

# Working with the Build-Out Wizard



Working with the Build-Out Wizard  
Scenario 360 v.5.1

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## About build-out

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Build-out analyses allow planners to estimate the amount and location of development for an area. Performing a build-out analysis is the step in the community planning process that identifies the holding capacity of the land. A build-out is a supply-side calculation applied to a clearly delineated area that is based on assumptions for density, physical constraints to development, and land-use regulations that define the size and placement of structures for that area. A build-out analysis provides an answer to the question “how many buildings *could* be built in this area according to current land-use regulations?”. A build-out analysis provides a convenient reference for future planning because it represents a theoretical maximum. It does *not* imply or forecast how many buildings will *actually* be built.

Traditionally, planners have performed build-out analyses by using spreadsheet tables to associate build-out assumptions with a hard copy map. GIS improves this technique by associating the digital land use plan with a database of associated attributes. The Scenario 360 Build-Out Wizard automates the entire build-out process. The Wizard guides users through the choices and selections that will form the basis of a build-out analysis.

Build-out analysis results will usually reflect the **remaining capacity** for an area (excluding existing buildings). You can estimate the number, location, and appearance of buildings based on land use or zoning information. You can set density assumptions in dwelling units per area, minimum lot size per dwelling unit, or floor area ratio. You can also assign design assumptions, including layout efficiency, building offsets, development constraints, layout pattern, and building type to your analysis.

There are many uses for build-out analyses. For example:

- What impact changing the zoning classification would have on the number of buildings an area could hold.
- What would happen if you changed the allowed density.
- What would be the impact if we modified the efficiency factor based on local conditions? For example, the factor for medium density residential might be 80%, but in steep areas it might reduce to 60%.
- How using different constraints would spatially limit where development may take place.

The build-out process contains 3 separate, but integrated steps: numeric, spatial, and visual. Each of these has certain data requirements and numerous options, and only numeric build-out is required. A Build-Out Tutorial is available for download on the CommunityViz website at <http://placeways.com/communityviz/index.html>.

## Numeric build-out

Numeric build-out is the first step in the build-out analysis process. Numeric build-out is a mathematical calculation that measures the holding capacity of land. Numeric build-out provides an estimated building capacity (in numbers) for each polygon in a layer based on its area, permitted or planned density rules, and other factors. The starting build-out calculation is simple: multiply the allowed density (buildings per area) by the area. For example, if an empty area of 100 acres is zoned for 1 acre residential lots, the build-out capacity for that area is 100 units. A zoning or land-use plan might have a combination of density designations (1 acre, half-acre, 10 acre, etc.). In Scenario 360, these are represented by polygons in a land-use layer, where each polygon has a designated land-use and each land-use has an associated density. With this information, Scenario 360 can easily calculate the area of each polygon, multiply by its density, and produce a resulting number of allowed buildings. From there, additional refinements and variations can be made. You can specify residential, commercial, and mixed-use buildings; prohibit development in certain areas; and transfer or adjust density in specified areas.

## Spatial build-out

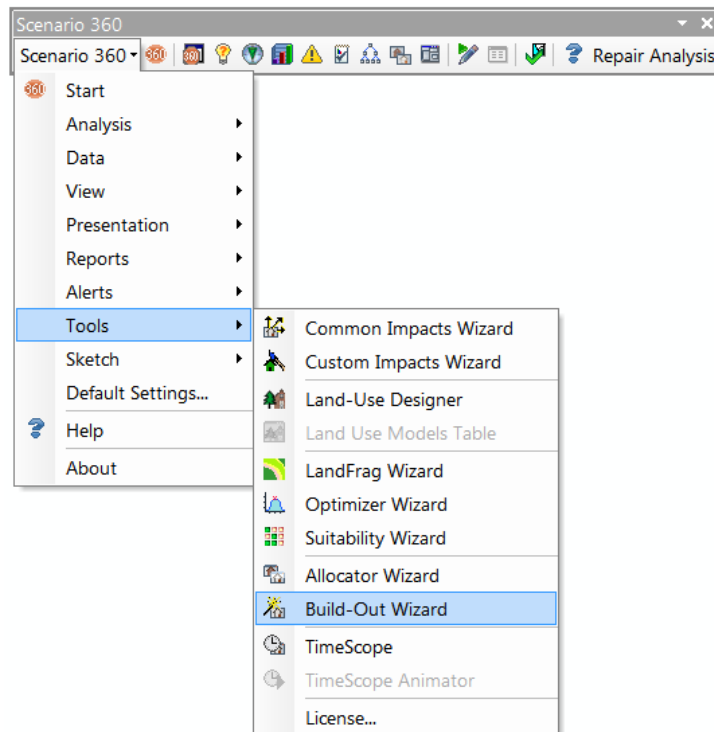
Spatial build-out is an optional further step that places building points or polygons on a 2D map. It converts the numeric building counts into points or squares representing individual structures. It then refines the numeric building counts by taking into account the actual geometry of land-use areas and buildings. For example, an oddly shaped lot may have enough total area for 2 buildings, but because of setback rules or minimum separation distances, it may only fit 1 unit. You must first run a numeric build-out analysis (to get the numeric building counts) before running a spatial build-out analysis.

## Visual build-out

Visual build-out automatically associates a 3D model with each building point created by spatial build-out. The models can be KMZ or DAE format. Spatial build-out placed the building points onto the 2D map. Visual build-out designates the 3D building model file for use in creating a 3D scene. Note: You must have access to 3D model files (like those in the 3D Model Library or those exported from SketchUp) to run visual build-out. Visual build-out only creates an attribute giving the 3D model to use for each building point; to view the models, you must use Scenario 3D, ArcScene, or Google Earth. You must first run spatial build-out (which requires you to run numeric build-out) before running visual build-out.

## Working with the Build-Out Wizard

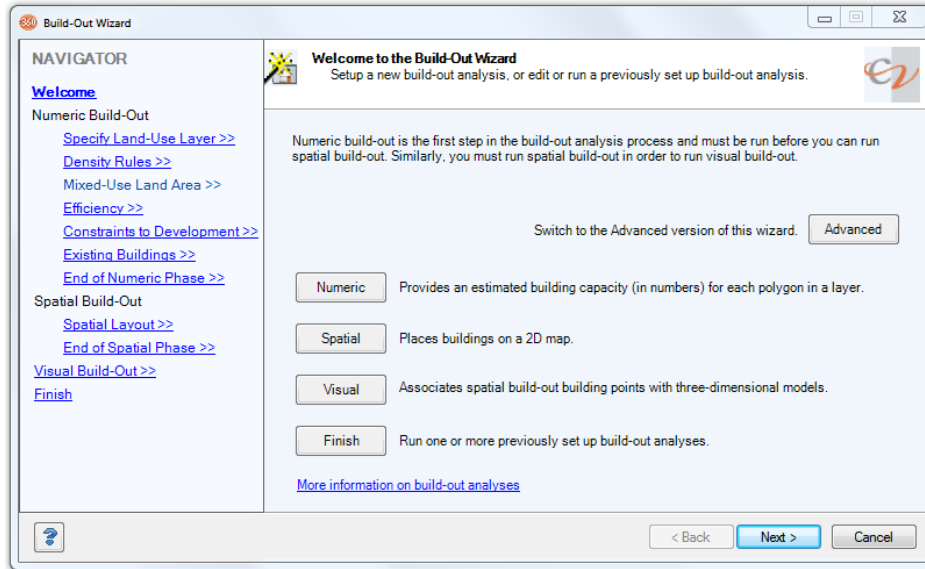
The Scenario 360 build-out analysis tool (the Build-Out Wizard) automates the entire build-out process. It guides you through the choices and selections that will form the basis of your build-out analysis. You can access the Build-Out Wizard using the Scenario 360 toolbar. Click the **Scenario 360** drop-down list, point to **Tools**, and click **Build-Out Wizard**.



In order for the Build-Out Wizard to be enabled the following must be true:

- The Scenario 360 extension is installed, licensed, and enabled
- The current map document is a CommunityViz analysis
- The Build-Out decision tool is installed
- The active dataframe must be a scenario
- The ArcMap Editor must be OFF
- The scenario must contain at least one polygon layer with a Projected Coordinated System

The Build-Out Wizard prompts you to enter data and assumptions to set up your build-out analysis. Based on this information, it runs a build-out analysis and creates new layers, attributes, indicators, and reports to display the results.



## Navigator

The left-hand side of the Wizard screens contain a **Navigator**, which is a table of contents for the wizard.

To jump to a particular screen in the wizard, click its name in the Navigator. You can jump to any screen whose name is in blue and underlined. Screens turn “on” in this way when you have entered sufficient information to make them applicable.

As you progress through the Wizard screens, the Build-Out Wizard will save information you have entered. This allows you to use the **Back** button when working in a Wizard session to return to previous steps and modify information. You can then use the **Next** button to return to screens you haven’t completed yet. Any information you previously entered into the Wizard screens will be retained. The **Save & Exit** button allows you to save the settings you have entered from the current Wizard session, exit the Wizard, and return to the Wizard to continue experimenting with your build-out analysis at a later time. The **Cancel** button will close the Wizard and discard any information you entered since you last clicked the **Save & Exit** button.

## Advanced Wizard

To display additional features and options in the Build-Out Wizard, click the **Advanced** button on the first screen. This will configure all screens in the Wizard to their advanced version. To return to the default version of the wizard, close it and reopen it.

## Use Attributes: Populating the Wizard using existing attribute values

This option is available only from the Advanced Build-Out Wizard. To access it, click the **Advanced** button the first page of the Wizard and then navigate normally.

For each build-out setting, you can enter values in the Wizard fields or use the table available in the **Use Attributes** option to specify a value from a pre-existing field in the land-use layer. When using this option, you can specify if one or more build-out settings is available in an existing data source. The data source information that you specify will automatically populate the Wizard. Any information that is not available in an existing data source can be entered in the Wizard manually.

To use the Use Attributes option, click the Advanced button the first screen of the wizard and then use the **Use Attributes** on the numeric build-out density rules screen, and on the spatial and visual build-out set up screens. Once information is entered into the Advanced table, an asterisk (\*) will be displayed next to that data and you will not be able to modify that information in the Wizard. During numeric build-out set up, you can use the **Import Table** option to import some or all numeric build-out values from an existing table.

## Running a build-out analysis

You can run a numeric build-out analysis by itself or as the first step in running a spatial or visual build-out analysis. Numeric build-out converts land-use information (like density, design efficiency factors, and constraints to development) into numeric building counts. Spatial build-out refines those numeric build-out building counts by taking into account the actual geometry of land-use areas and buildings. Spatial build-out then places the building points onto the 2D map. Visual build-out designates the building model file for your buildings for use in the visual 3D scene. So you must run a numeric build-out analysis in order to run a spatial build-out analysis, and you must run a spatial build-out analysis in order to run a visual build-out analysis.

At any point, you can save your Wizard settings and exit the Build-Out Wizard using the **Save & Exit** button. When you are ready to run one or more of the build-out analyses you set up for a scenario, open the Build-Out Wizard and click the **Finish** button.

Build-out analysis results will reflect the remaining capacity for an area (they will not include the existing buildings for the area). You will be prompted to specify any layers containing existing buildings. Associated dwelling units and floor space will then be subtracted from the build-out capacity calculation.

Each time you run a new build-out analysis on a given scenario, the old build-out analysis for that scenario will be overwritten and a new report will be generated. To explore and compare different alternatives without overwriting your previous results, you can create and use new scenarios in your analysis or compare your build-out reports side by side. For example, you may want to compare "build-out if we impose more restrictive zoning" versus "build-out if we create an enterprise zone". You will be asked if you want to create a new scenario each time you re-run a build-out.

Performing Build-Out analysis on a feature-intensive land-use layer can be very time consuming. The following items can significantly assist you with processing time:

- Start with a small test area until you find the right combination of settings.
- Reduce the number of features in your land-use layer.
- Reduce the number of constraints being considered.
- Do not consider existing building points
- Use a grid or random layout pattern, rather than the "follow roads" pattern.
- Use a smaller minimum separation distance.

## Cancelling a build-out run

Hitting ESC or SPACEBAR key on your keyboard will prompt you to cancel the build-out run. If you click YES, the build-out run will be cancelled, but the parameters supplied to the Wizard will be saved (similar to using the **Save & Exit** feature). If you click NO, the wizard will shut down and exit, and none of the calculations or results will be saved.

## Manually checking your build-out results

You can verify your build-out results using the calculation information later in this guide. This can be accomplished by picking a polygon in the original land-use/zoning/parcel map and then following the calculations for each item. The steps may start with area (5 acres), deduct land area in constraints (-1 acre of flood plain = 4 acres left), multiply density (x 3

DU/acre = 12 DUs), then apply the efficiency (x 75% = 9DUs). The manual calculation should match the results in your build-out analysis.

## Setting up a numeric build-out analysis

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The Build-Out Wizard guides you through the choices and selections that will form the basis of your build-out analysis. For a numeric build-out analysis, the Wizard will calculate the estimated building capacity (in numbers) for each polygon in an area. Open the Build-Out Wizard and click the **Numeric** button to create or edit a numeric build-out analysis. Remember, you must run a numeric build-out analysis if you wish to run spatial or visual build-out. You can, however, run only a numeric build-out analysis.

### Data requirements

When following the numeric Build-Out Wizard steps, you will be prompted to specify:

- A land-use layer (like a zoning map, master land-use plan, or a parcel map). This must be a projected coordinate system (as opposed to a geographic coordinate system). For information on coordinate systems, see ArcMap help.
- The attribute in that layer that specifies the land-use designation (like zoning type, permitted use description, or land-use code).
- Optionally, the attribute that specifies the unique identifier of each land-use area (like feature ID or parcel number).

### Setting up density rules

When setting up a numeric analysis, set up dwelling units and/or floor area using the **Density Rules** Wizard screen. Click in any field and type a number or select an option from a drop-down list. Use the **Use Attributes** option to populate the Wizard using existing values.

Density is an indication of the number of buildings per unit area. Attributes specifying land-use designations may contain fields that describe the permitted (or projected or planned) densities in each polygon. For residential polygons, density is often provided in dwelling units per area, number of dwelling units, or minimum lot size per area. For non-residential polygons, density is usually provided in floor area or by using a floor area ratio (FAR).

Dwelling Units per Area (DU/area) (DU/area) density usually describes residential land-use density in a land-use plan (master, community, or comprehensive plan). Frequently the density is listed as a range (3-6 DU/area), but numeric build-out requires you enter a single number. You can create two scenarios and run the Build-Out Wizard using the low and high range for comparison. When entering DU quantities into the Wizard, you must specify a measurement unit in the field provided.

The default is **DU/acre** but you can choose other units.

- **Min lot size** is the average minimum area used by each dwelling unit. Usually this is the inverse of DU/area. For example, 0.2 DU/acre works out to an average minimum lot size of 5 acres per dwelling unit. This number is an average. If your regulations prevent any building at all on parcels below a certain size, use the setting on the **Constraints to Development** screen.
- **Number of DU** is used for planned unit developments (PUDs) and other cases where the number of dwelling units in a polygon is specified as a particular number rather than a number per unit of area. This would normally be used for a land-use designation that applied to a single polygon.

**Floor Area** refers to the amount of building floor space (see details below). Density of commercial building such as offices, retail, and industrial buildings is usually specified in terms of Floor Area Ratio (FAR), which is the area of building floor (including all stories) divided by the area of the polygon.

*Example:* A 3-story building with a 1000-square foot footprint standing on a 4000-square foot lot has a FAR of  $(3 * 1000)/(4000) = \frac{3}{4} = 0.75$ .



Floor area is also used to designate mixed-use buildings that contain both dwelling units and commercial space. You can specify an exact amount of floor space for a given land-use designation. Use the Advanced version of the Wizard and then choose square feet or square meters in the FAR units drop-down box. This would normally be used for a land-use designation that applied to a single polygon.

### **Transferring density**

**Density transfer** will take the original estimate of buildings in a polygon, and locate them in a smaller, developable area. The effective density in that portion will be greater than originally set. When transferring density, the allowance for number of buildings on the lot ignores the constrained area, even though the actual buildings cannot be placed there. For example, if you lose 10% of your developable area due to a constraint area, the density can be transferred and compressed into other areas in that land-use designation.

## **Understanding floor area ratio (FAR)**

A build-out analysis can include residential dwelling units *and/or* commercial or mixed-use buildings. Although the build-out concept is the same, the way density is specified for commercial buildings is often different from how it is specified for residential buildings. Residential densities are usually given in terms of "dwelling units (DU) per area," with units like DU/acre, DU/parcel, or minimum lot size (i.e., acre/DU). Commercial densities, on the other hand, are often specified in terms of "building area per lot area," with the most common unit being "floor area ratio," or FAR.

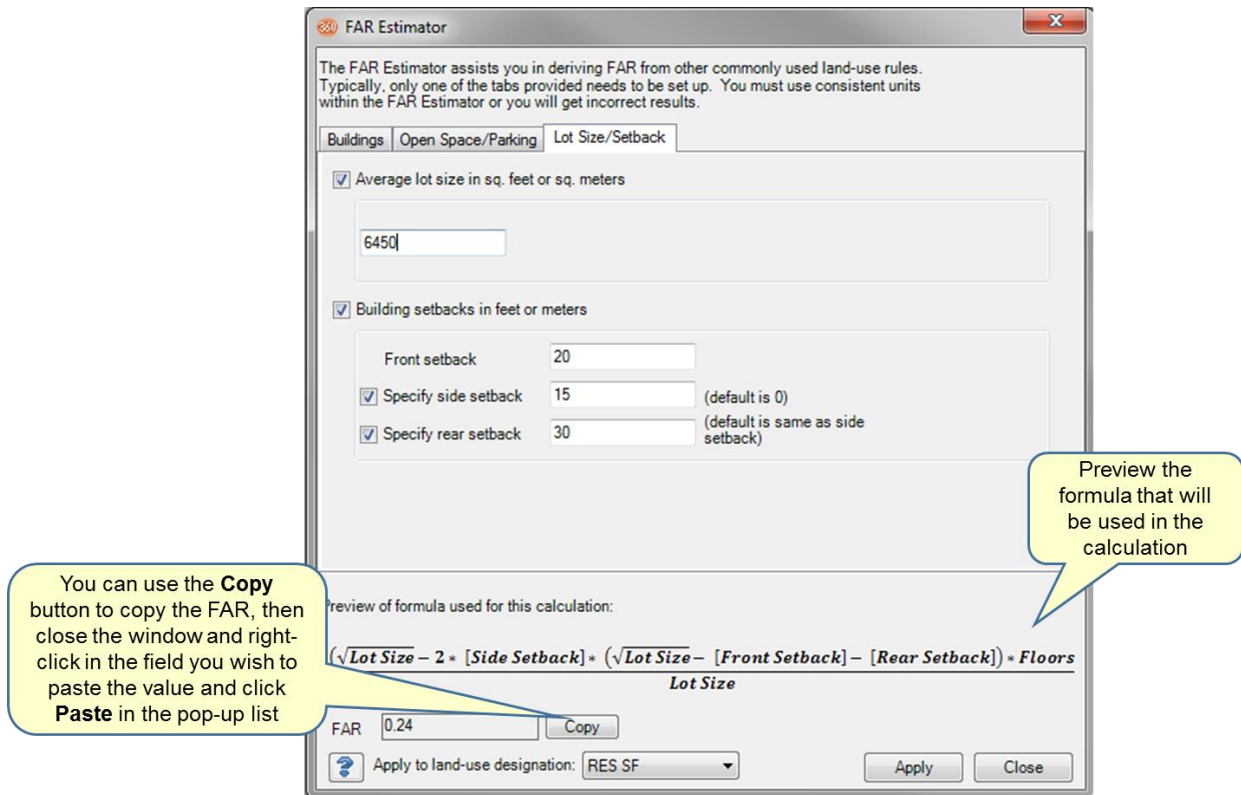
FAR is the ratio between the total floor space in a building (including all stories) and the area of the land it is built on. It is calculated by dividing the total floor area of all buildings or structures on a lot by the total area of the lot. Some example FAR estimates:

- A building containing 20,000 square feet of floor area on a zoning lot of 10,000 square feet has a FAR of 2.0.
- A one-story building that covers an entire lot has an FAR of 1.
- A one-story building that covers ½ of a lot has a FAR of 0.5.
- A typical suburban mall would have a FAR of .25.
- A high-use office may have a FAR of over 10.0.

### **Using the FAR Estimator**

This option is available only from the Advanced Build-Out Wizard. To access it, click the **Advanced** button the first page of the Wizard and then navigate normally. Sometimes, land-use regulations don't specify FAR but instead use other rules such as minimum set back from lot lines and maximum building height. The Build-Out Wizard includes a FAR Estimator to help you derive FAR from other commonly used land-use rules.

1. When setting up a numeric analysis, click the **FAR Estimator** button on the **Density Rules** Wizard screen.
2. Click the appropriate tab and enter information about buildings, open space, parking, lot size, and/or setback.
3. Click the **Apply to land-use designation** drop-down list and select the designation you wish to apply the calculation to and click **Apply**.
4. Click the **Close** button to close the FAR Estimator to view the FAR on the Wizard screen.



You can use the **Copy** button to copy an estimated FAR into Microsoft® Word, Notepad, Excel, or other application. You can also copy and paste the estimated FAR into any **Floor Area Quantity** field by doing the following:

1. Perform the FAR calculation using the FAR Estimator.
2. Click the **Copy** button.
3. Close the FAR Estimator.
4. Right-click in the **Floor Area Quantity** field on the **Density Rules** table and click **Paste** on the pop-up menu.

## Using the Import Table option

This option is available only from the Advanced Build-Out Wizard. To access it, click the **Advanced** button the first page of the Wizard and then navigate normally. For each numeric build-out setting, you can enter a value in a Wizard field or use the Import Table option to import some or all values from an existing table. When using this option, you can import a table created in ArcCatalog™ or Microsoft® Access into the analysis, or you can specify if one or more build-out settings is available in a table that is already in the analysis. The information specified in the table will automatically populate the Wizard. Any information that is not available in the table can be entered in the Wizard manually. Any information you choose to change in the Wizard will not change the source table. For detailed information on table formats, see the Appendix, p. 20.

## Specifying Mixed-Use Designations

You can specify mixed-use (residential + commercial) land-use designations.

If desired, you can also specify mixed-use buildings.

### Examples:

- Mixed-use land area: A 2-acre polygon shows 5 DU/acre and 0.4 FAR on the Density screen. Assuming no other constraints, build-out will allow 10 DUs and 0.8 acres of commercial floor space on the polygon.
- Mixed-use buildings: A 3-acre polygon shows 0 DU/acre and 2.0 FAR on the Density screen and the mixed-use buildings box is checked. On the mixed-use buildings screen, it is stipulated that 50% of each building consists of apartments with 1200 sq feet per dwelling unit. Build-out calculates 6 acres (= 3 acres \* 2.0 FAR) of commercial floor space. It also calculates that half of the space consists of 1200-sq foot apartments, which works out to about 60 DUs.

## Specifying Mixed-Use Land Area

To specify mixed-use *land areas*, provide both a residential density and a commercial floor area on the **Density** screen.

Later in the Wizard, a **Mixed-Use Land Area Percentages** screen will appear automatically because you entered both residential and commercial density. Usually you can accept the default of "assume 100% of area is available for both use types," but you may want to modify this depending on how your density rules area specified.

100% means that the number of DUs and the amount of floor area are calculated independently using the entire area of each polygon.

*Example:* On a 1-acre polygon with density of 5 DU/acre and 0.4 FAR, 100% usage allows 5 DUs and 0.4 acres of commercial floor area.

Less than 100% reduces the area each use is allowed.

*Example:* If the regulation is that 60% of the land is to be used for residential and 40% for commercial purposes, and the Density screen specified 5 DU/acre and 0.4 FAR, then on a 1-acre lot the number of DUs allowed is  $(5 \text{ DU/acre}) * (1 \text{ acre}) * (60\%) = 3 \text{ DUs}$ . The amount of floor space is  $(0.4 \text{ FAR}) * (1 \text{ acre}) * (40\%) = 0.16 \text{ acres of floor space}$ .

Smaller percentages in mixed-use land area do *not* need to add to 100%.

## Specifying Mixed-Use Buildings

To specify mixed-use buildings, you must use the Advanced Build-Out Wizard. To access it, click the **Advanced** button the first page of the Wizard and then navigate normally.

Specifying mixed-use *buildings* is less common than mixed-use land area but well supported in the Build-Out Wizard. Mixed-use buildings contain both residential dwelling units (DUs) and commercial floor space such as offices or retail.

1. On the **Density Rules** Wizard screen, specify non-zero Floor Area density for the designation containing mixed-use buildings. This is the floor area of the entire building, including its residential portions. Enter 0 dwelling units at this time. (Rare exception: If the land use regulations ALSO call for single-use residential buildings in this area, enter their density on this screen.)
2. Place a checkmark next to the link **One or more designations include mixed-use buildings**
3. After filling in the DU and floor area for your other designations, click **Next**.
4. Place a checkmark next to designation that contains mixed-use buildings and click **Next**.
5. In the **Building Use** field, type the floor area use (you can specify up to 5 uses per designation). Examples are "apartments," "offices," "retail," etc.
6. In the **Percent of Floor Area** field, type the percentage of floor area to be used for this building use. For example, if apartments will take half the building space, enter 50 next to apartments. The percents must add to 100.
7. In the **Floor Area per DU** field, select a measurement unit from the drop-down list, then type the size of each dwelling unit in this field. For example, for 1200 sq foot apartments, type 1200. For non-residential building uses like retail and

office, leave these fields blank. You can also leave these fields blank for apartments or other residential uses if you don't want the wizard to calculate their equivalent DUs.

8. Ensure that your building use percentages add up to 100% and click **Next**.

## Using efficiency factors

Efficiency factors adjust density values to reflect common density losses. They are entered as a percentage where 100% means complete efficiency (no density lost), and 0% means no buildings will be estimated for that land use.

Efficiency factors can be very versatile ways of affecting development. For example, an efficiency factor can represent the composite efficiency of development taking into account how much land has to be dedicated for roads, schools, and open space. It can also contain less obvious factors that reduce development. For example, the likelihood that an area will be developed can be factored in. In addition, the element of time can be introduced, by limiting what portion of the build-out may be developed in any one year. If you have detailed data on constraint layers and you plan to use spatial build-out, efficiency factors may be unnecessary.

There is no set formula for coming up with a composite efficiency factor. In some cases, you may want to add the factors up. For example, if 10% of your developable land has to be set aside for parks, and 20% for roads, then you should add these to come up with a composite efficiency of 70% (100% - 10% - 20%). However, if you want to consider a likelihood factor (e.g. "given economic pressures, chances are about 50% that build-out will occur in the next 10 years"), you should multiply it by the other factors (e.g.  $(70 / 100) \times (50 / 100) \times 100 = 35\%$ ).

Dwelling Units/Area	Percent Efficiency
0.01	100
0.02	90
0.5	80
3+	75

Efficiency factor examples:

- In urban areas owners with a single house that spans multiple lots may build on the more vacant adjoining lot. Only a percentage choose to build, which would mean you would select lower efficiency factor based on expectations of the percent of owners that can or wish to build on these lots.
- A road right-of-way (ROW) of 50 feet with 100 foot deep lots uses 20% of the land for roads. Cross streets require additional dedications or deductions.

## Entering building information

This option is available only from the Advanced Build-Out Wizard. To access it, click the **Advanced** button the first page of the Wizard and then navigate normally. The **Building Information Wizard** screen allows you to set up building size, dwelling units per building, and footprint of each building. This step is optional.

Building Information can apply to either residential dwelling units or to commercial floor space. Do not use this screen for mixed-use buildings. Instead, see *Specifying Mixed-Use Buildings*.

**Residential Designations:** Change the number of DU per building from the default of 1 to a higher number like 2, 4, or 8 to specify multi-family residences like apartments, duplexes, or condos. The numeric calculation of DUs will not change, but the number of buildings and spatial points placed will be reduced by a factor of 2, 4, 8 or whatever was specified. The Area fields are not applicable to purely residential designations.

**Commercial Designations:** Most land-use regulations specify only total floor area, not number of buildings. Realistically, however, a total allotment of floor area may be broken into several buildings. By default, the Build-Out Wizard places one commercial building point per commercial polygon regardless of its size. You can use the Building Footprints fields on this

screen to specify the size and stories of commercial buildings so that more than one building point is created per commercial polygon. Fractional buildings are ignored.

Click in any field and type your DU per building, area, and floor information. Use the drop-down list under **Area** to select the measurement units.

The **Building Footprints Area** field on this screen is the same as the **Footprint Size** field on the **Spatial Buildings** screen. Changing the data in one screen causes it to change in the other.

## Specifying constraints to development

There are many uses for the ability to limit development. The obvious use is to keep development out of areas that should not be developed due to statutes and laws, such as wetlands, cemeteries, golf courses, and historical districts. Exclusions may also be made due to unstable soils, contamination, proximity to sources of noise or pollution, and steeped sloped areas. When prompted to specify your constraint layers, simply click to select your constraint layer(s) then click the **Add selected layer(s) to constraints** button.

If you do not have a polygon layer, but would like to exclude the area around points or lines, such as around cell towers, air traffic control towers, roads, or rivers, you can buffer these layers using standard ArcMap tools, and specify the resulting polygon layer as a constraint to development so buildings will not be placed in these buffer zones. See also "Setting up density rules" on page 8.

Tip: Using as few constraints as possible will significantly reduce the time it takes to run a spatial build-out. If you have multiple constraints and are an advanced ArcGIS user, you can use the union, dissolve, then explode commands to decrease the number of constraint polygons.

## Minimum lot size

In practice, a legal building lot may start out smaller than the minimum lot size, or its buildable area may become smaller than the minimum lot size after constraint layers are applied. By default, the wizard uses the rule that a legal lot always allows at least one building regardless of the size of the lot or its buildable area. This is in keeping with policy and practice in many jurisdictions, but it is a controversial rule and in some cases it may lead to an overestimate of the number of buildings allowed. If you choose to "Specify a minimum size for buildable parcels," no buildings will be placed on parcels where the buildable area (after constraints have been applied) is smaller than the area you specify.

Even if you choose this option, there is a risk that numeric build-out will still overestimate the number of buildings. This is because your analysis may contain "slivers" – long thin polygons that are too narrow for a real building but whose total area is greater than the minimum size you have specified. If you suspect you have slivers of this type, run spatial build-out with a non-zero setback distance. Set-back is calculated from the edge of the polygon after constraints have been applied and it will effectively prevent buildings from being placed on slivers.

## Specifying layers with existing buildings

Build-out analysis usually tries to calculate the **remaining** capacity for an area, excluding existing buildings. In other words, it calculates total theoretical capacity, then subtracts buildings that are already built. In this screen you are prompted to specify any layers containing existing buildings. The associated dwelling units and floor space will be subtracted from the gross capacity.

1. Click to select a layer from the **Available Layers** column.
2. Click the **Move** button to add the layer to the list of layers containing existing buildings.
3. In the **Value or attribute specifying floor area** field, select a measurement unit from the drop-down list.
4. When you have added and customized all layers in your analysis containing existing buildings, click the **Next** button.

If you have building footprints you would like to include as existing buildings, you can designate the footprint polygons as constraint layers. Note that this may be resource-intensive for large numbers of existing building footprints.

## Numeric build-out analysis results

Numeric build-out converts land use information (like density, design efficiency factors, and constraints to development) into numeric building counts.

Running a numeric build-out analysis will produce:

- Two new layers visible in the **Build-Out** layer in the ArcMap table of contents. One is called **Buildings** and the other is **Buildable Area**.
- A **Build-Out LandUses** table. You can click the **Source** tab, right click on the **Build-Out LandUses** table and click **Open** on the pop-up menu to view the contents of this table.
- Six indicators. Click the **List Indicators** button on the Scenario 360 toolbar to view the new indicators.
- A **Build-Out** report. Click the **List Reports** button on the Scenario 360 toolbar then click on the report name to view the report.
- Three new charts: **Build-Out Dwelling Units**, **Buildings**, and **Floor Area**. Click the **View Charts** button on the Scenario 360 toolbar to open the charts view.
- A new **Buildings Difference Buildable Area** alert. Click the **List Alerts** button on the Scenario 360 toolbar then click **Show all alerts** to view the alert.

The screenshot displays the ArcMap interface with the Scenario 360 extension. The Table of Contents on the left shows the 'Build-Out' layer with sub-layers for 'Buildings' and 'Buildable Area'. The central map shows a color-coded land use map. Several toolbars are visible, including the Scenario 360 toolbar. Callout boxes point to specific elements:

- Two new layers viewable in the Build-Out layer in the ArcMap table of contents:** Points to the 'Buildings' and 'Buildable Area' layers in the Table of Contents.
- Six new indicators:** Points to the 'Indicators' window, which displays a table of indicators and their values.
- A build-out report:** Points to the 'Reports in Build Out' window, showing a report titled 'Build-Out Study Area 5.26.2012'.
- Three new charts:** Points to three bar charts: 'Build-Out Buildings', 'Build-Out Floor Area', and 'Build-Out Dwelling Units'.
- A Build-Out LandUses table:** Points to the 'Table' window showing a data table with columns for OBJECT, SHAPE, Parent Landuse, Land Use Designation, Numeric Floor Area, and Numeric Dwelling Units.
- An alert:** Points to the 'Active Alerts' window, showing an alert for 'Buildings Difference Buildable Area'.

Indicator	Units	Study Area
Build-Out Numeric Dwell...	du	63.00
Build-Out Spatial Dwell...	du	0.00
Build-Out Numeric Build...	buildings	265.00
Build-Out Spatial Buildings	buildings	0.00
Build-Out Numeric Floor ...	floor area	2,333,385.83
Build-Out Spatial Floor Ar...	floor area	0.00

OBJECT	SHAPE	Parent Landuse	Land Use Designation	Numeric Floor Area	Numeric Dwelling Units
31	Polygon	1	Mixed Use C	371947.215076	
32	Polygon	2	Commercial	394314.433947	
33	Polygon	3	High Density Residential	0	
34	Polygon	4	Mixed Use B	885211.044159	
35	Polygon	5	Municipal	161794.167797	
36	Polygon	6	Park/Openpace	0	
37	Polygon	7	Park/Openpace	0	
38	Polygon	8	Park/Openpace	0	
39	Polygon	9	Mixed Use A	520118.971877	

## Setting up a spatial build-out analysis

Remember, you must first run a numeric build-out analysis before running a spatial build-out analysis. Spatial build-out uses the numeric building counts (the result of numeric build-out) to create and populate a build-out point layer you can view on

your 2D map. It also refines the numeric building counts by taking into account the actual geometry of land-use areas and buildings.

## Data requirements

When setting up a spatial build-out analysis, you will be prompted to specify building separation distance rules for your land-use designations.

## Specifying building separation distances

Site plans often contain fewer buildings (or building space) than authorized by the land-use plan or zoning district. Reasons for these reductions may include:

- Irregular parcel shapes frequently require some larger lots.
- Road, school, and park dedications.
- Larger lots are required in curved sections of streets and at the end of cul-de-sacs.
- Moderate slopes make development patterns less efficient by requiring more land for grade transitions. Cut and fill slopes can reduce the usable land on a lot. Proper drainage and flat activity spaces require larger side and rear yards. Non-residential and higher density residential activities are typically more sensitive to steep slopes due to expanses of flat parking lots and building pads.

Building separation identifies the minimum offset between building centroids. Low separation distances are preferable for infill and redevelopment areas. Low separation numbers may cause buildings to touch other buildings on your map or 3D representation. High separation numbers may prevent placement of all of the buildings identified in numeric build-out. High building separation distances may make small or narrow lots unbuildable, creating no building points in a lot that is buildable. These under utilized areas will require adjustment of the minimum distance because low settings may cause buildings to encroach into inappropriate areas.

Some common rules of thumb for building separation are:

Dwelling Units/Acres	Separation (in Feet)
0.01	200
0.02	100
1	50
3+	25
20 *	75

\*20 dwelling units per acre with 12 units per building.

The **minimum separation distance** is used as a buffer between adjacent new buildings in a polygon. If, for example, ten buildings are placed in one zoning polygon, they will not be closer to each other than the specified minimum separation distance. A new building placed in an adjacent polygon may be closer, since the minimum offset measurement is restricted to one polygon at a time. In the case of existing buildings, the minimum separation between a new building and any existing building is measured, even if the existing building is in an adjacent polygon.

Minimum separation distances are only taken into account when you run spatial build-out. New points that are manually added to the new buildings layer will not be automatically restricted by the separation distance.

## Choosing a layout pattern

You have control over whether the spatial build-out building points are distributed in a random or grid pattern, or if you want the points to follow a road layer. The grid pattern is good for urban development and random for suburban type development. Choosing the random layout pattern will produce the fastest results. The follow roads layout pattern is the most

computationally intensive calculation and will take the longest to produce results. The Build-Out Wizard does not distinguish between road types. Therefore, if you manually edit a roads layer, you should re-run spatial build-out for accurate results.

## Spatial build-out analysis results

Spatial build-out places building points on your 2D map so that they avoid development constraints, other buildings, and polygon boundaries (land-use areas, zone districts, or lot lines). Potential building points are distributed two-dimensionally into each polygon one at a time. Spatial build-out is not a layout tool (e.g. designing roads, orienting buildings, or accounting for site amenities).

Spatial build-out analysis takes into account factors which cannot be accounted for in numeric build-out, such as the minimum allowable separation between building or parcel shapes. Existing buildings, if you specified any, are avoided. Therefore, the results of spatial build-out are sometimes lower than the numbers estimated during numeric build-out.

Running a spatial build-out analysis:

- Populates fields in the Buildable Area attribute table. You can right-click on the **Buildable Area** layer in the ArcMap table of contents and click **Open Attribute Table** to view the contents of this table.
- Populates fields in the Build-Out LandUses table. You can click the **Source** tab, right click on the **Build-Out LandUses** table and click **Open** on the pop-up menu to view the contents of this table.
- Adds information to the Build-Out report.
- Updates the Spatial information in the charts created during numeric build-out.
- If your spatial build-out results did not meet your numeric build-out estimates, the Buildings Difference Buildable Area alert created during numeric build-out will be triggered. Click the **List Alerts** button on the Scenarion 360 toolbar then click **Show all alerts** to view the alert. If you have triggered the alert, the alerted area is displayed in the map view with a bold outline.

If you use the Follow Roads layout pattern, you must also specify a Setback distance. The setback is the exact distance from the road centerline to the building point or center of the building polygon. Setback distances are ignored when the grid or random layout pattern is used.

**Tip:** Setback distances should be greater than half the minimum separation distance and greater than the distance from the road centerline to the edge of the land-use polygon. Otherwise, no building will be placed.

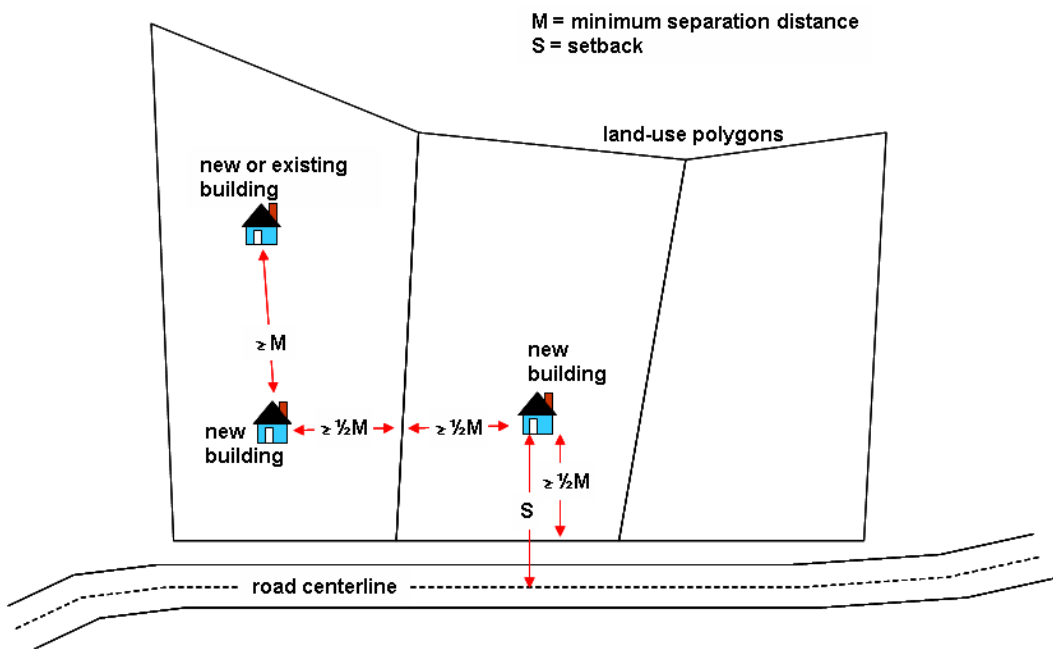
Keep in mind the following when viewing the results of a spatial build-out analysis:

- A new building point will be separated from another new building point in the same polygon by at least the minimum offset distance specified for that polygon's land-use class.
- A new building point will be offset from its containing polygon's edge by at least half the minimum offset distance specified for that polygon's land-use class.
- A new building point will be separated from any existing buildings in the same polygon by at least the minimum offset distance specified for that polygon's land-use class.
- If a building does not appear in a polygon when you expect one to appear, or if fewer buildings are added than there is capacity, examine the attributes of the polygon. Was an estimated capacity correctly computed? Are there more existing buildings in the polygon already than there is capacity? Also, examine the dimensions of the polygon. Perhaps the minimum offset distance is too large.
- After spatial build-out has been run, you are free to edit the new buildings layer manually. You can add, move, or delete building points. This way you can turn a planning-level building pattern into more of a design-level distribution, with buildings following a uniform frontage line, etc.

After spatial build-out has been run, you are free to edit the new buildings layer manually. You can add, move, or delete building points.

The following diagram represents minimum separation distance and setback rules:





If a building does not appear in a polygon when you expect one to appear, or if fewer buildings are added than there is capacity for, try these troubleshooting steps:

- Check your capacity estimate for the polygon, keeping in mind minimum separation rules, road setback rules, existing buildings, and constraint layers.
- Try decreasing the minimum separation distance.
- Try increasing the road setback.
- Uncheck the Minimum Lot Size option on the Constraints to Development screen of the wizard.

## Spatial Buildings

This option is available only from the Advanced Build-Out Wizard. To access it, click the **Advanced** button the first page of the Wizard and then navigate normally.

On the Spatial Buildings screen, you can specify whether spatial build-out buildings are created as points or as square polygons. You can also specify the area of the squares used for each land-use type. These polygons are useful for making extruded 3D buildings and for performing overlap and building-area calculations.

**To create footprints:** For each land-use, click in the table under "Building Type" to choose Footprints instead of Points. The "Footprint Size" field will automatically be populated by any value you entered in the "Building information" page of Numeric section of the Wizard. You can change it here if you wish by clicking on the number; your changes will also be reflected in the earlier screen.

The number entered will be used as the total area of the square polygon that will be created for each building. Note that the squares drawn are meant to represent the amount of land covered by each building, not total floor space. In multi-story buildings, the total floor space is usually estimated as the size of the footprint multiplied by the number of stories.

## Setting up a visual build-out analysis

Spatial build-out placed the building points onto the 2D map. Visual build-out designates a 3D model file for those building points that can be viewed in a 3D scene. Therefore, you must first run spatial build-out (which requires you to run numeric build-out) before running a visual build-out.

Visual build-out is optional. It provides a convenient way to specify 3D building models that will be used in a 3D scene, but it is not the only way to do so.

## Data requirements

You must have access to 3D model files (like those in the 3D Model Library or C:\CVFiles\3D Models) or elsewhere to run visual build-out. Visual build-out only creates an attribute giving the 3D model to use for each building point; to view the models, you must use Scenario 3D, ArcScene, Google Earth or another 3D viewer.

1. Open the Build-Out Wizard.
2. Click the **Visual** button.
3. Click once in the **3D Model** field next to your land-use designation then click the **Browse** button.
4. To specify a 3D model, navigate to the location that stores your 3D models (3DS, KMZ, or DAE files), browse for a suitable building, click once to select it, then click the **Select** button. You can also type a **full path** name. If you specify multiple buildings for one land use, the wizard will select among them randomly for each building point. Model names should be separated by semicolons in the table.
5. Continue steps 3 and 4 for all of your building layers. When you have completed selecting models, click **Next**.

## Visual build-out analysis results

Running a visual build-out analysis will populate the 3D Model attribute with the full path name of each model you have chosen.

The **Use Attributes...** button allows you to point to an existing value in an attribute field to specify 3D models.

## Creating a 3D Scene

Once you have specified your models and run visual build-out, you must create a 3D scene to view the results in 3D. To do this in Scenario 3D:

1. Create a 3D scene with the Scenario 3D Exporter using the directions in the Scenario 3D Help.
2. To represent the build-out buildings, choose the **Buildings** layer on the **Scenarios & Layers** tab of 3D Scene Settings. Double-click it.
3. Choose Substitution Method: Model Attribute.
4. Under Model Attribute, choose "3D Model."
5. Optionally, under Options you may choose an Orientation based on the *AngleTo* function. This requires creating a new attribute in the Buildings layer.
6. Click **OK** to save your settings. Make sure the Buildings layer has a yellow cube and a green check mark in the Layers list, then click **OK** to exit 3D Scene Settings.
7. Click **Export Now** and then **Launch 3D** Viewer to see the buildings.

For detailed information on creating a 3D scene, see the Scenario 3D Help.

To do this in Google Earth scenes:

1. Open the Google Earth Export Settings window.
2. On the **Layers** tab, click on the Buildings layer and place a check in its box.
3. For "Export Layer As," choose "3D Models."
4. Under 3D Model Settings, choose "Get 3D model file from a field."
5. For the field, specify "3D Model."
6. Optionally, you may choose an Orientation based on the AngleTo function. This requires creating a new attribute in the Buildings layer.
7. **Save** your settings for later use or **Export Now**.



## Appendix

### Conversion factors

The chart below lists the conversion formulas used in build-out analysis calculations.

Convert From	Convert To	Multiply By
Acres	Hectares	0.404687
	Sq Feet	43560
	Sq Feet (US Survey)	43559.826
	Sq Kilometers	$4.04686 \times 10^{-3}$
	Sq Meters	4046.856421
Feet	Kilometers	$3.048 \times 10^{-4}$
	Meters	0.3048
	Miles (statute)	0.000189
Hectares	Acres	2.471
	Sq Feet	107639.1
	Sq Kilometers	0.01
	Sq Meters	10000
Kilometers	Feet	3280.84
	Meters	1000
	Miles (statute)	0.62137
Meters	Feet	3.28084
	Feet (US Survey)	3.28083
	Miles (naut, int)	0.00053996
	Miles (statute)	0.000621
Miles (Statute)	Feet	5280
	Kilometers	1.609344
	Meters	1609.344
Sq Feet	Acres	$2.2957 \times 10^{-5}$
	Sq Meters	0.0929
Sq Feet (US Survey)	Acres	$2.2957 \times 10^{-5}$
Sq Kilometers	Acres	247.1054
	Sq Feet	$1.07639 \times 10^7$
	Sq Feet (US Survey)	$1.07639 \times 10^7$
	Sq Meters	$1 \times 10^6$
Sq Meters	Acres	0.000247
	Hectares	0.0001
	Sq Feet	10.7639
	Sq Kilometers	$1 \times 10^{-6}$

## Schema definition for tables

When creating a table to import into the Build-Out Wizard (see "Using the Import Table option" on page 10), you can use the schema definitions below as a guide. If the source table uses the exact same fields names as defined below, the **Import Table** option will automatically find and align the field with the correct parameter. You can choose to use other field names. In this case you will have to manually align the field with the parameter. The source field **MUST** match the data type defined below (i.e. you can not have a text field for the number value "efficiency"). The values contained in the field must meet the domain parameters (i.e. the density type code must match one of the given values below).

Field name	Field type	Notes
USE_CODE	text	100 character maximum
NONRESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table below
NONRESIDENTIAL_DENSITY_VALUE	double	
NONRESIDENTIAL_USE_PERCENT	double	0 – 100
RESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table below
RESIDENTIAL_DENSITY_VALUE	double	
RESIDENTIAL_USE_PERCENT	double	0 – 100
MIXED_USE_BUILDING_USES	text	See "Mixed Use Building Use" note below
COMPOSITE_BUILDOUT_EFFICIENCY_PERCENT	double	0 – 100
BUILDING_FOOTPRINT_AREA	double	
FLOORS_PER_BUILDING	integer	
DWELLING_UNITS_PER_BUILDING	integer	
MINIMUM_BUILDING_SEPARATION	double	
SPATIAL_LAYOUT_PATTERN	text	See "Spatial Layout Patterns" in the <b>Domain</b> table below
SPATIAL_LAYOUT_ROADS_LAYER	text	See "Spatial Layout Patterns" in the <b>Domain</b> table below
SPATIAL_LAYOUT_ROAD_SETBACK_DISTANCE	double	
DDD_MODELS	text	File path for 3D models

Domains	Allowable values
SPATIAL LAYOUT PATTERNS	None, roads, grid, random
DENSITY MEASUREMENT	
<ul style="list-style-type: none"> <li>RESIDENTIAL</li> </ul>	None, DU per hectare, Min. Lot Size (acres), Min.Lot Size (hectares), number of DU
<ul style="list-style-type: none"> <li>NONRESIDENTIAL</li> </ul>	None, floor Area (sq. meters or sq. feet), FAR

### NOTES:

For 3D models, use the full path to the file and separate each using a semicolon. For example:

C:\My3DModels\ranch\_house.flt;C:\My3DModels\two\_story\_house.flt

For mixed use building use, there are 4 parameters for each use:

- description: any text
- percent: 0 – 100
- floor area value: any double, only the residential uses need to fill this in
- floor area unit: sq feet, sq meters

These four parameters are combined using a semicolon and enclosed in hard brackets. For example:

[1bdr apt;25;750;sq feet]

Multiple use strings are simply added together. For example:

[1bdr apt;25;750;sq feet] [2 bdr apt;25;1500;sq feet] [3bdr apt;25;3000;sq feet]  
[retail;25;0;sq feet]

## Tables created during build-out

The tables created during build-out include the following fields (field information is also provided):

### CVBO\_LANDUSES (build-out input parameters)

Field name	Field type	Notes
USE_CODE	text	100 character maximum
NONRESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table on page 23
NONRESIDENTIAL_DENSITY_VALUE	double	
NONRESIDENTIAL_USE_PERCENT	double	0 – 100
RESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table on page 23
RESIDENTIAL_DENSITY_VALUE	double	
RESIDENTIAL_USE_PERCENT	double	0 – 100
MIXED_USE_BUILDING_USES	text	See "Mixed Use Building Use" note on page 21
COMPOSITE_BUILDOUT_EFFICIENCY_PERCENT	double	0 – 100
BUILDING_FOOTPRINT_AREA	double	
FLOORS_PER_BUILDING	integer	
DWELLING_UNITS_PER_BUILDING	integer	
MINIMUM_BUILDING_SEPARATION	double	
SPATIAL_LAYOUT_PATTERN	text	See "Spatial Layout Patterns" in the <b>Domain</b> table on page 23
SPATIAL_LAYOUT_ROADS_LAYER	text	See "Spatial Layout Patterns" in the <b>Domain</b> table on page 23
SPATIAL_LAYOUT_ROAD_SETBACK_DISTANCE	double	
DDD_MODELS	text	File path for 3D models

### CVBO\_BUILDABLE AREA (build-out polygon results)

Field name	Field type	Notes
USE_CODE	text	100 character maximum
NONRESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table on page 23
NONRESIDENTIAL_DENSITY_VALUE	double	
NONRESIDENTIAL_USE_PERCENT	double	0 – 100
RESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table on page 23
RESIDENTIAL_DENSITY_VALUE	double	
RESIDENTIAL_USE_PERCENT	double	0 – 100
MIXED_USE_BUILDING_USES	text	See "Mixed Use Building Use" note on page 21
COMPOSITE_BUILDOUT_EFFICIENCY_PERCENT	double	0 – 100
BUILDING_FOOTPRINT_AREA	double	
FLOORS_PER_BUILDING	integer	
DWELLING_UNITS_PER_BUILDING	integer	
MINIMUM_BUILDING_SEPARATION	double	
SPATIAL_LAYOUT_PATTERN	text	See "Spatial Layout Patterns" in the <b>Domain</b> table on page 23
SPATIAL_LAYOUT_ROADS_LAYER	text	See "Spatial Layout Patterns" in the <b>Domain</b> table on page 23
SPATIAL_LAYOUT_ROAD_SETBACK_DISTANCE	double	
DDD_MODELS	text	File path for 3D models

### CVBO\_BUILDINGS (build-out point results)

Field name	Field type	Notes
USE_CODE	text	100 character maximum
NONRESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table below
NONRESIDENTIAL_DENSITY_VALUE	double	
NONRESIDENTIAL_USE_PERCENT	double	0 – 100
RESIDENTIAL_DENSITY_MEASUREMENT	text	See "Density Measurement" in the <b>Domain</b> table below
RESIDENTIAL_DENSITY_VALUE	double	
RESIDENTIAL_USE_PERCENT	double	0 – 100
MIXED_USE_BUILDING_USES	text	See "Mixed Use Building Use" note on page 21
COMPOSITE_BUILDOUT_EFFICIENCY_PERCENT	double	0 – 100
BUILDING_FOOTPRINT_AREA	double	
FLOORS_PER_BUILDING	integer	
DWELLING_UNITS_PER_BUILDING	integer	
MINIMUM_BUILDING_SEPARATION	double	
SPATIAL_LAYOUT_PATTERN	text	See "Spatial Layout Patterns" in the <b>Domain</b> table below
SPATIAL_LAYOUT_ROADS_LAYER	text	See "Spatial Layout Patterns" in the <b>Domain</b> table below
SPATIAL_LAYOUT_ROAD_SETBACK_DISTANCE	double	
DDD_MODELS	text	File path for 3D models

Domains	Allowable values
SPATIAL_LAYOUT_PATTERNS	None, roads, grid, random
DENSITY_MEASUREMENT	
<ul style="list-style-type: none"> <li>RESIDENTIAL</li> </ul>	None, DU per hectare, Min. Lot Size (acres), Min.Lot Size (hectares), number of DU
<ul style="list-style-type: none"> <li>NONRESIDENTIAL</li> </ul>	None, floor Area (sq. meters or sq. feet), FAR

## Numeric Calculations

The calculations run during numeric build-out are described below. Note: fractions are calculated by taking the percent value and dividing by 100.

### Existing Floor Area

The build-out engine selects building features from each user supplied existing buildings layer contained in the input land-use feature polygon. The floor area for each building is summed together for a total existing floor area value. This value is stored in the buildable area feature's "existing floor area" attribute.

$$\text{Existing Floor Area} = \Sigma [\text{floor area for buildings contained in the land-use polygon}]$$

The existing floor area for an individual building is determined in one of two ways:

- An exact floor area value is selected in the Wizard
- An attribute in the Wizard that contains floor area value for a feature is selected

## Capacity Floor Area

The capacity floor area for a given polygon is calculated in one of two ways:

- EXACT

Capacity floor area = density value \* units conversion \* efficiency fraction

- FAR

Capacity floor area = polygon area \* use fraction \* unit conversion \* density value \* efficiency fraction

## Existing Dwelling Units

The build-out engine selects building features from each user-supplied existing buildings layer contained in the input land-use feature polygon. The dwelling units for each building are summed together for a total existing dwelling unit value. This value is stored in the buildable area feature's 'existing dwelling units' attribute.

Existing Floor Area =  $\Sigma$  [dwelling units for buildings contained in the land-use polygon]

The existing dwelling units for an individual building are determined in one of two ways:

- An exact dwelling units value is selected in the Wizard
- An attribute in the Wizard that contains dwelling units value for a feature is selected

## Capacity Dwelling Units

The capacity dwelling units for a given polygon is calculated by adding together dwelling units from single use buildings and dwelling units in mixed use buildings. The values resulting from the following calculations are rounded to whole numbers as specified by each method.

Capacity dwelling units = Single-use dwelling units + Mixed-use dwelling units

Single-use buildings' dwelling units are calculated in one of three ways:

- DU<sub>P</sub>A

Single-use units = polygon area \* use fraction \* unit conversion \* density value \* efficiency fraction

Rounding: if result = 0, then 0  
if result > 0 and < 1, then 1 (for example, 0.24 => 1)  
if result > 1 then round down to whole number (for example, 5.84 =>5)

- EXACT

Single use units = density value \* efficiency fraction

Rounding: round down to whole number (for example, 5.84 => 5)

- MINLOT

Single use units = (polygon area \* use fraction \* unit conversion) / density value \* efficiency fraction

Rounding: if result = 0, then 0  
if result > 0 and < 1, then 1 (for example, 0.24 => 1)  
if result > 1 then round down to whole number (for example, 5.84 =>5)

Mixed-use buildings' dwelling units are calculated for each residential use (dwelling unit floor area > 0) and summed for a total.

Mixed-use units =  $\Sigma$  [(remaining floor area \* unit conversion \* building use fraction) / unit floor area]



Rounding: round down to whole number (for example, 5.84 => 5)

## Remaining Dwelling Units

The remaining dwelling units are the final result of numeric build-out. This value is stored in the buildable area feature's 'numeric dwelling units' attribute. If existing buildings are not supplied as input parameters then the numeric dwelling units result is equivalent to capacity dwelling units.

```
Remaining dwelling units = capacity dwelling units - existing dwelling units
```

If existing dwelling units are greater than capacity dwelling units then remaining dwelling units is set to zero.

## Existing Buildings

The build-out engine selects building features from each user-supplied existing buildings layer contained in the input land-use feature polygon. This value is stored in the buildable area feature's 'existing buildings' attribute.

```
Existing Buildings = Σ [buildings contained in the land-use polygon]
```

## Remaining Buildings

The remaining buildings are the final result of numeric build-out. This value is stored in the buildable area feature's 'numeric buildings' attribute. The remaining buildings is calculated by adding together the buildings required for remaining floor area and the buildings required for remaining single-use dwelling units. Buildings are calculated based on parameters supplied by the user in the Wizard. If any of the required building parameters are missing or equal zero then the calculation result is set to one.

```
Remaining buildings = mixed-use & single-use non-residential buildings + single-use  
residential buildings
```

```
Mixed-use & Single-use Non-Residential Buildings = remaining floor area / floor area  
per building;
```

```
Floor area per building = (building footprint area * unit conversion * floors)
```

```
Single-use Residential Building = remaining dwelling units / dwelling units per building
```

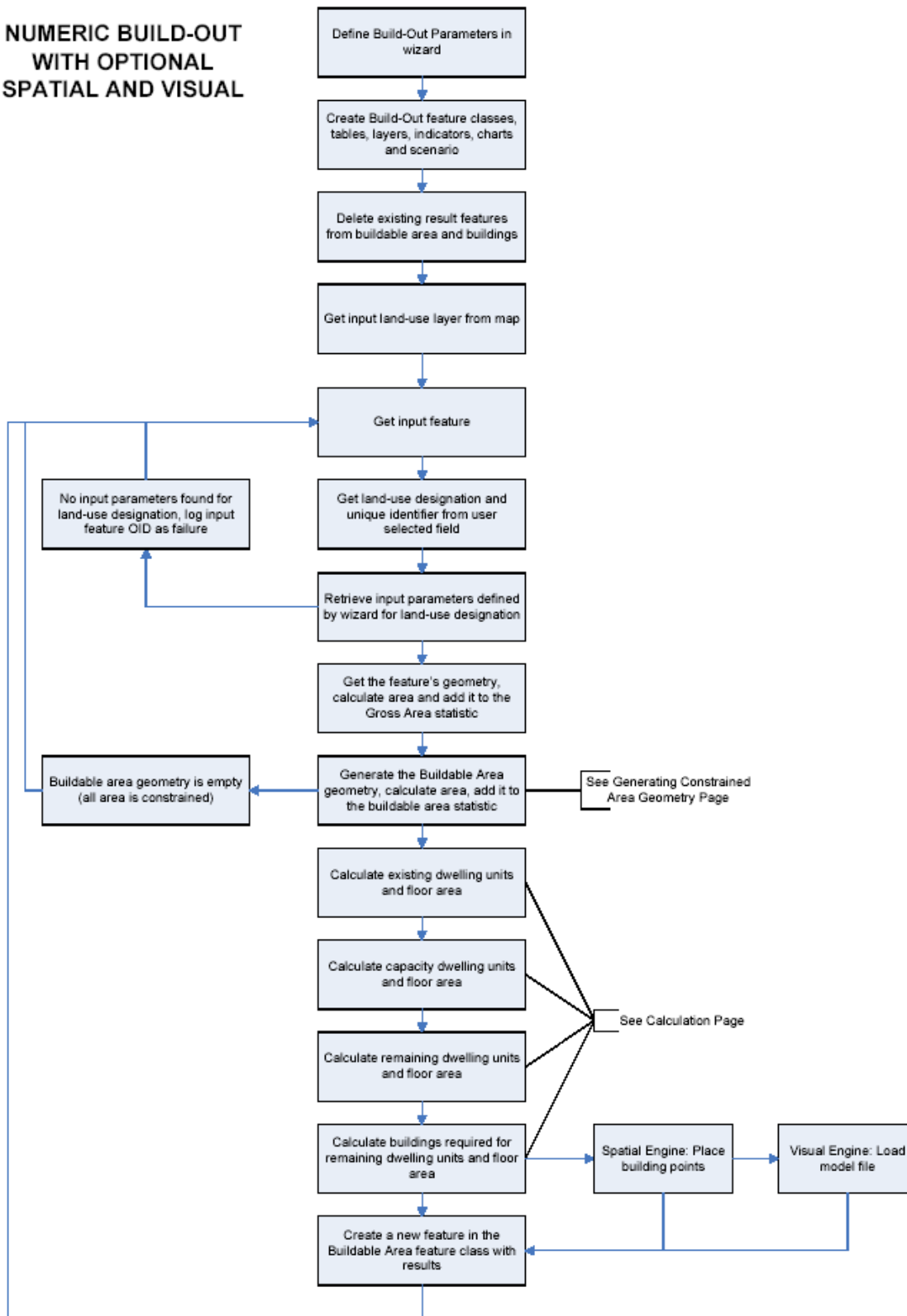
## Generating the constrained geometry

The following algorithm is used to generate the constrained geometry. This geospatial 'difference' process takes the input land-use polygon and subtracts out all overlapping constraint layers' polygons. The resulting geometry is used by the numeric model (with constraint layers that where density can not be transferred) to create the buildable area feature and by the spatial model (with all constraint layers) to create a geometry into which the buildings are placed.

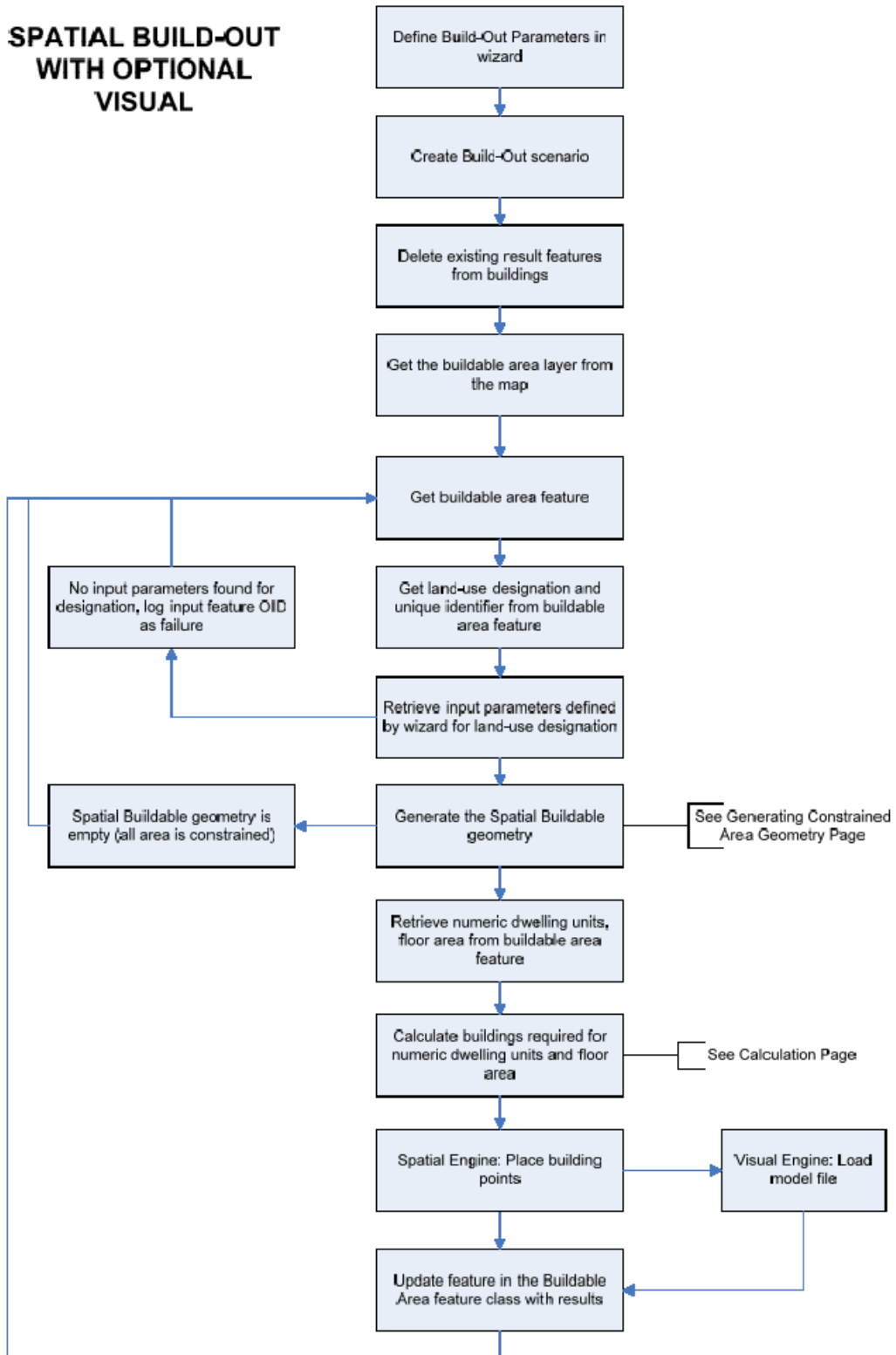
1. For each constraint layer (numeric=density transfer is not allowed; spatial=all)
  - a. Query all features that intersect the input land-use polygon
  - b. Union the found features into a single geometry
  - c. Subtract (difference) the union geometry from the input geometry
    - i. record constraint layer if an error occurs and continue to the next layer
2. Project the buildable area polygon if necessary

## Build-out process diagrams

### NUMERIC BUILD-OUT WITH OPTIONAL SPATIAL AND VISUAL



## SPATIAL BUILD-OUT WITH OPTIONAL VISUAL



## VISUAL BUILD-OUT

