

# Tutorial for Automatically Generating Axial Lines

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## Introduction

This tutorial aims to provide a step by step guide for generating axial lines based on urban street networks, and using Axwoman 6.0, an extension of ArcGIS 10. In the past, axial lines of a very large city have to be created manually by following some rule, i.e., starting with the first largest axial lines, followed by the second largest, and so on until all space is covered with intersected axial lines. It could take one week for a graduate student to finish the drawing. Now with the help of Axwoman, axial lines of a large city can be automatically generated within a few minutes from the road central lines, thanks to the new definition of axial lines based on walkability or drivability.

To perform the generation of axial lines, a French city Avignon is taken as an example in this tutorial. Before processing the data in ArcGIS with Axwoman extension, the shapefile data of OpenStreetMap should be downloaded from some website: e.g., <http://downloads.cloudmade.com/>, or <http://download.geofabrik.de/>. Although one can download the data directly from the OpenStreetMap sit, it could take a longer time and with some complicated procedures. Thus the above two sites are highly recommended for data downloading.

The remainder of the tutorial is structured as seven steps: importing data into ArcGIS, selecting the right area, making the right map projection, connecting or eliminating isolated arc segments, chopping arc in junctions (building up topology in terms of GIS), generating natural streets and finally generating axial lines and calculating space syntax parameters for the axial lines. Note that each step depends on the results of previous steps. Make it sure you understand the logic behind the steps, instead of blindly following the procedures.

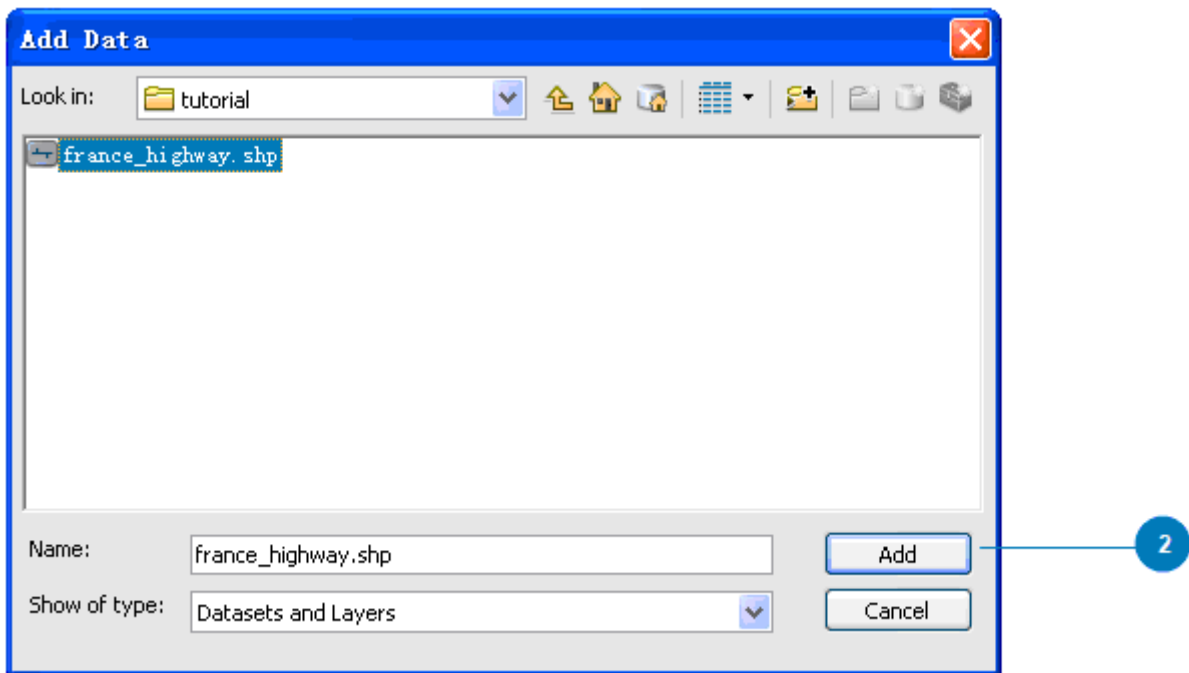
(A note of acknowledgement: This tutorial is developed as part of a course project. I would like to thank Professor Bin Jiang for his guidance in developing this tutorial. The data used in this tutorial is contributed by OpenStreetMap community.)

## Import data

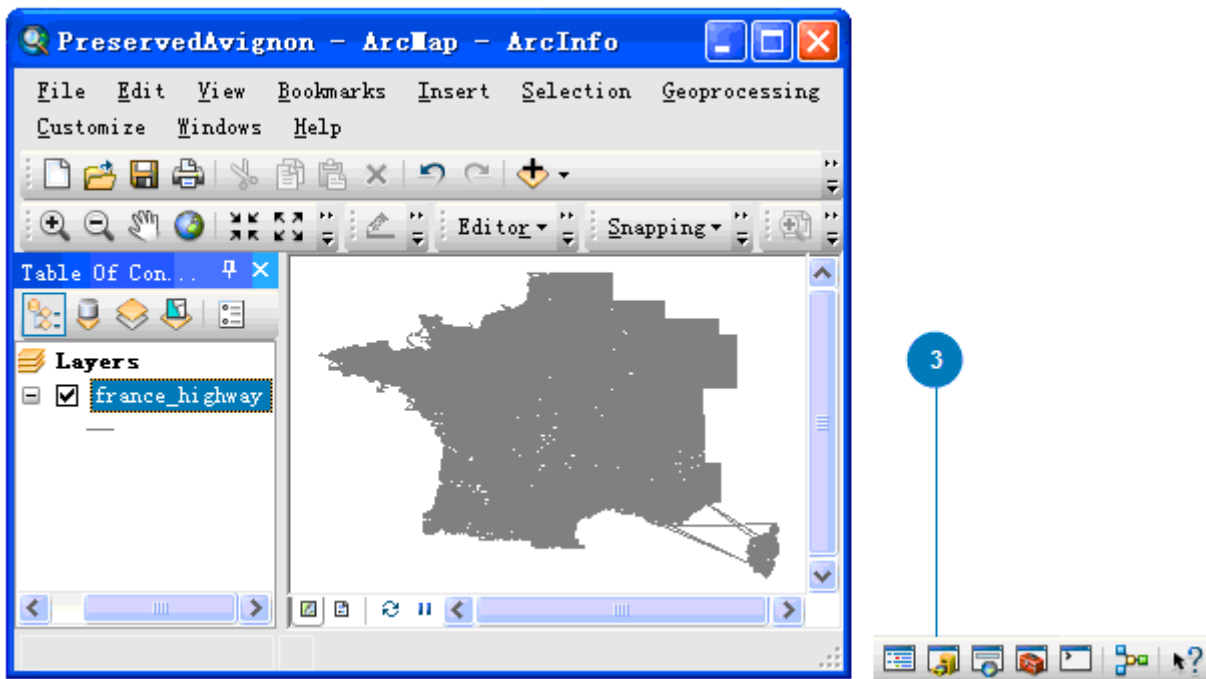
1. Start ArcGIS 10 and import the data when the shapefile data are already gotten. Click the button *Add Data* to add the needed layer.



2. Here only the street data is need to finally generate axial lines. Choose the shapefile *france\_highway* and click *Add*.



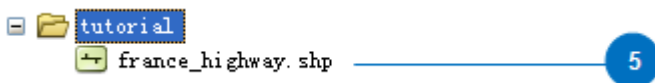
3. This is the streets for the whole country and a boundary is needed to clip the preserved area of Avignon. Click the button *Catalog window* in order to create a boundary layer.



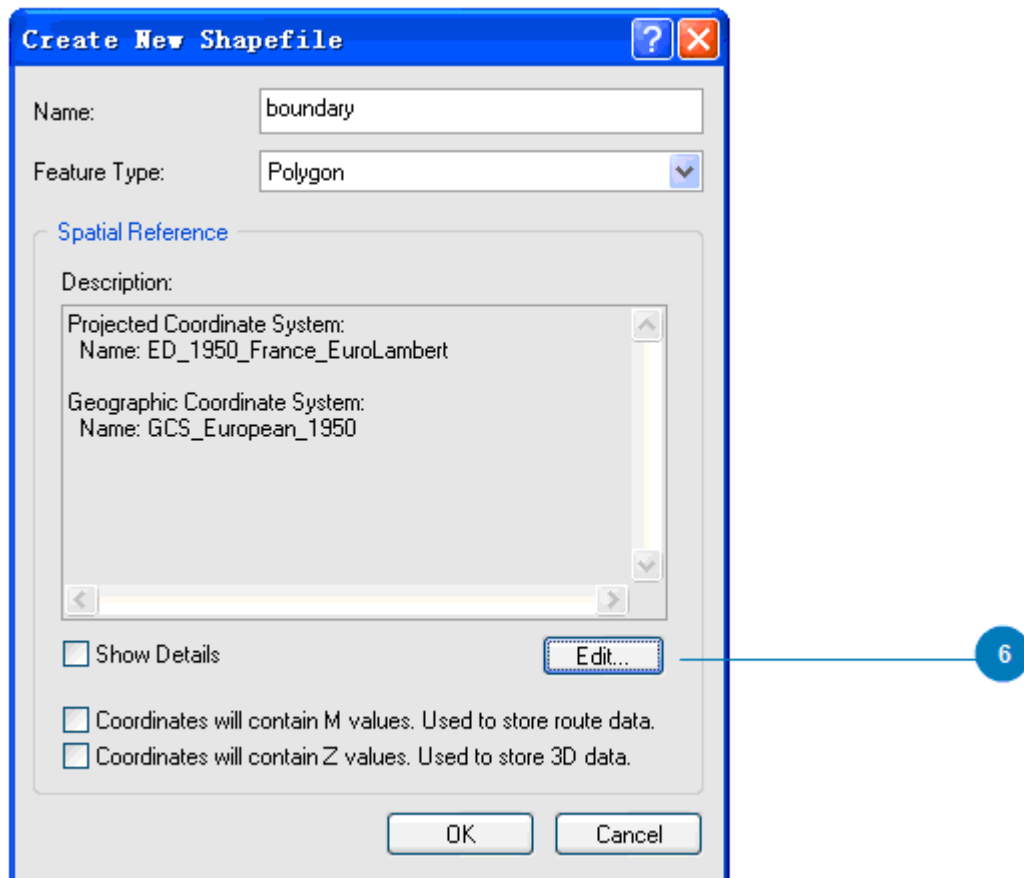
4. Click the button *Connect To Folder* in Catalog window. Choose the folder that you are working with and click *OK*.



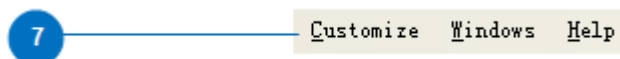
5. Right click *tutorial* folder in Catalog window and choose *New* then click *Shapefile*.



- Fill the name *boundary* and choose *Polygon* as Feature Type. You can select a coordinate system that is consistent with the street data by clicking *Edit*, then click *Select* to select a coordinate system and click *Add* and *OK*; you can also ignore this step. Click *OK* to add the boundary layer. Click *OK* if a message window with Unknown Spatial Reference comes out.



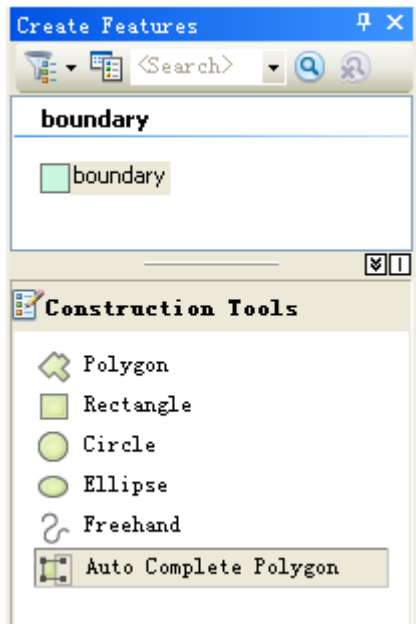
- Activate the Editor toolbar by clicking *Customize* and *Toolbars* and ticking off *Editor*.



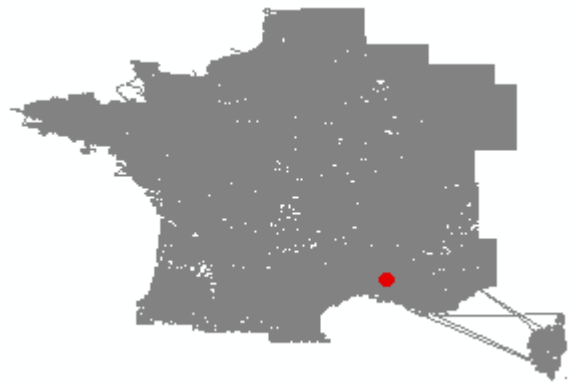
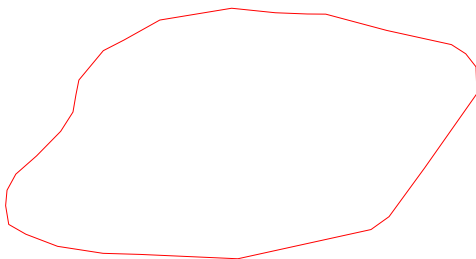
- In Editor Toolbar, click *Editor* and choose *Start Editing*. On the right side, Create Features window is opened. Click *Continue* if you meet the Start Editing warning window.



- Click *boundary* to highlight it and Choose *Auto Complete Polygon* in the Construction Tools. Draw the boundary of the preserved area of Avignon according to Google Map. To finish the complete polygon, make the last line connected to the first drawn line and double click. Click *Editor* again and then click *Stop Editing* and *Yes* to save it.



10. The boundary for this case is for the preserved area of Avignon. It is the part that encircled by the wall. You can briefly draw the boundary according to the wall.



## Select the right area

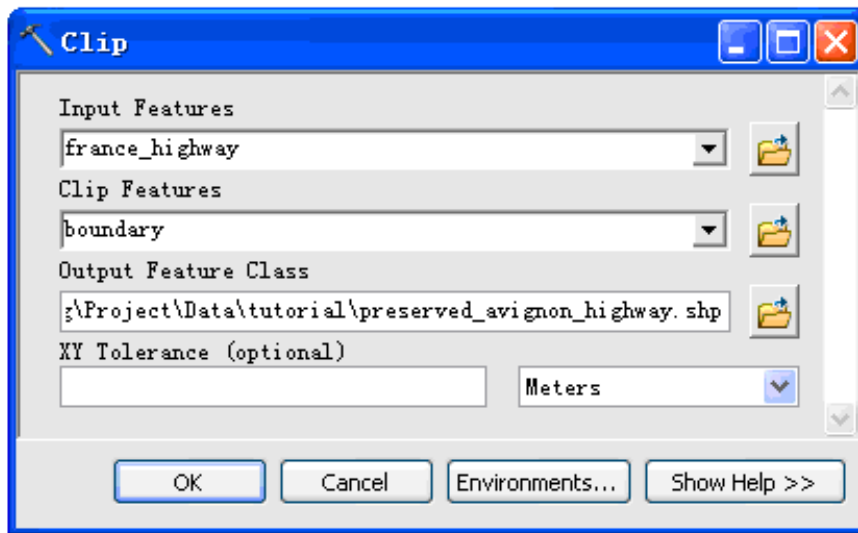
We usually focus on an area of interest, which is the preserved central city of Avignon. We select the needed data from the whole country shapefile. For this step, a boundary layer is required to clip the input features.

1. The street data of preserved area of Avignon is needed. The boundary layer is used to clip the France highway layer to get the needed area. Click the button *Geoprocessing* and choose *Clip*.



Geoprocessing Customize Windows

2. Click the arrow to choose the layer and Input Feature is *france\_highway* and Clip Feature is *boundary*. Set the storing folder and name the output *preserved\_avignon\_highway* by clicking the button next to Output Feature Class. When finish the setting, click *OK*. After processing, the new preserved Avignon highway layer will be automatically added to the main window.



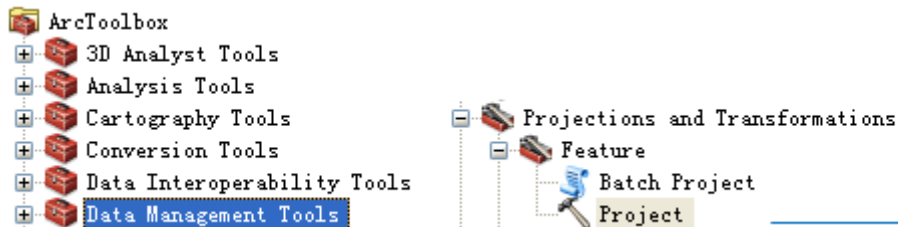
## Make map projection

There are various coordinate systems and we need to choose an appropriate projected coordinate system for the streets. The downloaded data are in WGS 84 and a right map projection with less geometric distortion should be selected. This step uses a project function within ArcGIS.

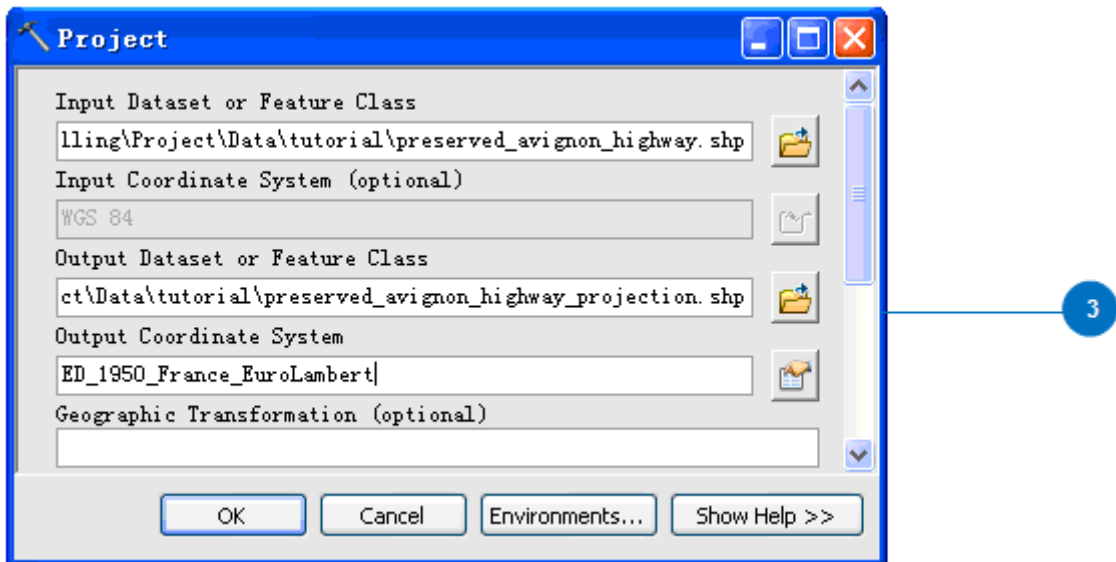
1. The Avignon highway data should be made a projection and set the appropriate projected coordinate system. Click the button *ArcToolbox window* to open it.



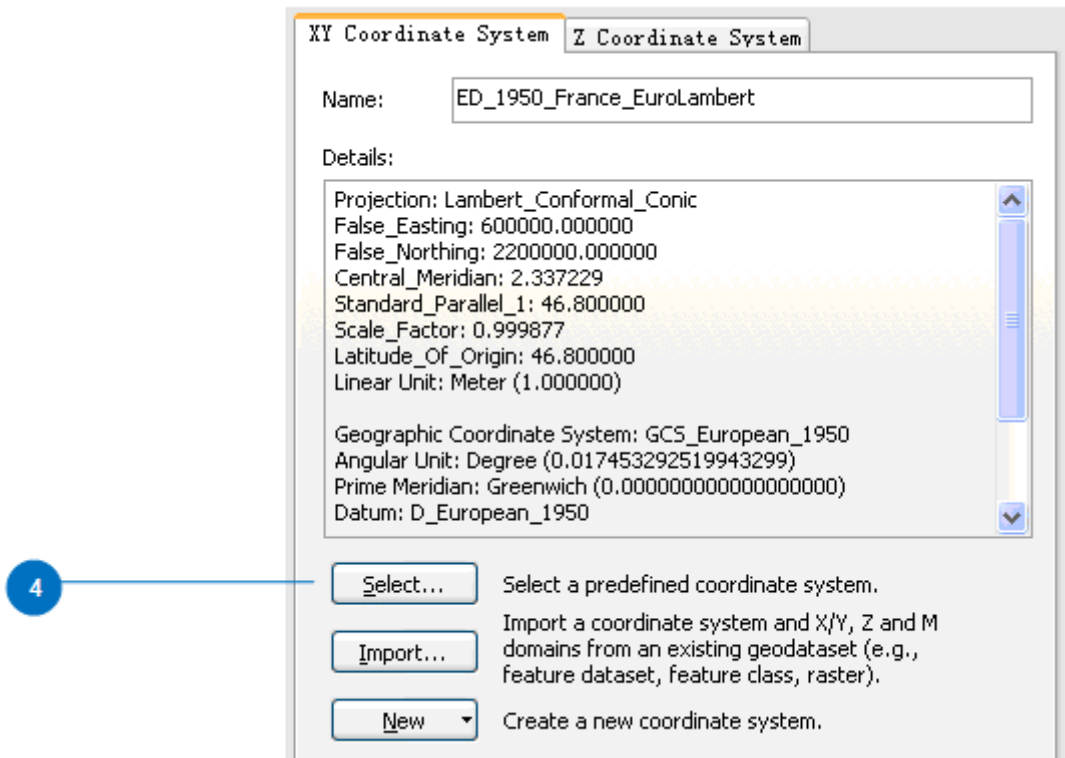
2. In ArcToolbox window double click *Data Management Tools* and *Projections and Transformation*. Extend *Feature* in *Projections and Transformation* and double click *Project*.



3. Setting the Project window, choose *preserved\_avignon\_highway* in Input Dataset or Feature Class and click the button next to Output Dataset or Feature Class to define the output dataset and name it *preserved\_avignon\_highway\_projection*. Click the button next to Output Coordinate System to choose an appropriate coordinate system.



- In Spatial Reference Properties window, click *Select* and *Projected Coordinate Systems*. It is optional to choose an appropriate coordinate system. For this city, the coordinate system is chosen from *National Grids, France* and *ED 1950 France EuroLambert.prj*. Click *Add* and *OK* to set the projected coordinate system for Avignon. Click *OK* to perform the map projection and the layer is automatically added to the main window after processing.



## Deal with the isolated arc segments

Because of the editing matters or current situation, there are some isolated arc segments that exist in the data. Carefully check the percentage of the isolated arcs, if they are not a high percentage or unimportant, simply delete them; otherwise do some according editing to keep them before the following processes. To judge whether or not the isolated arcs are important, you have to cross check with Google Maps or OpenStreetMap.

- After projecting the data into referenced coordinate system, the isolated arcs have to be deleted (note:

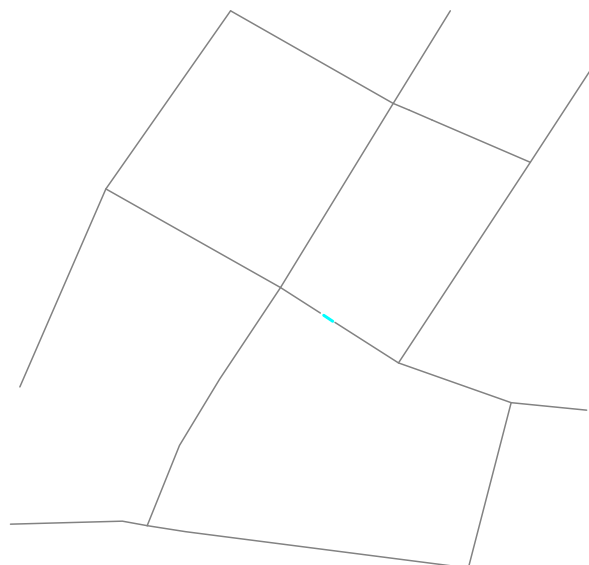
pay attention to the number of the isolate arcs and there is only a small part or no isolated arc). Before dealing with the street data, the Axwoman toolbar should be activated. Click *Customize, Toolbars* and tick off *Axwoman 6.0*. Now, the Axwoman toolbar is active.



2. Use the *Select Features* tool to select one arc on the *preserved\_avignon\_highway\_projection* layer and click the button *Get isolate lines* in Axwoman toolbar.



3. After the processing, you will get the information window and all the isolated arcs are marked. You should be critical to the number of isolated arcs and they only cover a small part of the whole street networks. Check the marked arcs and find out if there are some editing errors with the *Pan* tool to move the figure.



4. If some streets which should be connected are detected with isolated arc segments due to the editing matter of raw data, you need to manually join these arcs. Click *Editor* in Editor toolbar, select *Start Editing* and use the *Select Features* tool to select the arc that needed to be edited. Click *Edit Vertices* button and move the vertices of the arc in order to connect its adjacent one. Note: If there is no editing error for the detected isolated arc segments, you can ignore this step and just follow the next one.



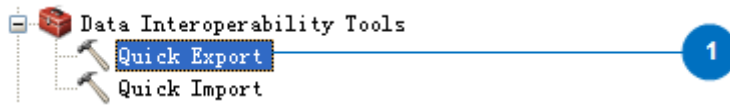
5. If you have done step 4, isolated arcs need to be checked again. When they are marked, click *Editor*, select *Start Editing* and press *Delete* on the keyboard. **Warning:** If the isolated arcs are deleted, you have to close ArcGIS and reopen it again due to some updating matters.

## Chop arcs at each junction into segments

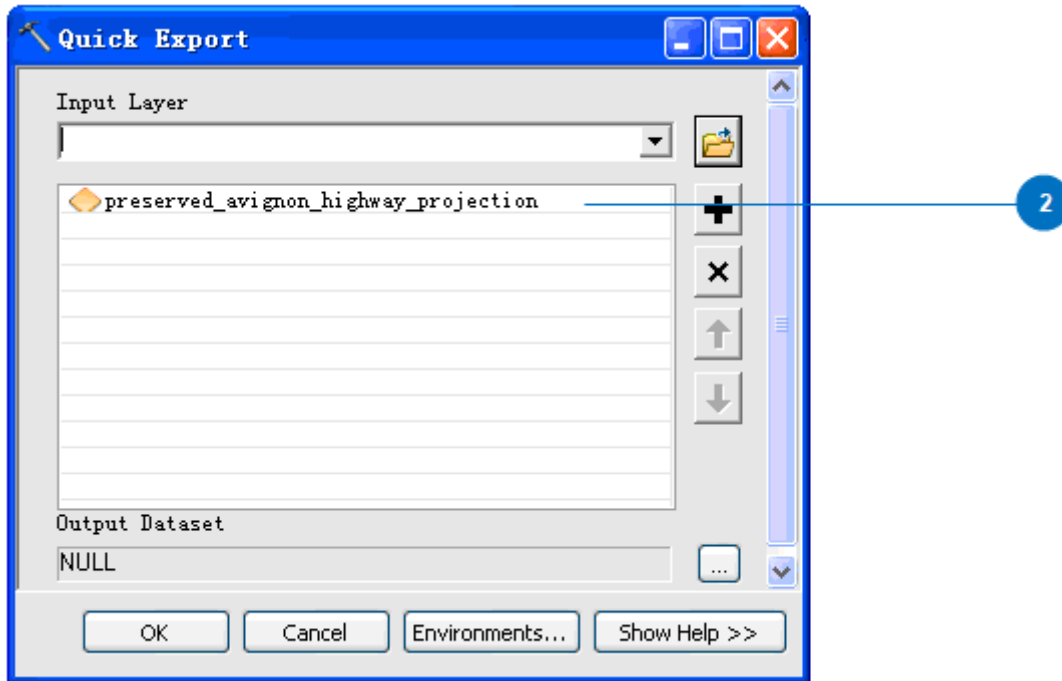
The step is called building up topology in terms of GIS. It is an important step in order to generate natural streets by joining neighboring street segments to form a good continuity. All the neighboring streets are connected to each other by predefined angle (e.g., 45 degree) at each junction. This step will

chop the arcs at each junction and convert them to street segments.

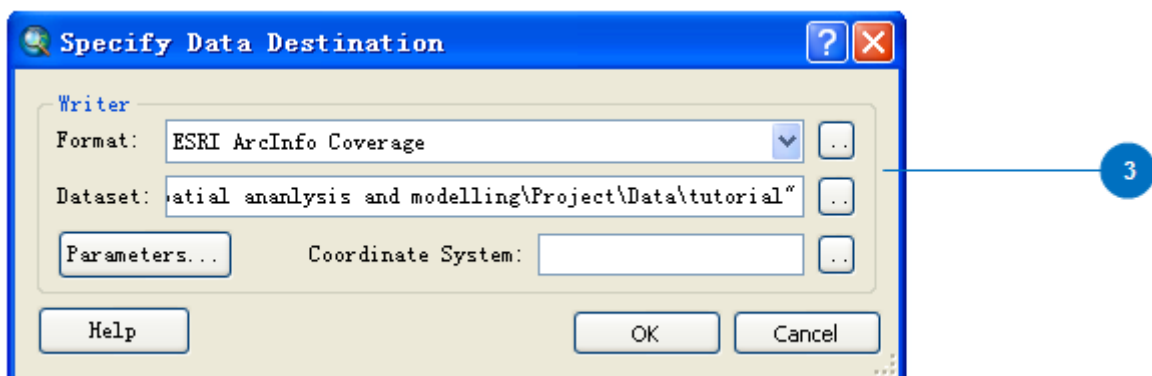
1. One important step is to create topology for these street segments and they need to be cut off at every junction for further generating natural streets. Go to ArcToolbox window; double click *Data Interoperability Tools* and *Quick Export*.



2. Click the arrow in Input Layer and select *preserved\_avignon\_highway\_projection* layer. Click the button beside Output Dataset and get Specify Data Destination window.

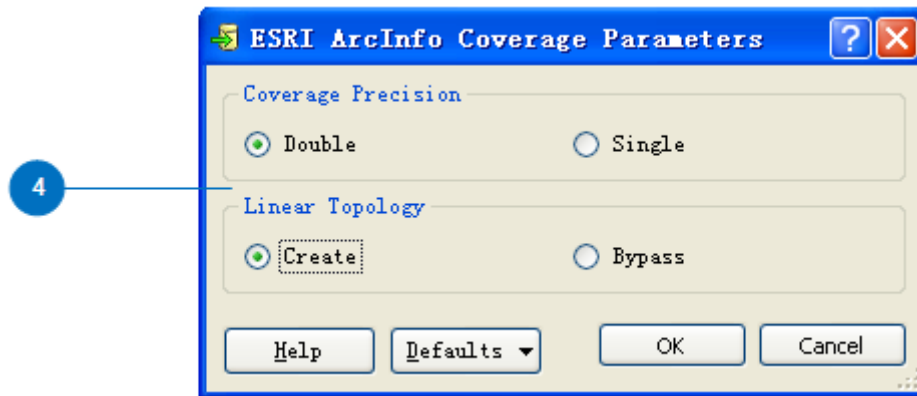


3. Fill in the Specify Data Destination window, choose *ESRI ArcInfo Coverage* for Format by clicking the button next to Format, click the button beside Dataset to choose the storing folder and click *Open*. You can also set an appropriate coordinate system as you want by clicking the button beside Coordinate System.



4. Click the *Parameters* button, mark *Double* for Coverage Precision and *Create* for Linear Topology and click *OK*. Click *OK* to close the Specify Data Destination window and *OK* again to finish Quick Export.

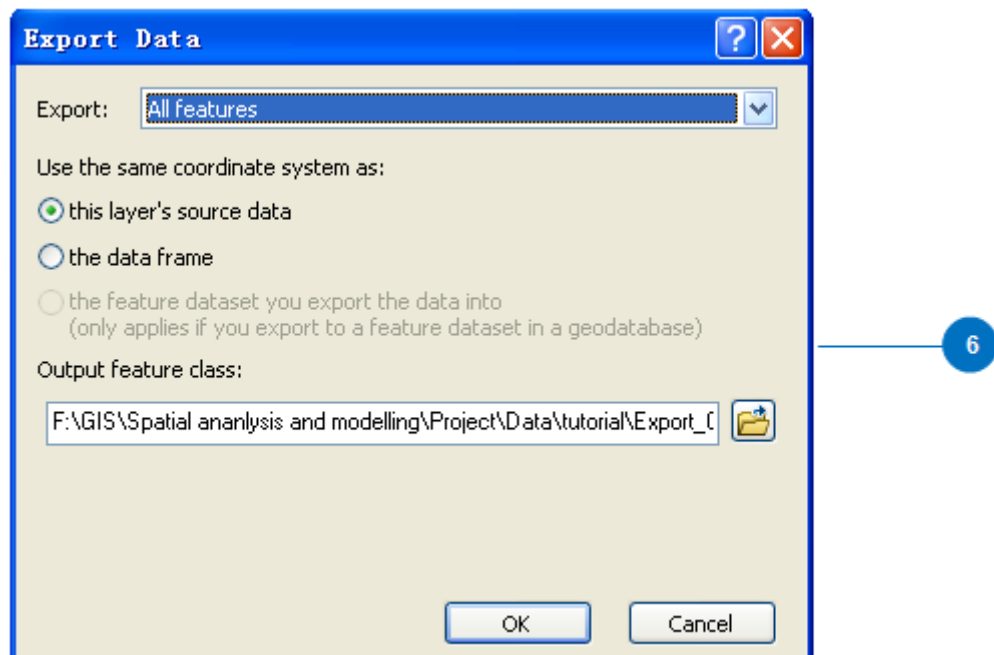




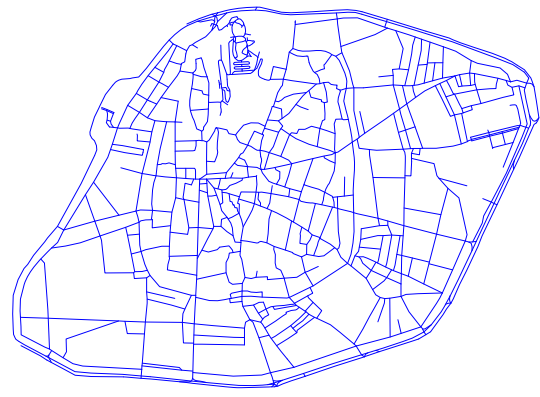
5. Check the right bottom processing bar and *add* this layer which is automatically named after finishing. Click *Close* when you meet the Geographic Coordinate Systems Warning window. In here it is called *preserved\_avi arc*. Now this layer has to be exported to shapefile format. Right click the layer and choose *Data* and *Export Data*.



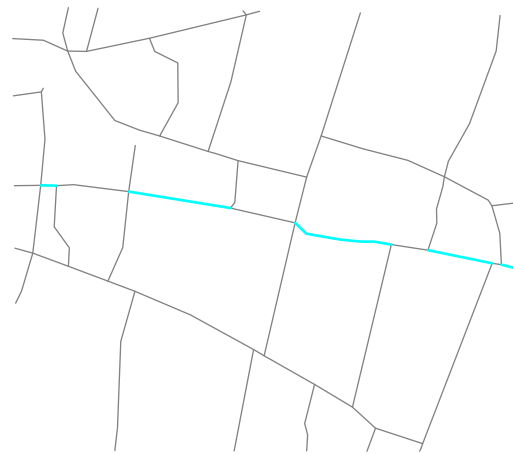
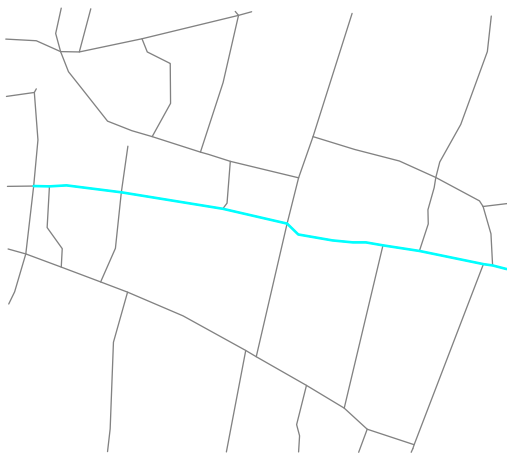
6. You will get the Export Data dialog. Export *All features* and set Use the same coordinate system as *this layer's source data*. Choose the folder that you are working with to store the output feature. After filling in it, click *OK* to process it. Click *Yes* when a window comes out to ask you to add the output data.



7. If the result of clipped area has some unexpected arcs, you have to click *Start Editing* in Editor toolbar and use *Select Features* tool to select the arcs which should be deleted (make sure this layer is active by highlighting it). Press *Delete* on the keyboard.



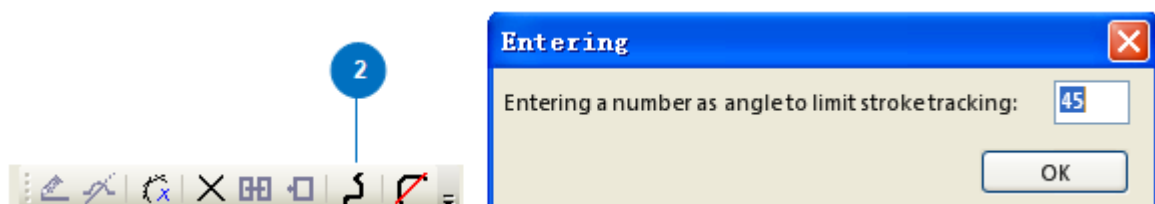
8. If you don't perform this step of quick export, you will get the result as the left one shows that the arcs are not chopped into segments at each junction. The needed result is represented in the right one and all the arcs are cut into segments.



## Generate Natural Streets

Natural streets can be automatically generated with Axwoman extension. For this tutorial, the threshold angle 45 degree is accepted to connect each adjacent street segment.

1. With the *Export\_Output* layer (street segments), natural streets will be generated. Before generating natural streets, isolate arcs should be checked again. Highlight the *Export\_Output* layer, select one arc on the layer and click the button *Get isolate lines* again. If isolate lines exist, start editing and delete them (**Warning:** Don't forget to reopen ArcGIS if there are some isolated arcs).
2. Click the button *Tracking strokes at junction by a limited angle* in Axwoman toolbar and click *Yes* in the Information window to track strokes. You can keep the default value in the Entering dialog and click *OK*. Choose the storing folder and name it as *avignon\_NaturalRoads* in the following window and click *Save*. Click *OK* when the tracking is done successfully.



3. You can set an appropriate coordinate system that you want to *avignon\_NaturalRoads*. In Catalog window find the *avignon\_NaturalRoads* shapefile under tutorial folder. Right click *avignon\_NaturalRoads* and select *Properties*. In Shapefile Properties window, mark *XY Coordinate System*, then click *Select* and choose a coordinate system that you want and click *Add*. Click *OK* to close this window otherwise *Cancel* it.

**Warning:** The arc at junctions must be chopped. If you forget doing this step, it will significantly affect the generation of axial lines. For example, an axial line which should be treated as one may become two.

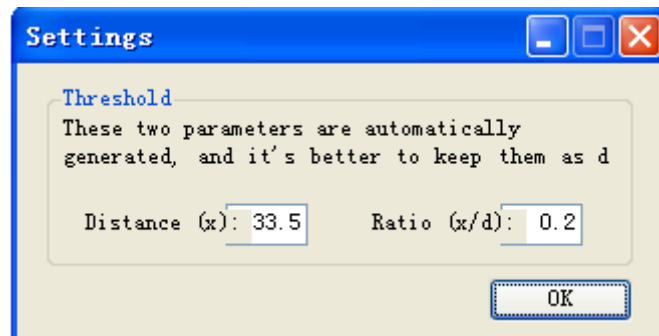
## Generate Axial Lines

For this tutorial, axial lines are automatically generated based on natural streets. The axial lines are produced from the street center lines so to speak. They will be used for analyzing the street networks and study the urban morphology.

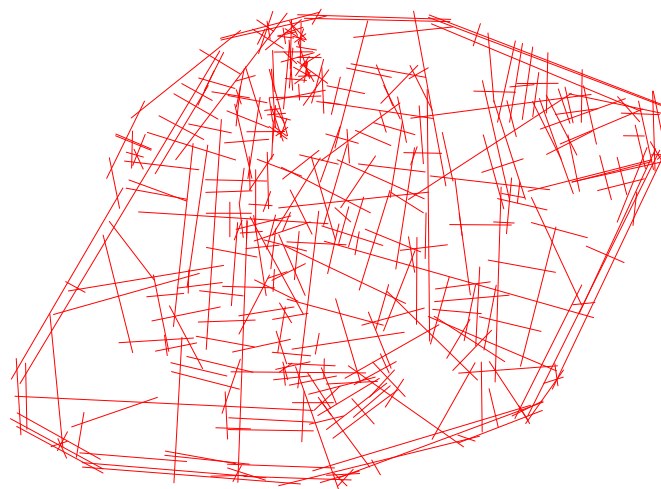
1. You should make sure that there is no isolated arc and repeat the previous steps to check the isolate arcs and delete them. Please notice again, if isolated arcs are checked out, reopen ArcGIS after deleting them. Based on natural streets, axial lines are generated. Highlight *avignon\_NaturalRoads* layer and click the button *Street to Axial* to make axial lines. Click *OK* to continue the processing otherwise *Cancel* it.



2. Click *OK* for the Settings window. **Warning:** If you happened to use Swedish version of ArcGIS, this threshold settings would be incorrect. This is because the decimal number in Swedish is by comma rather than dot as in English. You must use English version of ArcGIS.



3. Now, you have finished the generation of axial lines based on natural streets.



## Calculate parameters in case of lines with lines

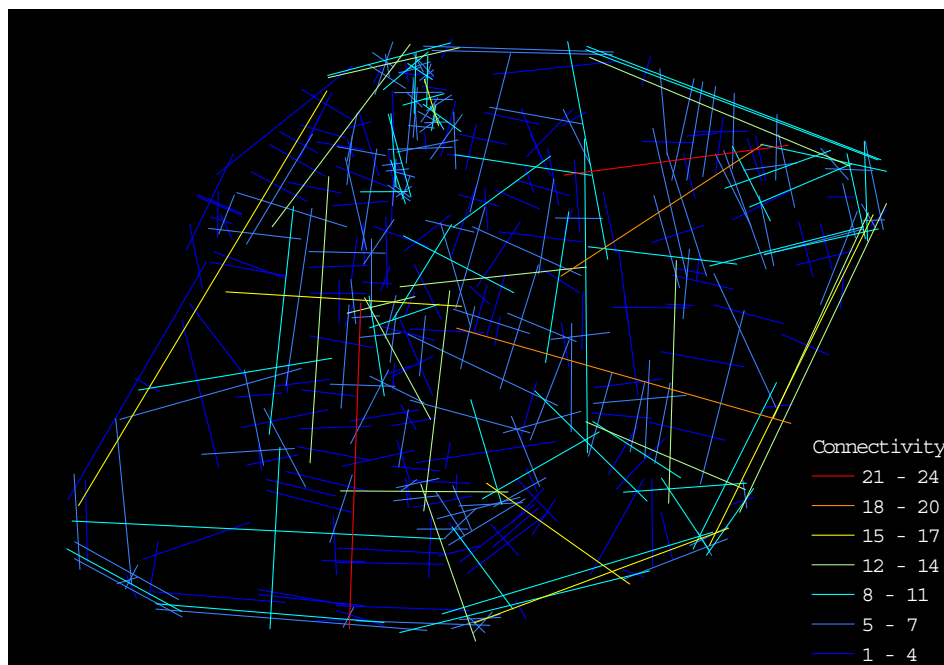
1. For further work, you need to calculate the space syntax parameters for the street networks to study the urban morphology. For this case, we focus on axial lines. Highlight *avignon\_NaturalRoadsAxial* in the Layers and click the button *Calculate parameters in case of lines with lines*. Click *OK* when the window comes out to ask you to calculate the space syntax parameters of the selected layer.



2. If a window appears and shows the information about catching some isolated points and checking the map, click *OK* and click *Start Editing* in Editor toolbar, highlight this layer and press *Delete* on keyboard to delete them. Close ArcGIS and open it again after deleting isolate arcs. Add the axial line layer and do the same procedure for calculating space syntax parameters.
3. The built-in classification in Axwoman is not good, because it is strictly based on 40% criteria. We suggest manual classification instead. Eventually, you will get a representation for the street networks with hierarchical patterns if the distribution of them follows a heavy-tail distribution.

#Axial lines	#In head	% in head	#In tail	Mean value
396	156	39.4%	240	5.5
156	57	36.5%	99	8.7
57	19	33.3%	38	12.0
19	8	42.1%	11	15.7
8	3	37.5%	5	18.3
3	1	33.3%	2	21.3

**Warning:** In case and at some point, you see the computing is stuck, we suggest you kill ArcMap (including AppROT.exe) from the Windows task manager.



After go through this tutorial, you have learned how to automatically generate axial lines from the raw data. These steps are applied to the shapefile data of Avignon and you can follow this tutorial as a guide to generate axial lines of your own street data. You can calculate the space syntax parameters for axial lines and produce a graph which will reveal the hierarchy of the urban streets as shown above.