# Street Canyon Tool



# *User Guide*    CERC

# ADMS

## Street Canyon Tool

**Version 2.0**

## User Guide

August 2018

Cambridge Environmental Research Consultants Ltd.
3, King's Parade
Cambridge
CB2 1SJ
UK

Telephone: +44 (0)1223 357773
Facsimile: +44 (0)1223 357492
Email: help@cerc.co.uk
Website: www.cerc.co.uk

# Contents

# SECTION 1  Introduction

## 1.1  About the Street Canyon Tool

The Street Canyon Tool generates street canyon data for use with the ADMS-Urban Advanced Canyon module, including canyon width, length and height.  The Street Canyon Tool runs inside ArcGIS and uses building and road datasets to calculate Advanced Canyon parameters.

## 1.2  Features

The Street Canyon Tool can be used to calculate the following for each road:

- Canyon heights (maximum, mean and minimum)
- Canyon widths
- Canyon length

The data is available as a new shapefile based on the input road layer, with new fields for the data and in a *\*.csv* format suitable for use with the ADMS-Urban module.

## 1.3  Requirements

The Street Canyon Tool toolbox requires the following:

- A copy of ESRI ArcGIS (Version 10.1 or later)

## 1.4  About this user guide

This *Street Canyon Tool User Guide* is a manual describing how to use the Street Canyon Tool.

To make this manual simpler to use, certain conventions have been followed with regard to layout and style.

- Canyon Height toolbox interface controls are shown in **Arial** font, e.g. click on **Generate Report**.
- Keyboard inputs are shown in **bold**, e.g. press **Enter**.
- Directory and file names are shown in *italics*, e.g. *\*.nc*.
- Table and figure references are shown in **bold**, e.g. see **Figure 3.1**

# SECTION 2  Using the Street Canyon Tool

## 2.1  Installing the Street Canyon Tool

To install the **Street Canyon Tool**, simply copy the contents of the install directory to a directory with full privileges on your machine. From the Start menu, open ArcCatalog.  Open the ArcToolbox window ( on the toolbar), right-click on the ArcToolbox window (see **Figure 1**) and select **Add Toolbox...**
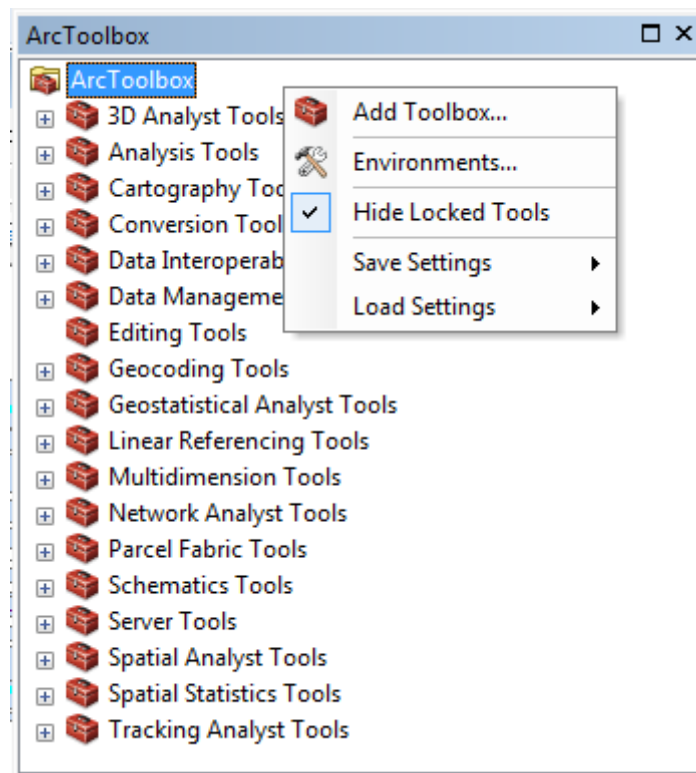


Figure 1 - The ArcToolbox

Navigate to the folder containing the **Street Canyon Tool** files and select StreetCanyon.pyt. **Street Canyon Tools** should now appear in the ArcToolbox in ArcCatalog and also in ArcMap, as shown in **Figure 2** below.  The toolbox has two tools, named **Create Street Canyon File** and **Display Canyon Widths**.
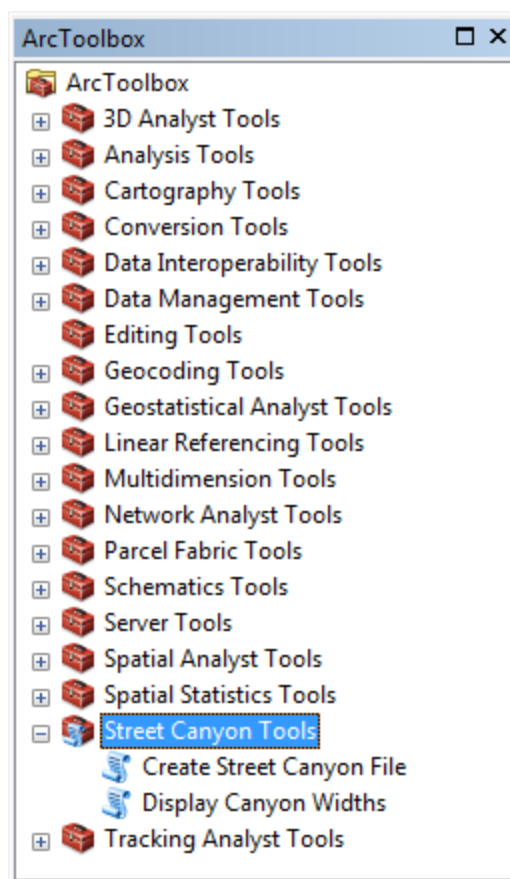
Figure 2 - The Street Canyon Tools toolbox

## 2.2 Running the Street Canyon Tool

Once **Street Canyon Tools** has been added to the ArcGIS' ArcToolbox window (refer to Section 2.1 Installing the Street Canyon Tool) it can be used by clicking on **Street Canyon Tools** to reveal the **Create Street Canyon File** tool.

*The user is advised (though not required) to load the required roads and building shapefiles into ArcGIS before running the tool. The input layers must be shapefiles, not (for example) geodatabase layers. All input shapefiles must be in the same coordinate system. This must be a projected coordinate system with units of metres.*

*Also the input layers must not have been created from ArcGIS's "Make Feature Layer" tool with the "Use Ratio Policy" option.*

## 2.3 Create Street Canyon File Tool

The main screen, shown in **Figure 3**, appears on clicking on the **Create Street Canyon File** tool in the **Street Canyon Tools** toolbox. Each of the features and buttons are described below.

*In the Create Street Canyon File main screen, click on* **Show Help >>** *to display information relating to each input.*
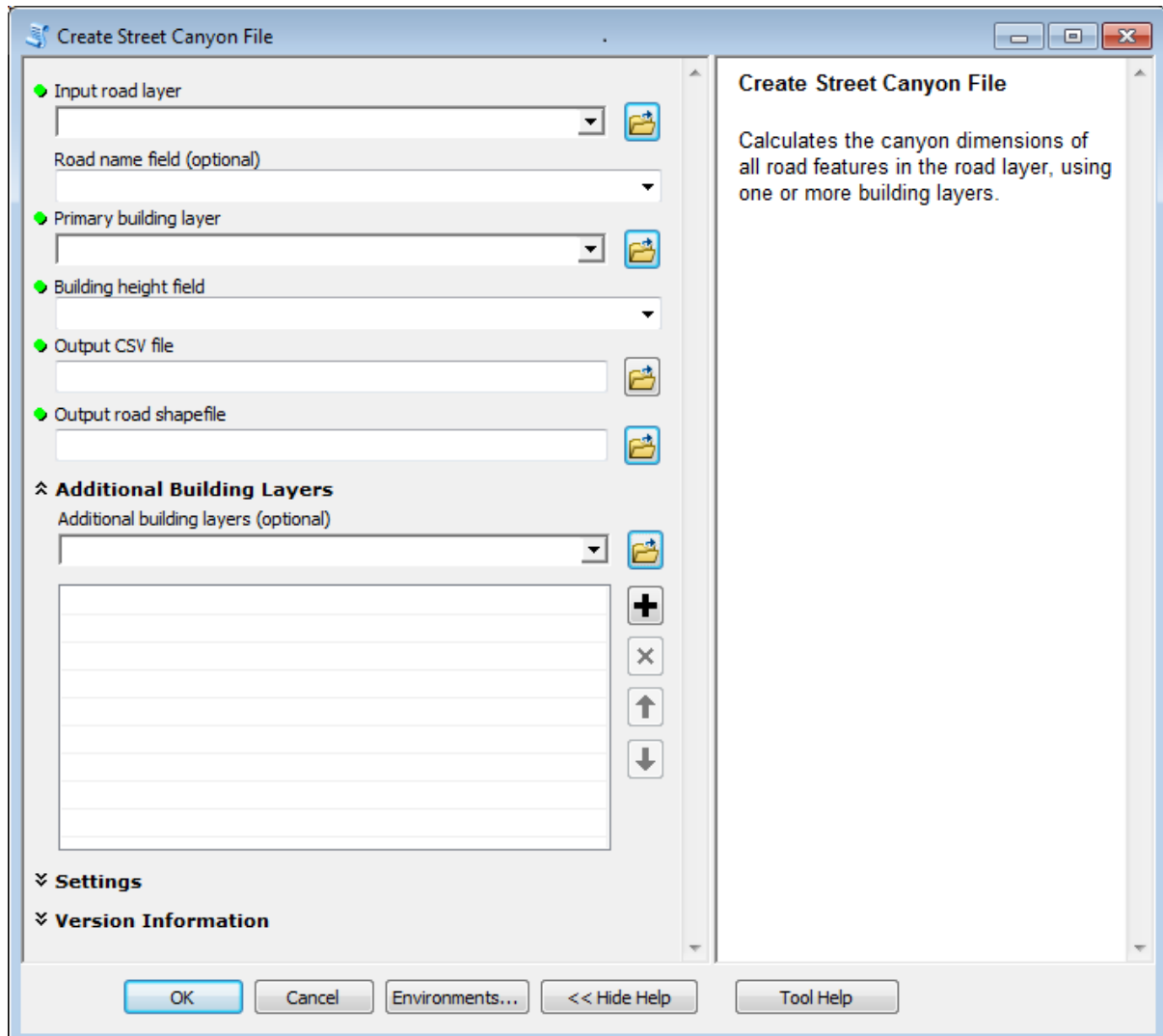


Figure 3 – The main screen

### 2.3.1  Input road layer

The **Input road layer** is the shapefile containing the road geometry for each road feature.  The road layer can be selected by using the dropdown, if the layer is already loaded in ArcGIS, or by clicking the **Browse** button to navigate to and select the shapefile.

*The* **Input road layer** *shapefile must use a coordinate system with units of metres.*

*If specific features in this shapefile are selected in ArcGIS, the* **Create Street Canyon Tool** *will output the results for these specific features only.  If no features are selected, the* **Create Street Canyon Tool** *will output results for all features.*

### 2.3.2   Road name field

The **Road name field** is the field in the Road Layer storing the name of the road.

*The road names in the **Road name field** must match those in the ADMS-Urban \*.upl file.*

### 2.3.3   Primary building layer

The **Primary building layer** is a shapefile containing building geometry and building height information for each building feature.  The primary building layer can be selected by using the dropdown, if the layer is already loaded in ArcGIS, or by clicking the **Browse** 🗁 button to navigate to and select the shapefile.

*The **Primary building layer** shapefile must use a coordinate system with units of metres.*

*The tool may run faster if buildings with height lower than 1m are manually deleted before running the tool.*

### 2.3.4   Building height field

The **Building height field** is the field in the **Primary building layer** which stores the building height information for each building feature.  The building height should be the height above ground level and should be in metres.

### 2.3.5   Output CSV file

The **Output CSV file** defines the location for the *\*.csv* results, for use with the ADMS-Urban Advanced Canyon module.

### 2.3.6   Output road shapefile

The **Output road shapefile** defines the location for the *\*.shp* results.  This shapefile contains the attributes from the input shapefile as well as the calculated canyon statistics.

### 2.3.7   Additional building layers

The **Additional building layers** section enables users to provide extra building layers. Additional building layers may be required if the building data is provided in tiles, or if there are multiple layers for different building types.
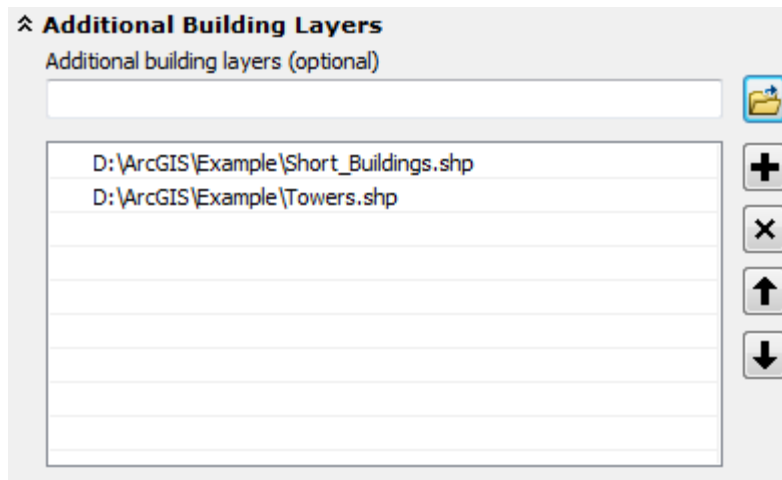
Figure 4 – The **Additional Building Layers** section

#### 2.3.7.1 Additional building layers

**Additional building layers** can be selected by using the dropdown, if the layers are already loaded in ArcGIS, or by using the **Browse** button to navigate to and select the shapefile. Layers can be removed from the list by using the ⊠ button to the right of the list.

*The **Additional building layers** shapefile(s) must be in the same coordinate system as the **Primary building layer** (refer to Section 2.3.3) and must have the same name for the **Building height field**.*

### 2.3.8  Settings
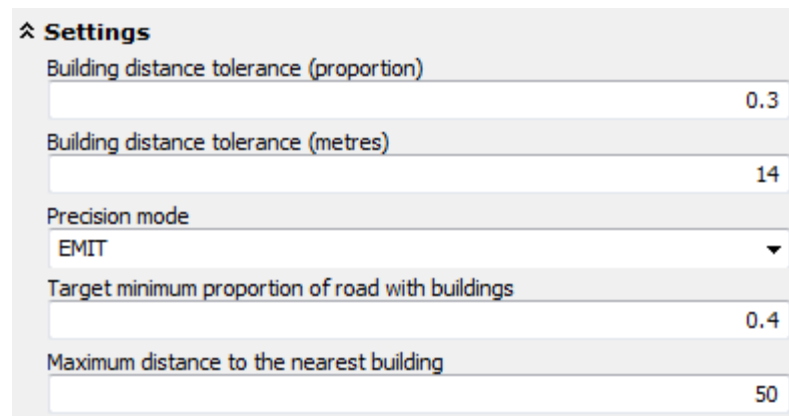


Figure 5 – The **Settings** section

*Appropriate values for all of the settings must be determined for the cityscape. A degree of experimentation may be necessary. Section 2.3.8.5 gives some values used by CERC in recent case studies.*

### 2.3.8.1  Building distance tolerance (proportion) and Building distance tolerance (metres)

These two settings define a tolerance buffer beyond the base building. Any buildings, or building sections, in this buffer will be included in the canyon height calculations.

The total tolerance distance is the sum of a proportion of the minimum distance (from the road centreline to the base building) and a constant distance. The **Building distance tolerance (proportion)** defines the proportion used. The **Building distance tolerance (metres)** defines the constant component of the total tolerance distance. **Figure 6** illustrates this. Section 3.2 explains the calculation in detail.
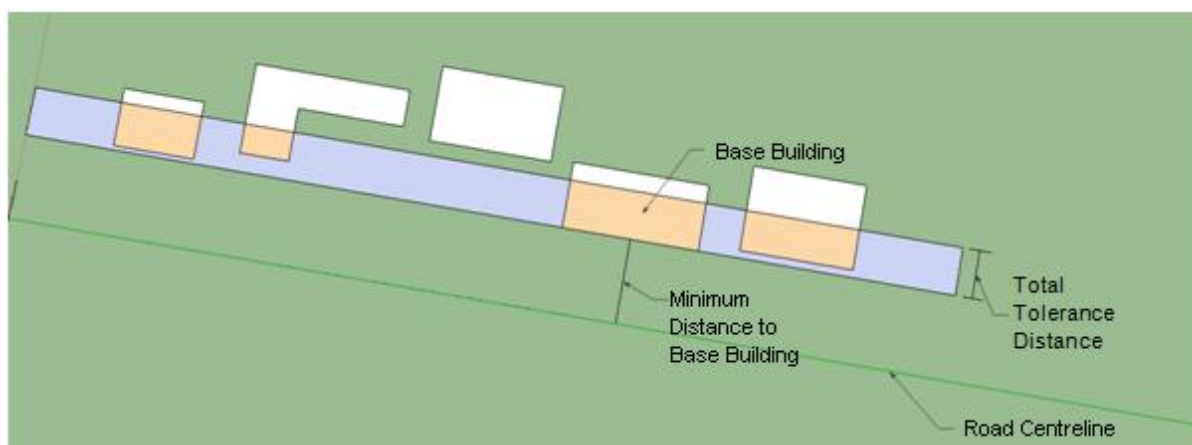


Figure 6 – Total tolerance distance. The blue rectangle is the tolerance buffer.

### 2.3.8.2  Precision mode

The **Precision mode** defines the precision of the results.

In **EMIT** mode, vertices and results are rounded to the nearest metre. In **ADMS** mode they are rounded to the nearest centimetre. These are set to match the requirements of the EMIT and ADMS models.

### 2.3.8.3  Target minimum proportion of road with buildings

The **Target minimum proportion of road with buildings** defines the goal used when the algorithm chooses the base building (see Technical Summary). The proportion of road with buildings is the ratio between the canyon coverage and the canyon length, e.g. 0.5 would expect 50% or more of the canyon's length to contain buildings.

In cases where some buildings on a road side are offset from others, larger values of this parameter may cause small buildings near the road centreline to be ignored, leading to the calculation of wider canyons that have greater canyon coverage (see **Figure 12**).

### 2.3.8.4  Maximum distance to the nearest building

The **Maximum distance to the nearest building** defines the distance from the road centreline the tool will search to find suitable base buildings. If there are no buildings within this distance, the canyon statistics for this side of the road will be zero.

**2.3.8.5 Example settings**

Appropriate values must be determined for the cityscape being modelled. **Table 1** below shows values used by CERC for some recent case studies.

| Case study: | London | Hong Kong |
|---|---|---|
| **Building distance tolerance (proportion)** | 0.3 | 0.3 |
| **Building distance tolerance (metres)** | 14 | 14 |
| **Target minimum proportion of road with buildings** | 0.0 | 0.4 |
| **Maximum distance to the nearest building** | 40 | 50 |

Table 1 – Example setting values

### 2.3.9 Version Information

The **Version Information** section contains information about the version of the tool. This information should be included in any correspondence with CERC.

### 2.3.10 Running the Tool

Clicking **OK** will run the tool. The ArcMap window will display scrolling text at the bottom right, indicating that the tool is running.

## 2.4 Monitoring Progress

In ArcMap, under the **Geoprocessing** menu, open the **Results** window. The top entry in the **Current Session** will be the tool in progress. The **Inputs** menu gives details of the tool inputs selected. The **Messages** menu displays progress messages from the tool. It is possible to cancel the tool run, by right-clicking on the tool in progress and clicking **Cancel**.
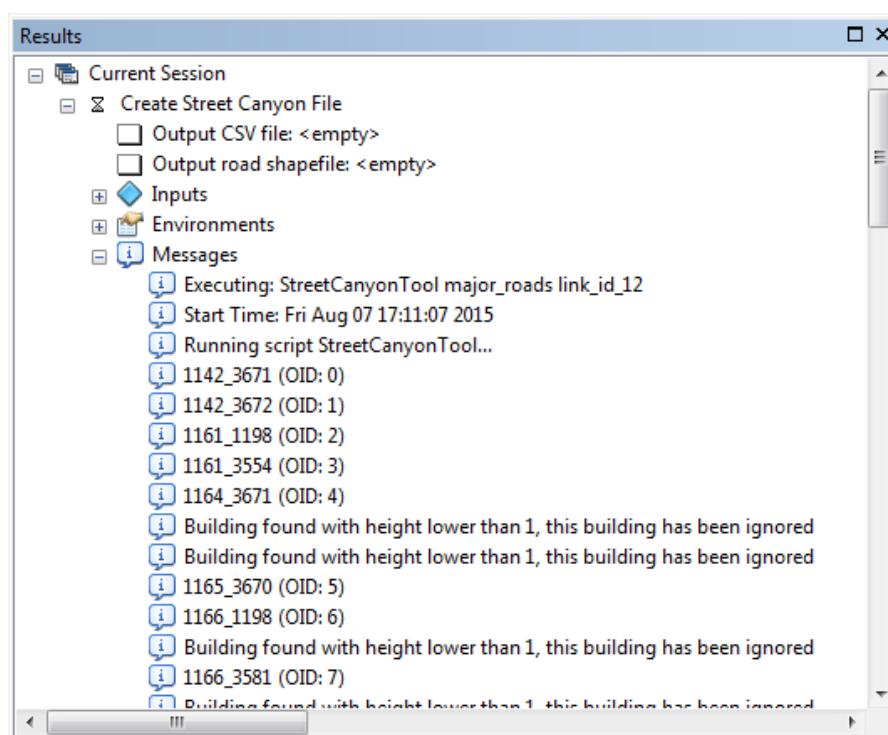
Figure 7 – The **Results** window in ArcGIS **Geoprocessing**

## 2.5   Viewing the results

### 2.5.1  Output CSV file

The results will be available in the *\*.csv* file selected in **Output CSV file**, as shown in **Figure 8**

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AdvancedCanyonVersion1 | | | | | | | | | | | | | | | |
| | ID | Name | X1 | Y1 | X2 | Y2 | width_L | avgHeight_L | minHeight_L | maxHeight_L | canyonLength_L | endLength_L | buildLength_L | width_R | avgHeight_R | minHeight_R |
| | 0 | road1 | 528337 | 179824 | 528282 | 179826 | 6.06 | 29.8 | 9.54 | 29.8 | 55.04 | 0 | 55.04 | 0 | 0 | 0 |
| | 1 | road10 | 532752 | 180245 | 532729 | 180257 | 5.66 | 25.76 | 16.71 | 25.76 | 25.94 | 0 | 25.94 | 0 | 0 | 0 |
| | 2 | road100 | 528318 | 181815 | 528306 | 181823 | 4.6 | 18.64 | 17.08 | 18.9 | 14.42 | 0 | 14.42 | 14.59 | 24.17 | 8.71 |
| | 3 | road10003 | 531887 | 174420 | 532016 | 174307 | 18.43 | 13.41 | 5.01 | 18.35 | 179.69 | 0 | 179.69 | 8.15 | 17.27 | 13.81 |
| | 4 | road10004 | 536664 | 175393 | 536891 | 175957 | 34.01 | 21.75 | 5.12 | 32.73 | 607.97 | 0 | 607.97 | 48.61 | 30.35 | 5.17 |
| | 5 | road10005 | 529801 | 182699 | 529720 | 182649 | 22.03 | 41.82 | 13.25 | 64.95 | 83.91 | 11.28 | 74.69 | 28.94 | 23.8 | 5.22 |

Figure 8 – Example *\*.csv* output

The results include the headers and parameters required to use the file with the ADMS-Urban Advanced Canyon option without any editing.

### 2.5.2  Road Layer shapefile

The resulting street canyon parameters will be added to the output road shapefile.  The results can be read from the Attributes Table, as presented in **Figure 9**.  Alternatively, the shapefile data can be viewed in the map by using the **Identify** tool 🛈 on any of the road features in the Road Layer.

The **Display Canyon Widths** tool can also be used, refer to Section 2.6 for more information.

| c_width_l | c_length_l | c_height_l | c_start_l | c_minh_l | c_maxh_l | c_cover_l | c_width_r | c_length_r | c_height_r | c_start_r | c_minh_r | c_maxh_r | c_cover_r | c_rdlength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.2 | 179.05 | 13.63 | 7.98 | 10.5 | 16.8 | 154.51 | 5.91 | 197.87 | 21.29 | 0 | 8 | 30.7 | 138.65 | 197.87 |
| 7.13 | 188.78 | 8.49 | 7.73 | 8 | 9.5 | 123.81 | 8.2 | 140.47 | 9.13 | 43.86 | 8 | 14.3 | 118.37 | 196.51 |
| 13.5 | 847.34 | 7.8 | 0 | 6.1 | 16.8 | 252.93 | 10.96 | 762.08 | 13.1 | 0 | 8 | 14.3 | 507.83 | 853.06 |
| 6.73 | 476.53 | 9.87 | 7.96 | 8 | 10.5 | 279.43 | 7.24 | 519.36 | 15.74 | 43.19 | 8 | 16.8 | 347.73 | 575 |
| 8.34 | 210.42 | 16.8 | 27.06 | 16.8 | 16.8 | 150.56 | 7.55 | 249 | 14.62 | 2.97 | 12.8 | 30.7 | 174.16 | 253.31 |
| 8.17 | 238.83 | 12.8 | 0.38 | 12.8 | 12.8 | 170.65 | 6.55 | 185.77 | 9.5 | 8.71 | 9.5 | 9.5 | 90.46 | 244.72 |
| 6.37 | 169.23 | 15.45 | 6.65 | 10.5 | 16.8 | 114.96 | 5.65 | 191.04 | 10.5 | 12.12 | 10.5 | 10.5 | 143.56 | 206.37 |
| 6.24 | 97.86 | 6.11 | 655 | 6.1 | 8 | 77.24 | 7.45 | 657.59 | 9.34 | 91.67 | 8 | 9.5 | 96.48 | 752.86 |

Figure 9 – Example results in the Output road shapefile Attribute Table

## 2.6 Display Canyon Widths Tool

The **Display Canyon Widths** tool provides a visual representation of the results of the Street Canyon Tool.

The main screen, shown in **Figure 10**, appears on clicking on the **Display Canyon Widths** tool in **Street Canyon Tools**.  Each of the features and buttons are described below.

*In the **Display Canyon Widths** tool main screen, click on **Show Help >>** to display information*



Figure 10 – The main Display Canyon Widths screen

### 2.6.1 Road layer

The **Road layer** is the shapefile containing the results of the **Create Street Canyon File** tool. The road layer can be selected by using the dropdown, if the layer is already loaded in ArcGIS, or by clicking the **Browse** 🗁 button to navigate to and select the shapefile.

*If specific features in this shapefile are selected in ArcGIS, the* **Display Canyon Widths** *tool will output the results for these specific features only. If no features are selected, the* **Display Canyon Widths** *tool will output results for all features.*

### 2.6.2 Canyon width (left)

**Canyon width (left)** is the field in the shapefile storing the canyon width for the left hand side of the road. When using a shapefile containing the results of the Street Canyon tool, this field will be c_width_l.

### 2.6.3 Canyon width (right)

**Canyon width (right)** is the field in the shapefile storing the canyon width for the right hand side of the road. When using a shapefile containing the results of the Street Canyon tool, this field will be c_width_r.

### 2.6.4 Output shapefile

The **Output shapefile** defines the location for the *\*.shp* containing the canyon width polygons.

### 2.6.5 Version Information

The **Version Information** section contains information about the version of the tool. This information should be included in any correspondence with CERC.

### 2.6.6 Running the Tool

Clicking **OK** will run the tool. The ArcMap window will display scrolling text at the bottom right, indicating that the tool is running.
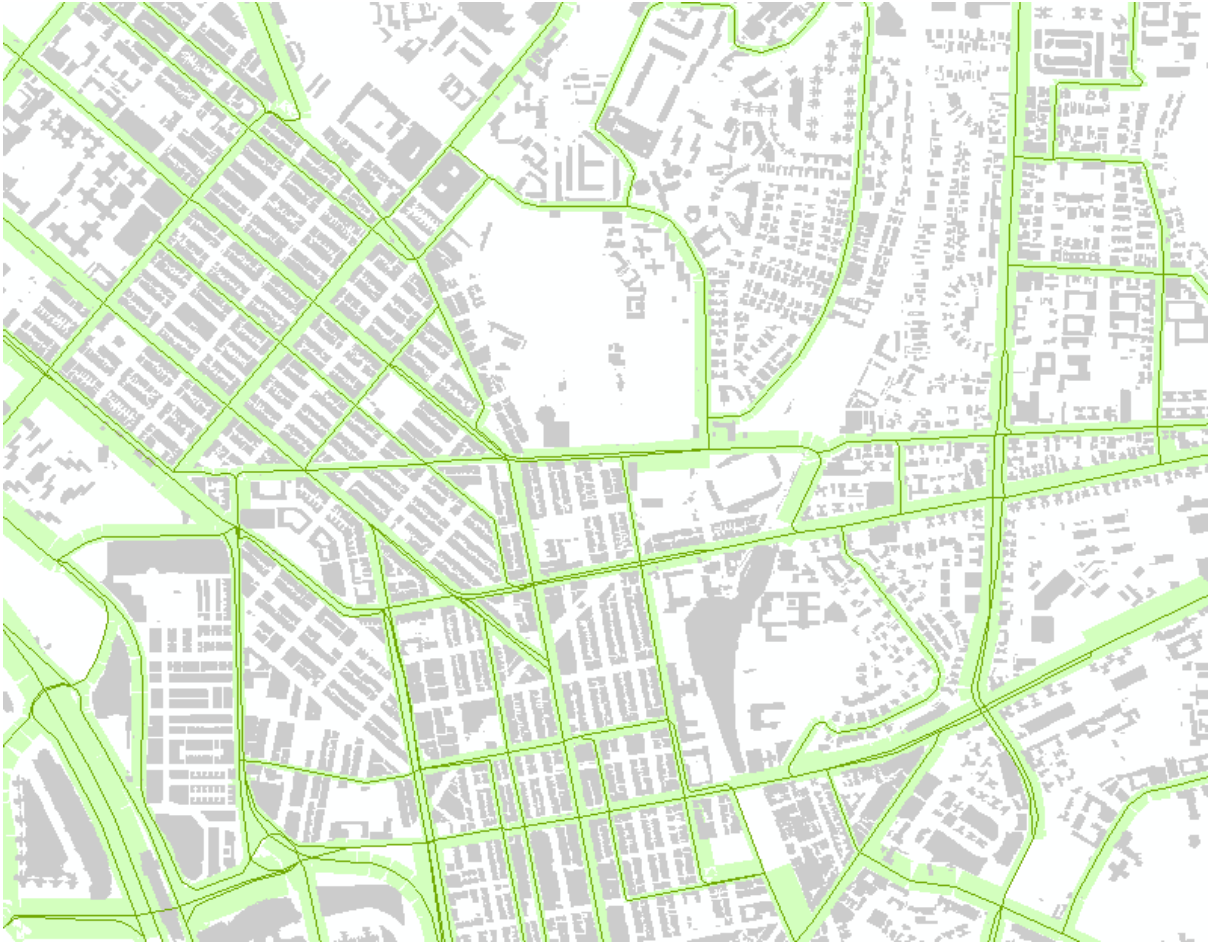
Figure 11 – Example Display Canyon Width output

# SECTION 3  Technical Summary

This section provides a technical summary of the **Street Canyon Tools** toolbox.  User-defined inputs to the tool are described in Section 2 of this User Guide.

The **Create Street Canyon File** tool generates a *\*.csv* format file that can be used directly with the Advanced Canyon module in ADMS-Urban. The file outputs all of the required headers, together with averaged canyon parameter data, for each road feature in the **Input road layer**. A shapefile can also be output from the tool, containing the same information, which can be viewed spatially in GIS software. The **Display Canyon Width** tool can be used to visualise the canyon widths in ArcGIS.

## 3.1   The Advanced Canyon module input data

The parameters required by the ADMS-Urban Advanced Canyon module are described in **Table 2**.  A schematic of the parameters is also presented in **Figure 12**, with the associated shapefile variable names.

| Variable name in *\*.csv* file | Variable name in shapefile | Units | Description |
|---|---|---|---|
| ID | ID | - | Source identifier (optional) |
| Name | Name | - | Source (road) name |
| X1, Y1 | X1, Y1 | m | x and y coordinates of first vertex (start) |
| X2, Y2 | X2, Y2 | m | x and y coordinates of second vertex (end of first segment) |
| width_L, width_R | c_width_l, c_width_r | m | Distance from road centreline to canyon wall on left and right sides respectively |
| avgHeight_L, avgHeight_R | c_height_l, c_height_r | m | Average canyon height on left and right sides respectively |
| minHeight_L, minHeight_R | c_minh_l, c_minh_r | m | Minimum canyon height on left and right sides respectively |
| maxHeight_L, maxHeight_R | c_maxh_l, c_maxh_r | m | Maximum canyon height on left and right sides respectively |
| canyonLength_L, canyonLength_R | c_length_l, c_length_r | m | Length of canyon on left and right sides respectively |
| endLength_L, endLength_R | c_start_l, c_start_r | m | Distance from start of road to first building in canyon on left and right sides respectively |
| buildLength_L, buildLength_R | c_cover_l, c_cover_r | m | Length of buildings in canyon on left and right sides respectively |

Table 2 – ADMS-Urban Advanced Canyon module input parameters,
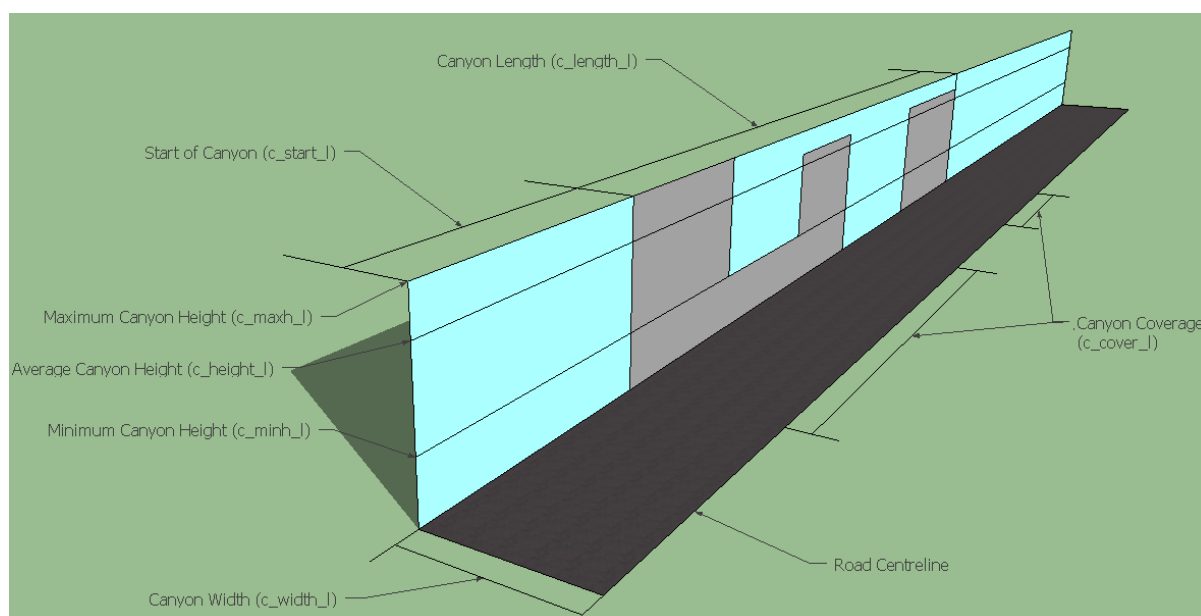which are output by the Street Canyon Tool

Figure 12 – Canyon height results (left hand side, as given in the Road Layer shapefile)

## 3.2 The Create Street Canyon File tool

### 3.2.1 Locating buildings that affect a road source

The **Create Street Canyon File** tool first identifies all building sections that may affect the road. These are the building sections within a tolerance buffer. The tolerance buffer is calculated using the road and building geometry and the tolerance settings defined by the user (see Section 2.3.8).

The left and right sides of the canyon are assigned according to the orientation of the first and second vertices, where the first vertex represents the start and the second vertex represents the end of the first straight-line segment of the road. The left and right side calculations are carried out independently. Note that the order of the vertices will be checked against the road source data in ADMS-Urban, based on the road name.

For each road and each side of the road, the **Create Street Canyon File** tool:

- Finds a suitable base building close to the road on that side for any road segment. The base building will be partially or completely within the **Maximum distance to the nearest building** to the road.
- If the **Target minimum proportion of road with buildings** is set to 0.0, the base building will be the nearest building to the road. For other values of **Target minimum proportion of road with buildings**, the selected base building may be further away in order to achieve better coverage. It selects the nearest building that satisfies the target minimum proportion, or if no building satisfies that proportion, it selects the building that gives the highest coverage.

- Calculates a total tolerance distance:

$$\text{Total tolerance distance} = fx + b$$

  where,

  $x$ is the minimum distance from the base building to the road centreline,

  $f$ is the user-editable **Building distance tolerance (proportion)**, and

  b is the user-editable **Building distance tolerance (metres)**.

- Determines a tolerance buffer for each road segment: this is a rectangle beyond the base building and within the total tolerance distance from the base building, perpendicular to the road centreline (see **Figure 15**). Parts of buildings outside the tolerance buffer are not included in the calculations.

- Stores the height and length of each building face as projected onto the road centreline, as illustrated in **Figure 13**.
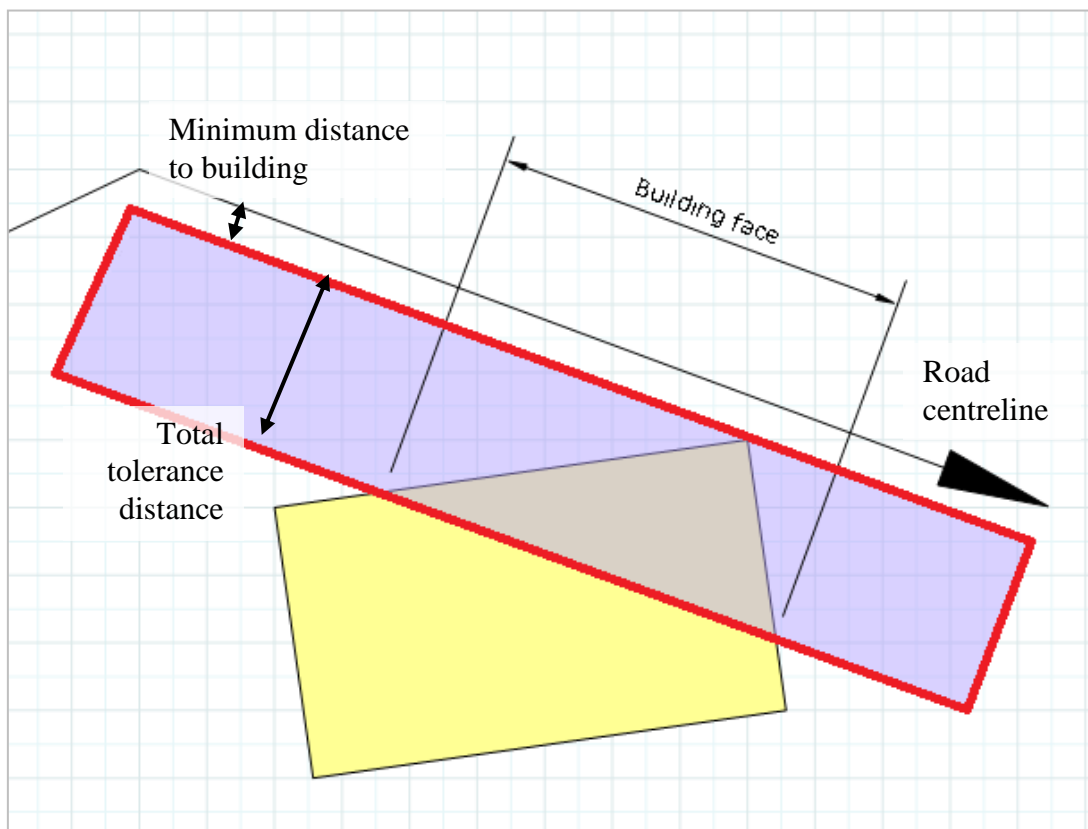


Figure 13 – Example total tolerance distance for the right hand side of a road feature. The red outline is the tolerance buffer. The yellow rectangle is the base building.

When two or more buildings or buildings of varying height are found in the same location, the height and length of each part of the building(s) is apportioned into multiple segments. The approach is illustrated in **Figure 14**.
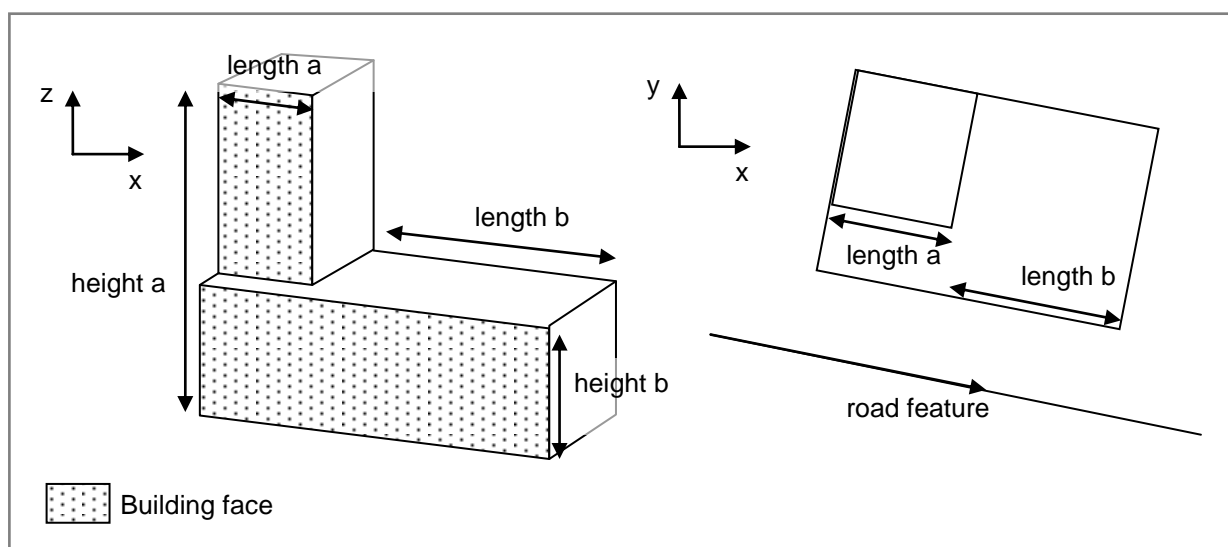


Figure 14 – Illustration of the approach taken with varying building height

The following limitations apply:

- A road with no adjacent buildings will be assigned values of 0 for all of the Advanced Canyon module parameters.

- Buildings that touch or cross the road centreline are ignored for that road segment.

- A minimum building height of 1 m is required for the building to be included in the calculation for any road segment.

- Multipart roads are ignored. Multipart buildings will be included in the calculations, provided they do not have "holes" (internal rings).

### 3.2.2 Calculating the canyon width

The canyon width is calculated from the minimum distance from the road for each building section in the tolerance buffer. The canyon width is calculated as an average of the building sections' minimum distances weighted by the buildings' face. The full calculation procedure is as follows.

- Locates the buildings that affect the road source, see 3.2.1.

- Calculates the canyon width on each side:

$$\text{Canyon width} = \frac{\sum c_x w_x}{\sum c_x}$$

where,

$c_x$ is the along-road length of the face of a building that affects the road source and

$w_x$ is the largest of the minimum distance from that building section to the road centreline and the minimum distance from the base building to the road centreline.

- Where building faces overlap, the building nearest the road is used for the canyon width calculation.

- Only the building sections within the tolerance buffer are used for the canyon calculations.

- Buildings completely outside the tolerance buffer are ignored for the canyon calculations.

The example in Figure 15 shows the base building, the building sections within the tolerance buffer (red outline) and the dimensions used for the calculation for the left hand side of the canyon.
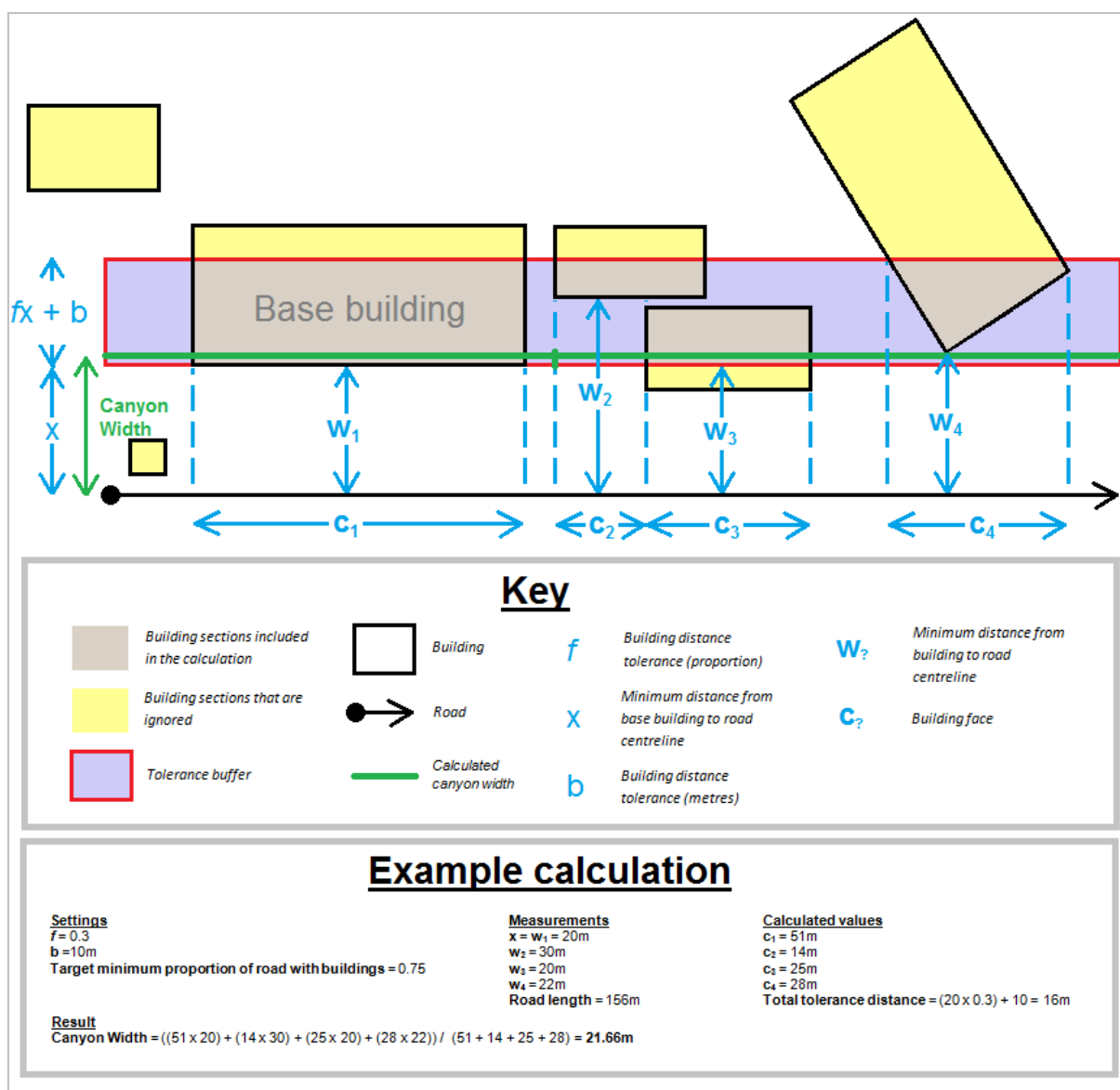
Figure 15 - Example canyon width calculation

### 3.2.3 Calculating the Advanced Canyon module parameters

The Advanced Canyon module parameters listed in **Table 2** are calculated from the projected extent of the buildings that are deemed to affect the road, for each road feature and side of the road, based on the tolerance settings (described in Sections 0 and **Error! Reference source not found.**1.1.1.1). **Figure 12** presents the Advanced Canyon module parameters schematically.

The start of the canyon, (named endLength_*<side>* in the *\*.csv* file and c_start_*<l or r>* in the shapefile), is defined as the distance from the first road vertex to the first building section within the tolerance buffer. The length of the canyon is determined from that start point to the last building section within the tolerance buffer, such that it includes gaps. The canyon width and maximum, minimum and average height are only calculated for sections of the road considered to be within a canyon (where a building occurs within the tolerance buffer). There is no double-counting: if a portion of the road is affected by multiple buildings, the width to the nearest point of the nearest building is used. The length of buildings in a canyon is calculated as the length of buildings within the canyon length, excluding gaps between

buildings.

# CERC