freeway*.

Intersections that are close to each other result in white area being displayed since road can not be modeled. *Change Intersection Type for the node from Smart to Crossing or Junction depending upon geometry*.



E X P E R T I S E E X P E R I E N C E C O M M I T T M E N T

The majority of the streets will be imported properly but there will be areas that will need to be addressed manually.



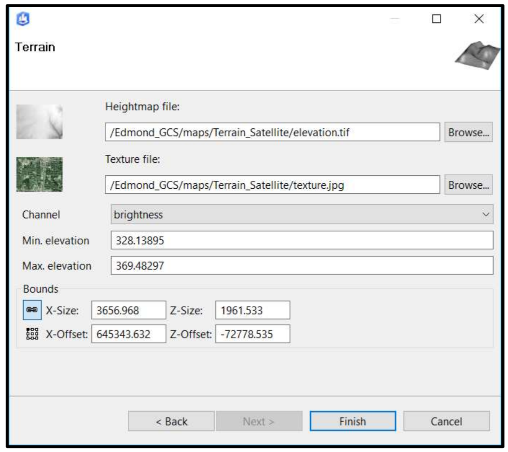
If a DSM is to be imported, the Terrain Import command can be selected.

Importing Terrain Data

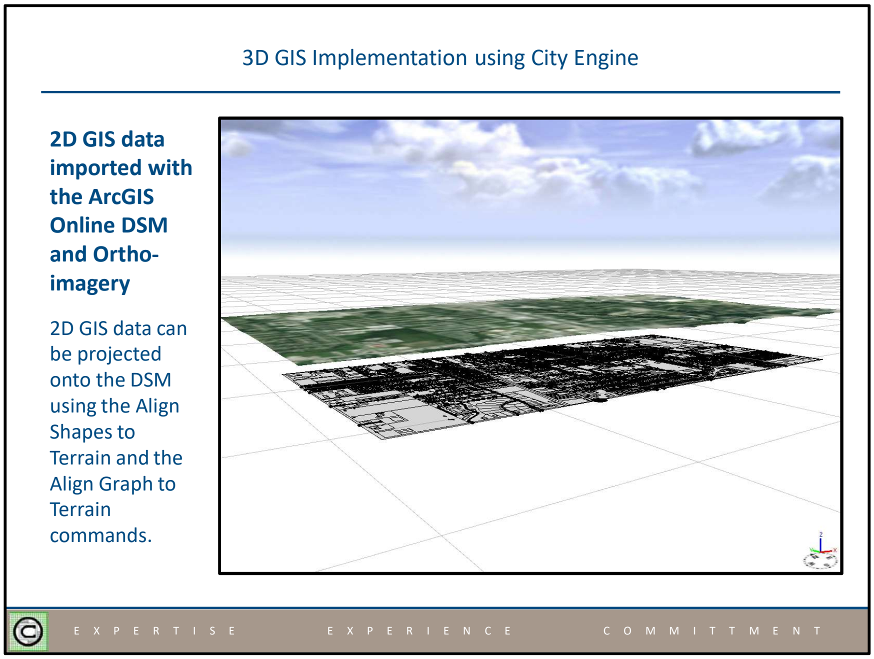
Dialog box for importing the ArcGIS Online data discussed earlier.

Comprised of a DSM and an image or texture as referred to in City Engine.

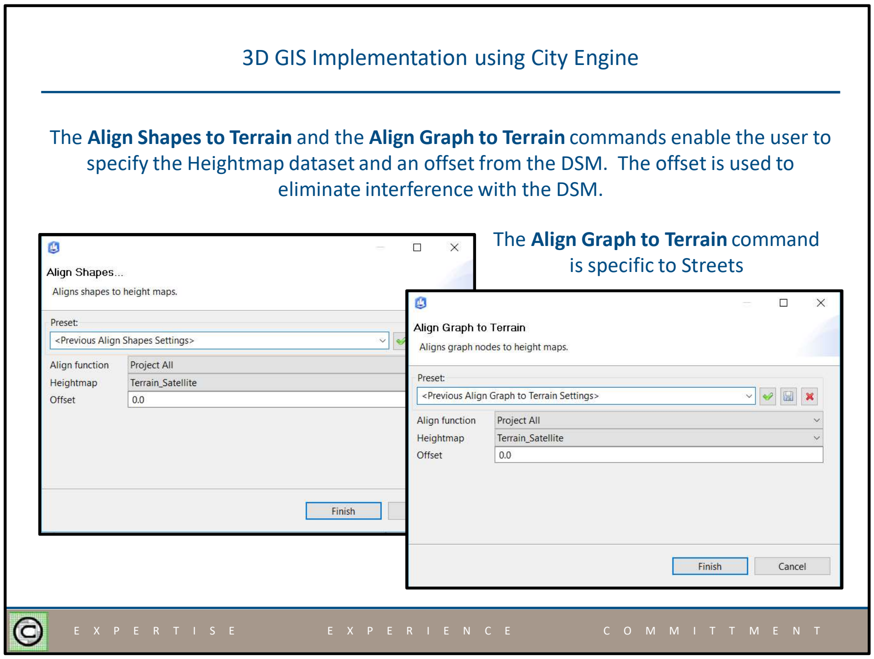
Used for visual and elevation computation purposes.



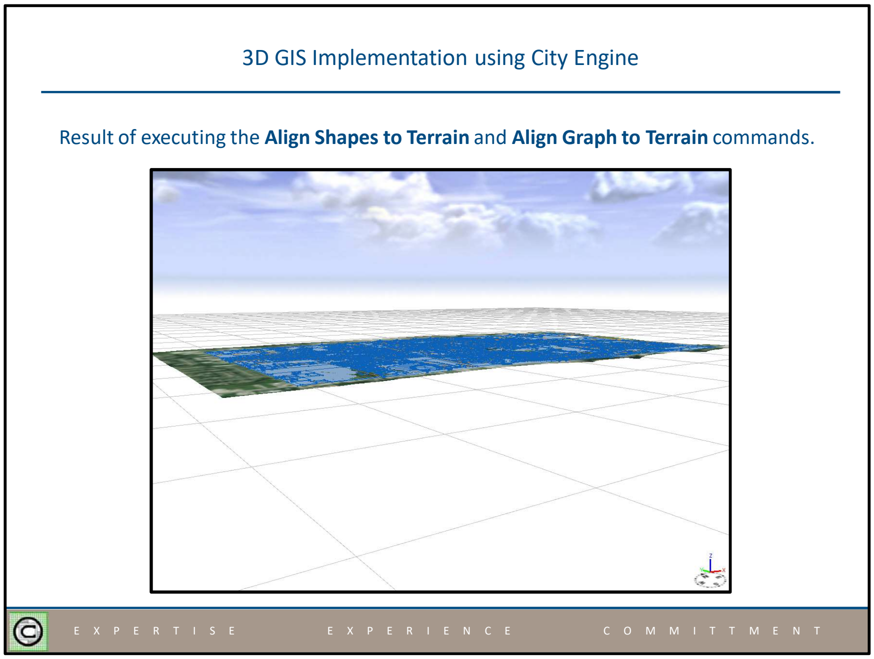
In this example we are importing the terrain we downloaded from ArcGIS Online. The DSM and Image files will be stored in the MAPS folder within the City Engine project folder.



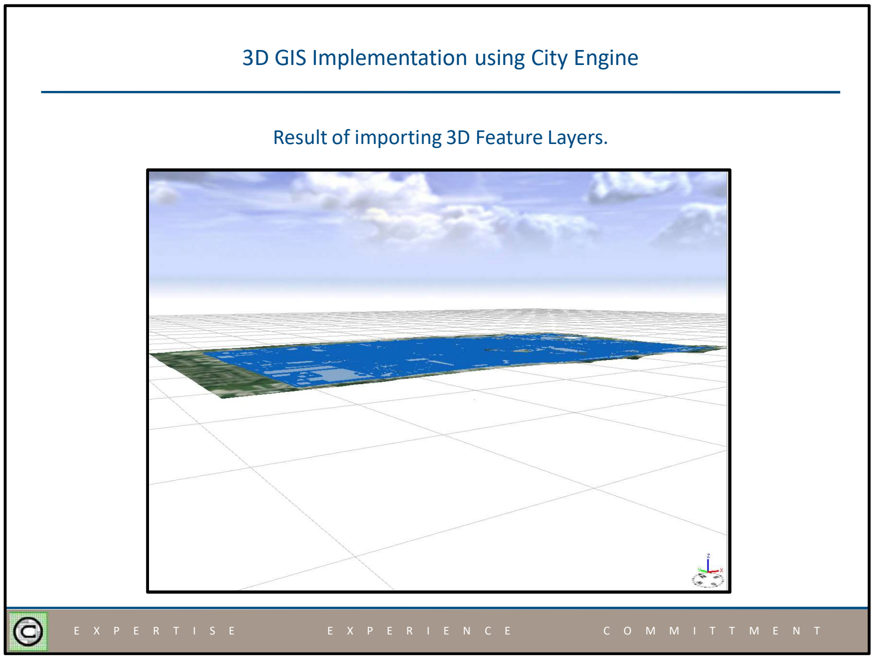
If a DSM is imported in conjunction with 2D feature data, you will find a display such as that shown in the slide. The DSM has elevation information while the 2D data is at elevation 0. City Engine has commands that will project the 2D feature data onto the DSM.



Specifically, the Align Shapes to Terrain and Align Graph to Terrain commands are used to project 2D feature data onto the DSM. The Align Graph to Terrain command is specific to street centerlines. The offset parameter enables the user to offset the features from the DSM by a specific amount in the Z direction.



Once the two commands have been executed, the 2D feature data will have been converted to 3D data and aligned with the DSM.



In the case of 3D feature data, the features should align with the DSM upon import. No additional processing should be required. However, if need be, the Align Shapes to Terrain and Align Graph to Terrain commands can still be utilized.

3D GIS Implementation using City Engine

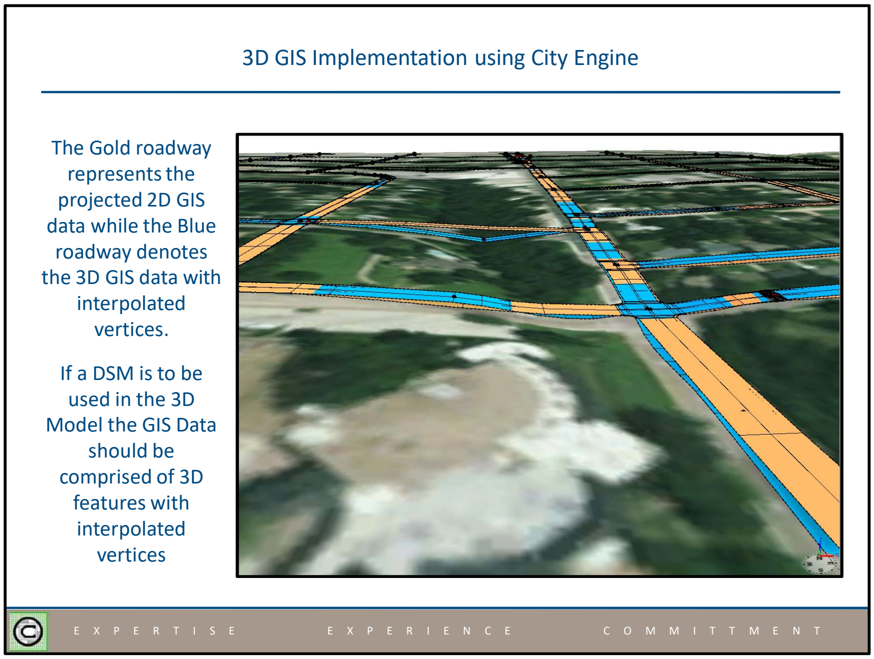
Left side image represents the 2D GIS data projected onto the ArcGIS Online DSM.

Right side image represents the 3D GIS data which had interpolated vertices computed every 5 feet superimposed onto the ArcGIS Online DSM.

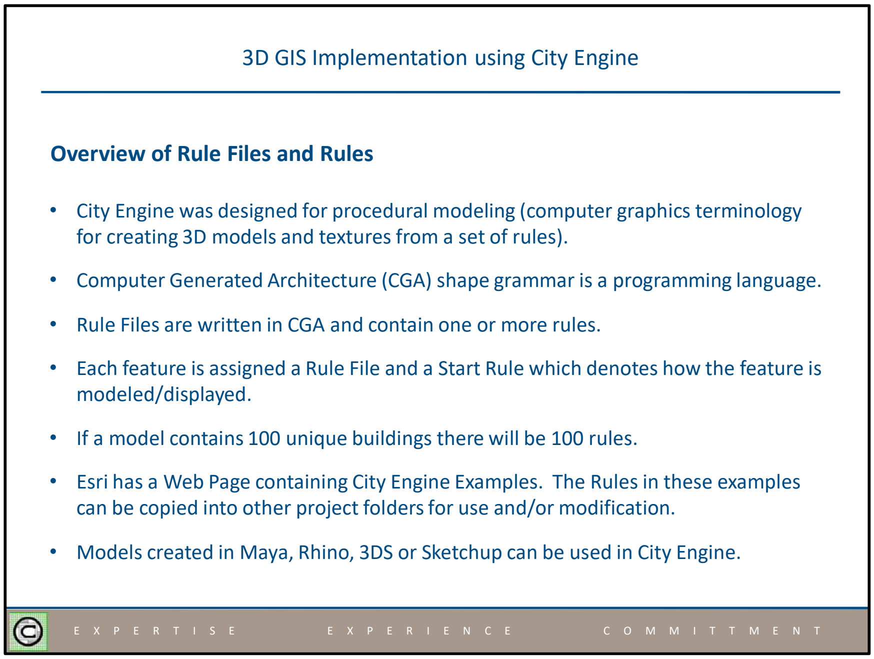
3D GIS data better fits the DSM due to the interpolated vertices.

EXPERTISE EXPERIENCE COMMITTMENT

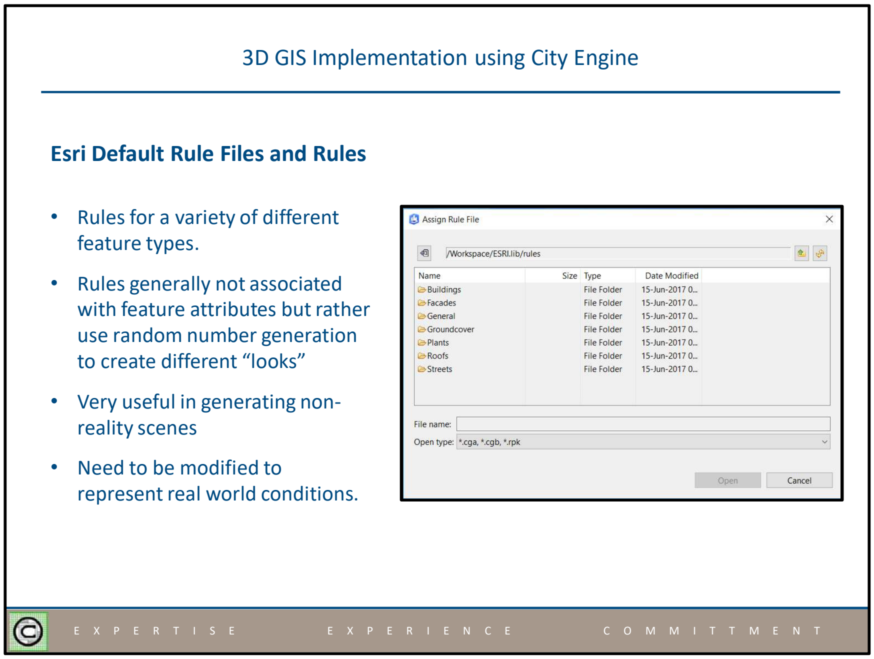
Previously we mentioned the Sampling Distance parameter when converting 2D feature data into 3D feature data. This parameter introduces intermediate vertices on a feature. The image on the left side represents 2D data with start and end points, no intermediate vertices. The image on the right side represents 3D feature data with intermediate vertices. Notice how the features in the right side image better follow the terrain of the DSM.



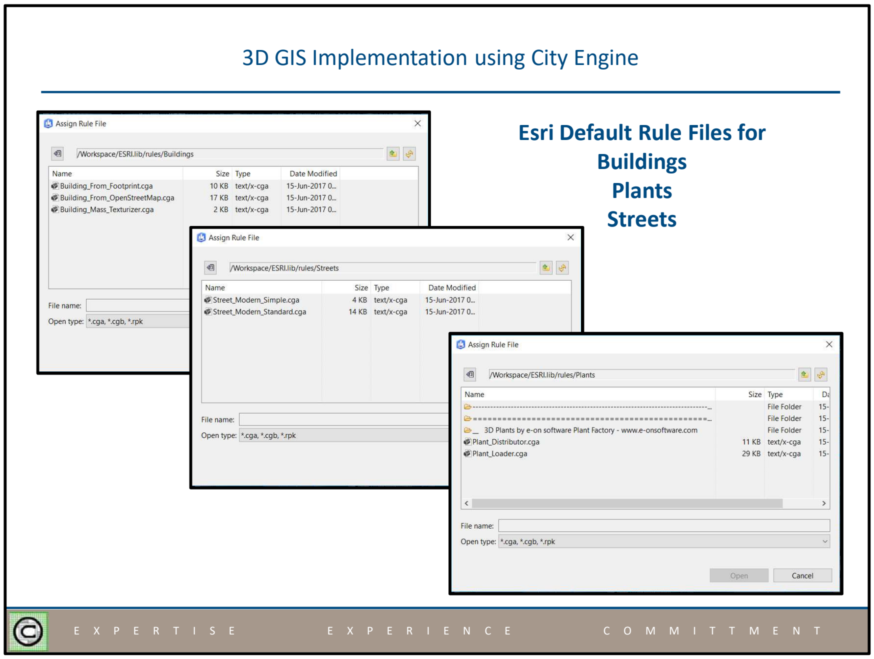
Just to make the point clearer, the image above shows the 2D feature data in gold, while the 3D feature data is displayed in blue. The take away from this is, if a DSM is to be used, intermediate vertices should be inserted so that features properly align with the DSM. Note that the closer the intermediate vertices are, the better the features will follow the terrain. The downside is, the larger the dataset becomes.



With the feature data imported in City Engine, the modeler can now go about the process of creating/assigning the Rule Files and Rules to the features. This assignment can be done on a feature by feature basis or to a group of selected features in one operation. City Engine renders a feature based upon the rule assigned to the feature. Note that it is possible to use 3D models created by another 3D modeler in City Engine.



Creating Rules can be complicated and one does need some sort of programming, as well as 3D modeling, experience. However, City Engine does come with some pre-defined rules that can be used out of the box. Unfortunately these rules will not generate models that represent real world conditions. The image in the slide illustrates what entities have pre-defined rules. Within each of the folders shown in the image are one or more Rule Files.



Each of the folders shown in the previous slide contains one or more Rule Files. It is these Rule Files that the user selects.

Here is a slide illustrating the model that is generated using the Esri Building from Footprint and Street Modern Standard Rule Files.

Here is a slide illustrating the model that is generated using the Esri Building from Open StreetMap and Street Modern Standard Rule Files. With the Building from Open StreetMap Rule File the user has a few options as to how the buildings should be modeled. In this example, the GenericMediumTown option is displayed.

3D GIS Implementation using City Engine

Esri Rule File for Streets – Complete_Street.cga

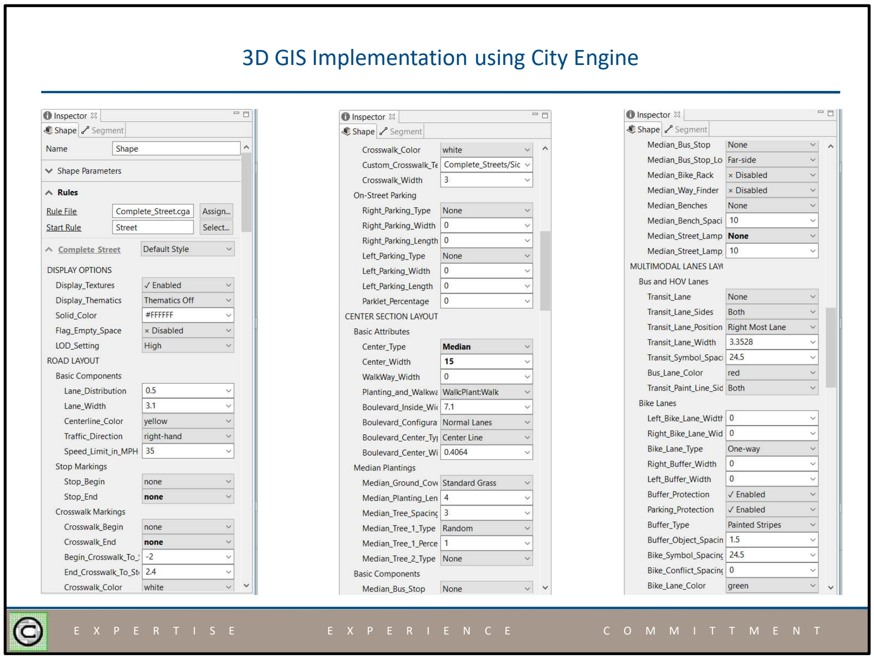
- Example Complete Streets Features 2015 released by ESRI Redlands.
- Comprised of the following Start Rules:

Street	Junction
Bridge Crossing	Median_TreeSplit
Crossing	Roundabout
Freeway	RoundaboutIsland
Freeway Entry	Sidewalk
Joint	

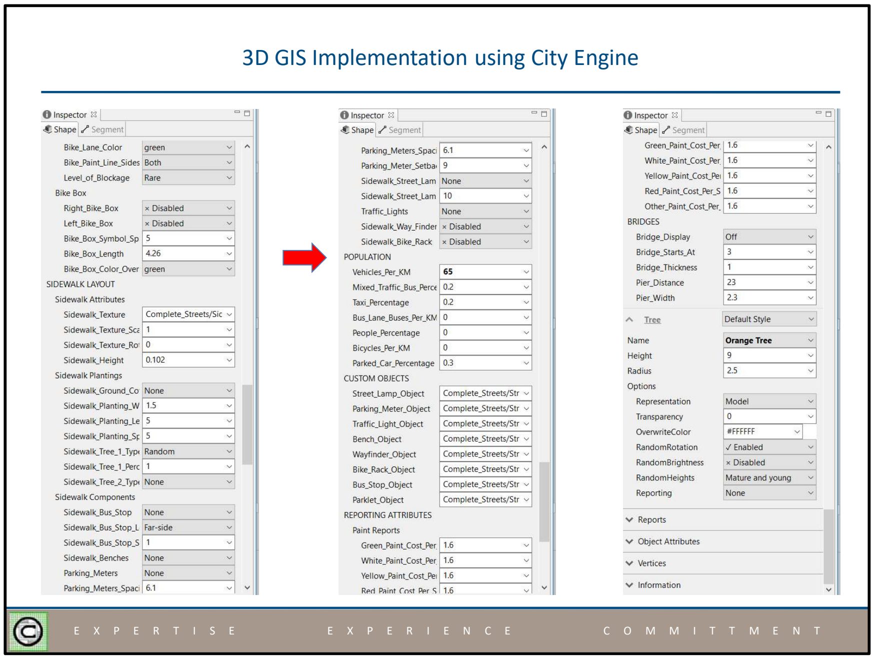
- Based on the Rule different look and different set of parameters.
- The Streets Rule has an extensive set of parameters as shown in the next 2 slides.

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

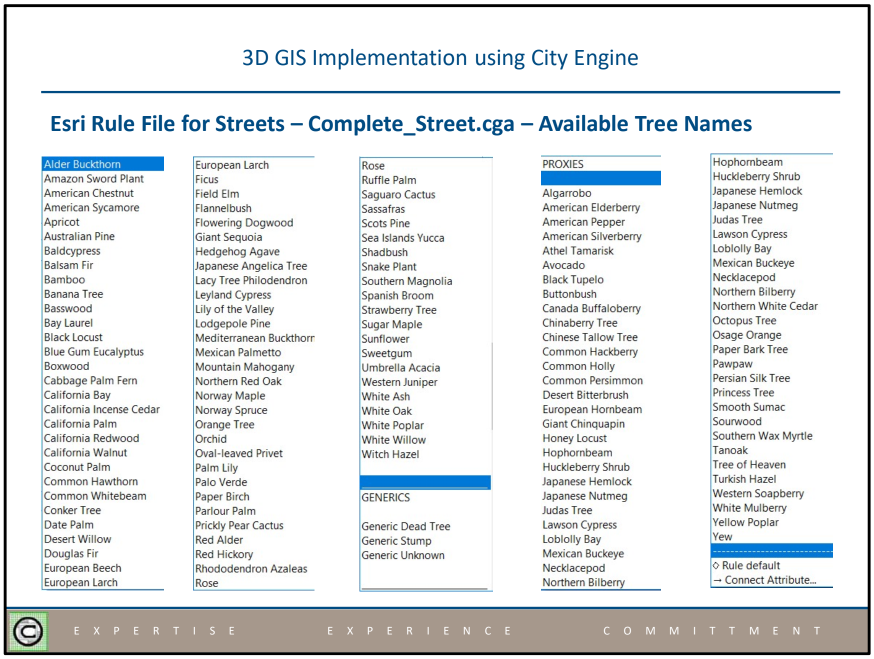
In addition to the default Rule Files, Esri offers the Complete_Street.cga Rule File. This is a robust Rule File that can serve as a starting point for rendering streets.



As can be seen, there are a number of parameters the user can modify to achieve the desired look. Note that distances such as Lane Width are specified in meters, not feet. This applies to all types of distances.



The Population category enables the user to add images of vehicles and people to the model.



A rather extensive list of tree names are available as well. These can be used when specifying Median and Sidewalk plantings.

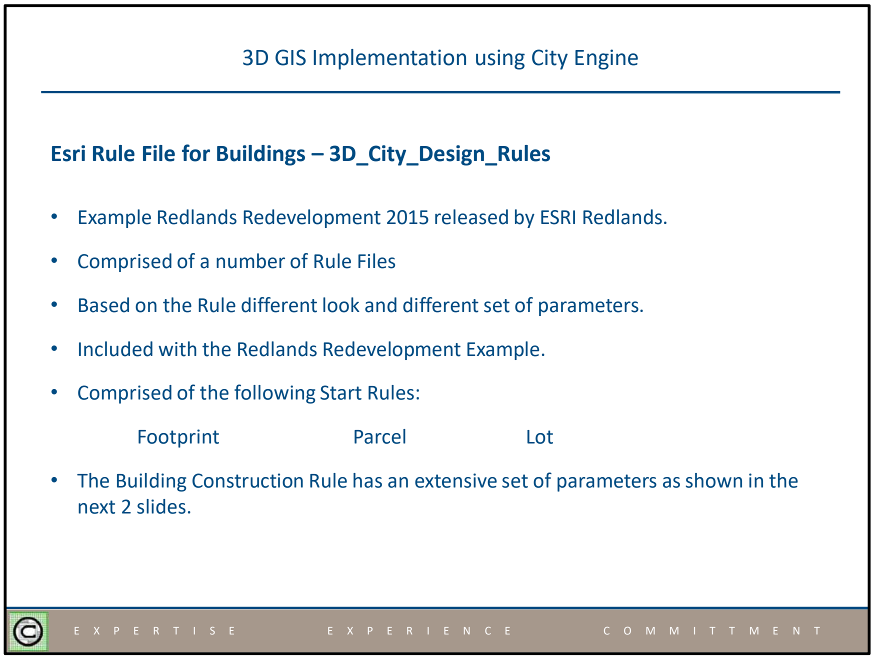
3D GIS Implementation using City Engine

Various Design Scenarios

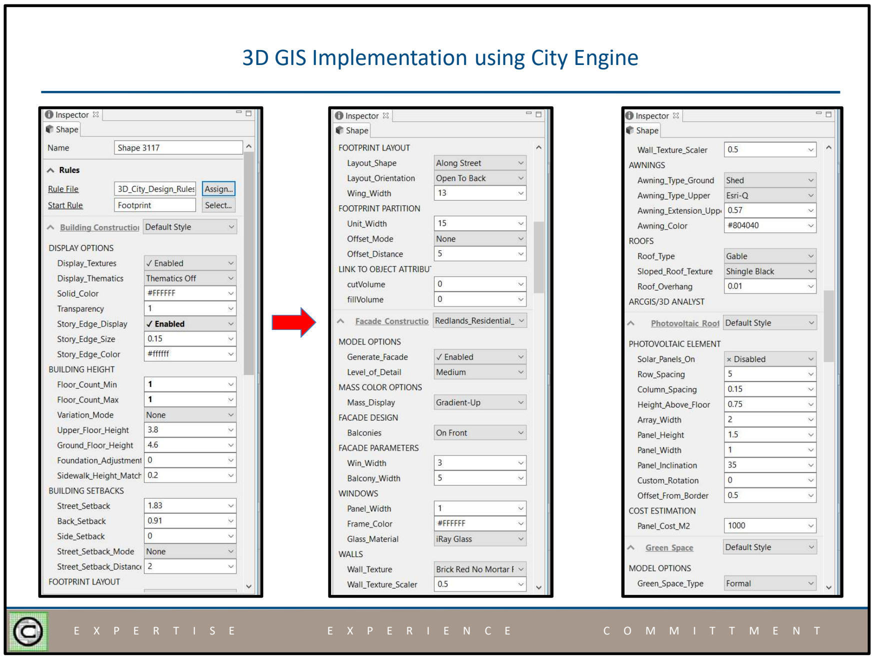
By adjusting the values of the Complete Street parameters the user is able to quickly generate various design scenarios. In this example, (a) no median, (b) median with planting and (c) a median with barrier and shoulder and side street parking are shown.

E X P E R T I S E E X P E R I E N C E C O M M I T T M E N T

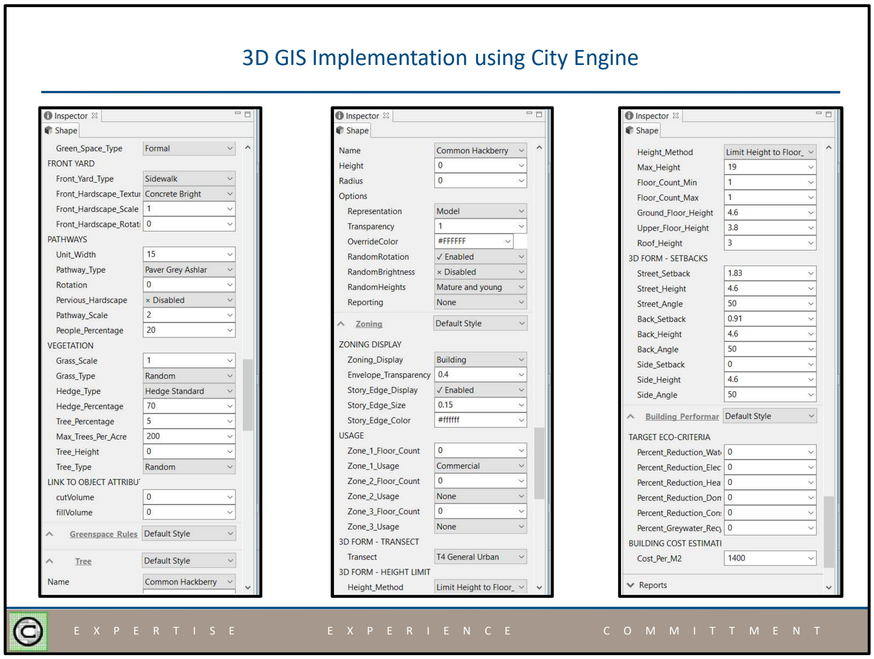
Using the parameters in the Complete_Street Rule, various roadway designs can be generated.



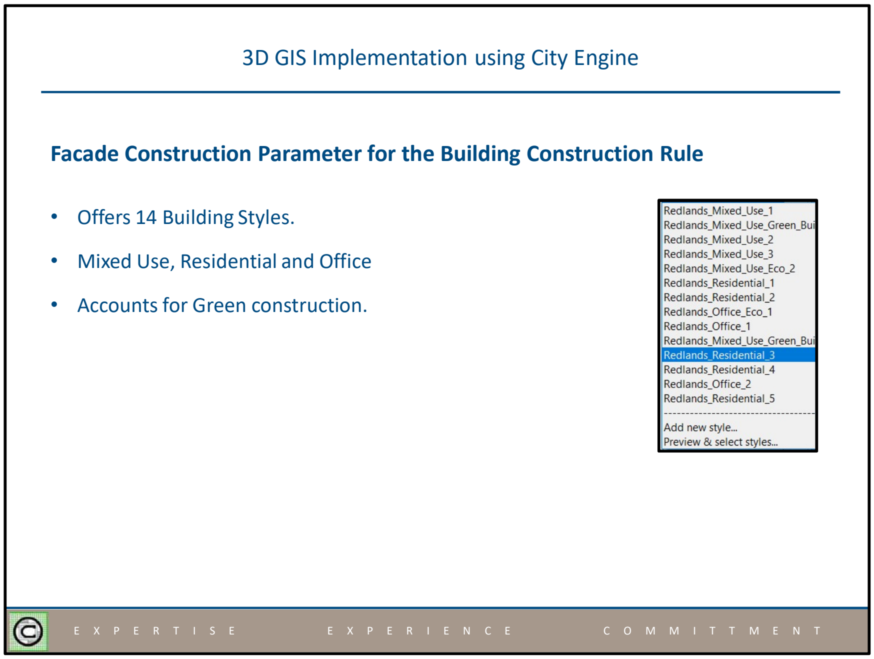
Moving on to Buildings, in the Redlands Redevelopment 2015 example there are a number of Rule Files. The Building Construction Rule File pertains to buildings, as the name implies. We decided to use this Rule File because of its robustness in being able to generate various types of building facades.



As can be seen there is an extensive list of parameters. A Key parameter is the Facade Construction parameter which controls the building style that is generated.



More parameters for the Building Construction Rule File.



Using the Facade Construction parameter the user can generate different building styles.

3D GIS Implementation using City Engine

Facade Building Styles 1 through 5 for the Building Construction Rule

Redlands_ Mixed_Use _1	Redlands_ Mixed_Use _Green_Building_1	Redlands_ Mixed_Use _2	Redlands_ Mixed_Use _3	Redlands_ Mixed_Use _Eco_2

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

Here are examples of the types of building facades that can be generated. Note that the user can control the number of floors, window size, balcony size and so forth.

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Facade Building Styles 6 through 11 for the Building Construction Rule

Redlands_Residential_1

Redlands_Residential_2

Redlands_Office_Eco_1

Redlands_Office_1

Redlands_Mixed_Use_Green_Building

Redlands_Residential_3

E X P E R T I S E E X P E R I E N C E C O M M I T T M E N T

The second set of building styles.

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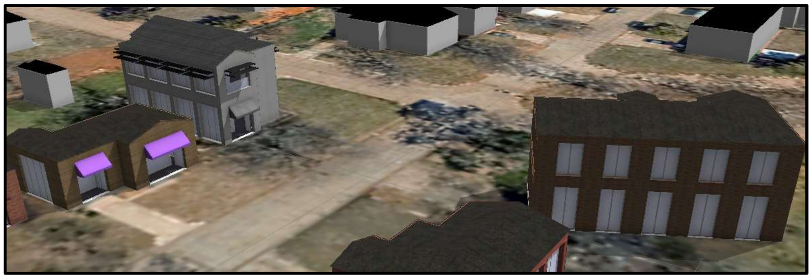
Facade Building Styles 12 through 14 for the Building Construction Rule



Redlands_Residential_4 Redlands_Office_2 Redlands_Residential_5

E X P E R T I S E E X P E R I E N C E C O M M I T T M E N T

The final set of building styles.

3D GIS Implementation using City Engine

Three Building Rule Files displayed in this view:

Generic Modern Buildings

Building

Building Construction

E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

In addition to the Building Construction Rule File within the 3D City Design Rules there are other building rule files that can be downloaded and accessed. The Rule Files mentioned in this slide were obtained from the Philadelphia 2011 Example, the Complete Streets 2015 Example and the Redlands Redevelopment 2015 Example, respectively. Another building rule file that can be considered is the /ESRI.lib/rules/Buildings/Building_From_Footprint.cga Rule File. This offers a number of different building styles with a much simpler user interface. This rule file is very applicable in cases where it is desired to assign a common building facade based upon zoning type.

3D GIS Implementation using City Engine

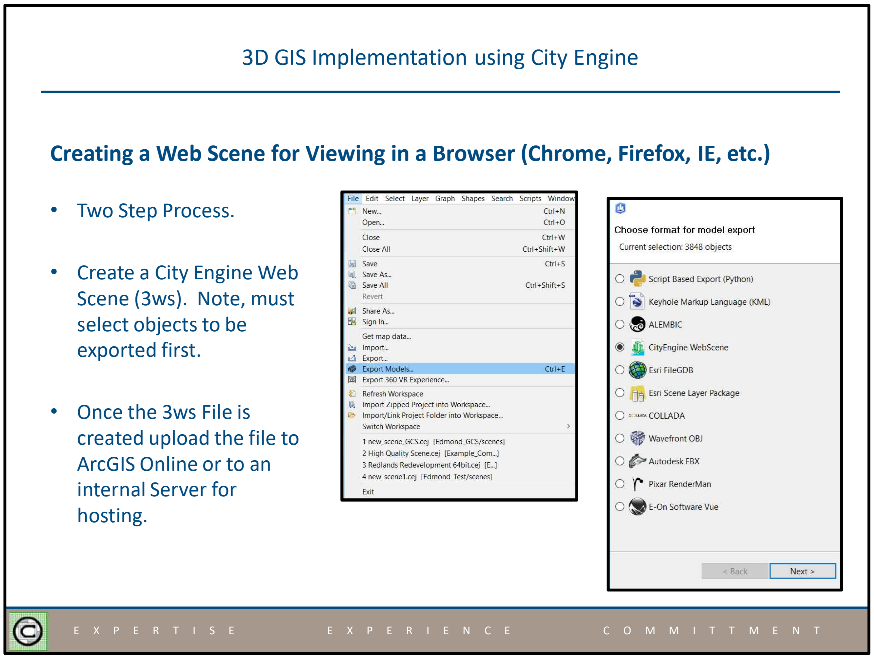
Buildings – Modeling Approaches

- Create a Rule for every *Building*.
  - Yields a very detailed and realistic model
  - Very time consuming and expensive
- Create a Rule for every *Type of Building*.
  - Yields an accurate model based upon use
  - Cost-effective
- Utilize Digital Photos as building facade texturing.
  - Yields a very detailed and realistic model
  - Very time consuming and expensive

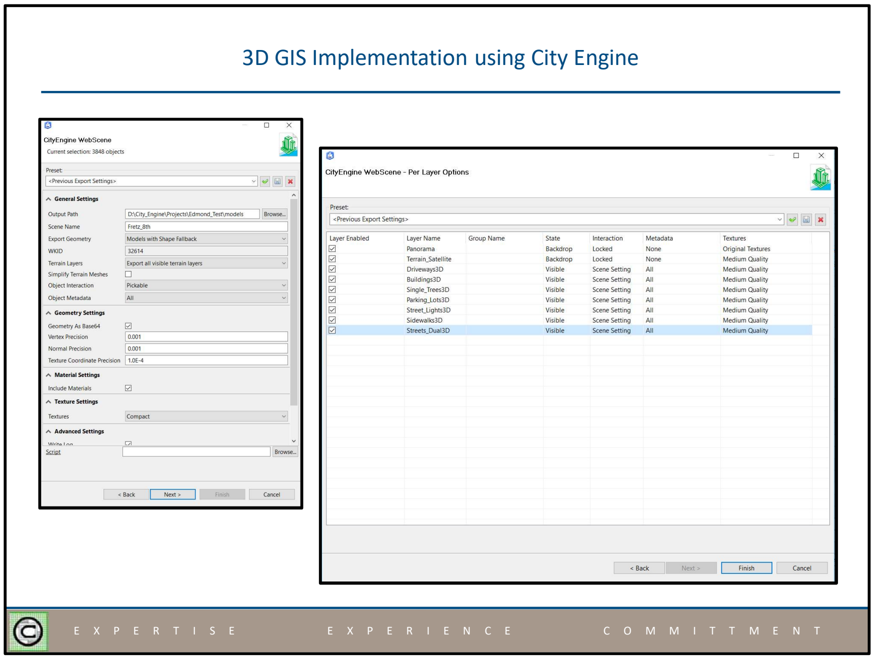
E X P E R T I S E   E X P E R I E N C E   C O M M I T T M E N T

Summarizing, depending upon how exact you want the model to look you can create a rule for every building or a rule for every type of building. Obviously, the less number of rules you have to create the faster the model building process will be. You can also download rules from the City Engine gallery and use those rules directly or customize them. Furthermore, the ability to utilize a digital photo of a building facade can be employed.

One last image illustrating the 3D terrain and ortho-imagery downloaded from ArcGIS Online with the 3D street centerlines and 3D building footprints. The streets have been assigned the Complete Streets Rule and the building footprints the Building from Open StreetMap Rule using the GenericMediumTown style. The most time consuming part of creating this model was the geometry post-processing of the streets in City Engine.



Once the model has been built there will probably be a need to make the model available for public or internal consumption via the Internet. To accomplish this, a City Engine Web Scene must first be created. This is an optimized web file carrying the 3ws extension. Once the file has been created it can be uploaded to ArcGIS Online or to an internal Server for hosting.



Once the user confirms that a City Engine Web Scene is to be created, there are a couple dialog boxes that are presented to the user. An important hint to remember is to disable the Simplify Terrain Meshes option. This will keep the Web Scene file small. Additionally, the Textures parameter enables the user to control the level of detail that appears in the Web Scene, while the Metadata parameter controls what attributes will be displayed when a feature is identified.

Prior to uploading the City Engine Web Scene file, it is possible to preview the Web Scene by navigating to the file from within City Engine and right-clicking on the file and opening the file using the 3D Web Scene Viewer. Note at the bottom of the Web Scene image, thumbnails of the bookmarks in the City Engine project will appear. To publish the Web Scene to ArcGIS Online, the Share As… menu item in the pop-up menu list can be selected.

**End of
Formal Presentation**

**We'd be pleased to
Respond to any Questions or Comments**

At the beginning of the presentation we had four questions we wanted to answer. We've addressed two of the four. That is how do we build the model and the level of difficulty. The remaining two, how long and cost really depends upon the level of detail that is desired in the model. The other factor to consider is the maintenance of the model. Like any other database there will be a maintenance effort to ensure the 3D GIS is current. As a rough estimate we would say that, for a two to six square mile area, a simple model can be generated in one to two weeks. A moderately realistic model is probably in the 1 to 3 month neighborhood, and a highly realistic model will be considerably longer. This assumes that the street centerline data will be used as is. If the centerline data has to be "cleaned up", the amount of time goes up.

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