Exercise: Network analysis for Bornholm

Contents

Purpose

This exercise will introduce you to network analysis in ArcGIS Pro. You will create the network yourself for the island of Bornholm based on road segment lengths as the cost variable. You will carry out experiments based on some of the network solvers available a.o. analyzing shortest paths and availability of doctors on the island from a patient's perspective.

Copy exercise data

1) Open **Windows File Explorer** and copy the folder ***I:\SCIENCE-IGN-CGD-UVMAT\GIS_course\Exercises\ArcGIS_Pro\Exercise_NetworkAnalysis*** to an existing or new folder on your H-drive or another drive but be aware that your folder's path must not include any Danish characters (æ,ø,å). From now on you will work on this copy to obtain write access to the data.

Set up ArcGIS Pro

2) Open ArcGIS Pro and select 'Start without a template'. Select the Insert menu -> New Map
3) Prepare folder connections:
   Due to a problem accessing folders from Science's I-drive in ArcGIS Pro, open Windows File Explorer and locate ***I:\SCIENCE-IGN-CGD-UVMAT\GIS\Geodata***, see Figure 1**.**

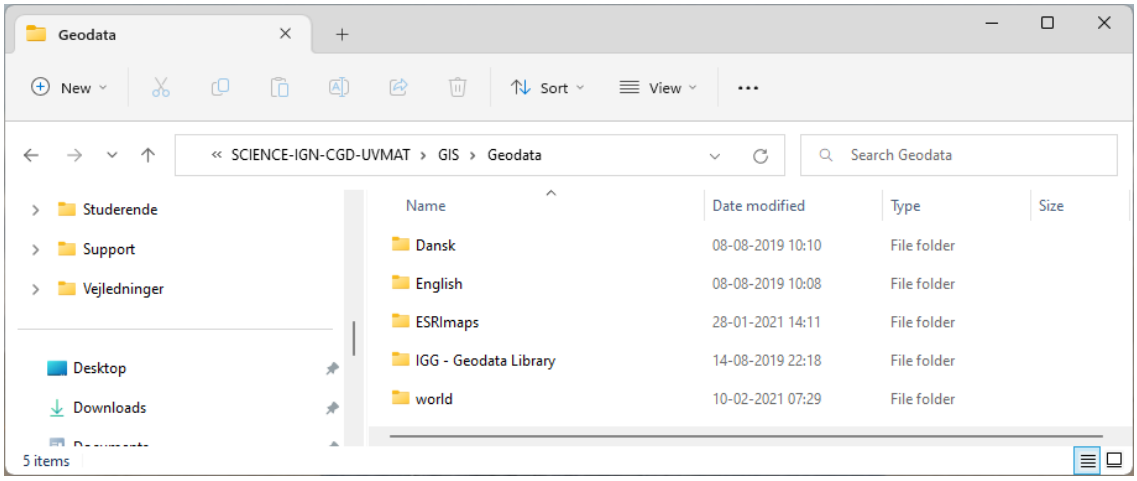

Figure 1 Add Folder Connection to folder on the I-drive

4) Make sure that both File Explorer and ArcGIS Pro are visible on your display. Press the left mouse button on the **Dansk**-folder in File Explorer and drag & drop the folder into the Folders-section in ArcGIS Pro's Catalog pane, see Figure 2. When done, close File Explorer.

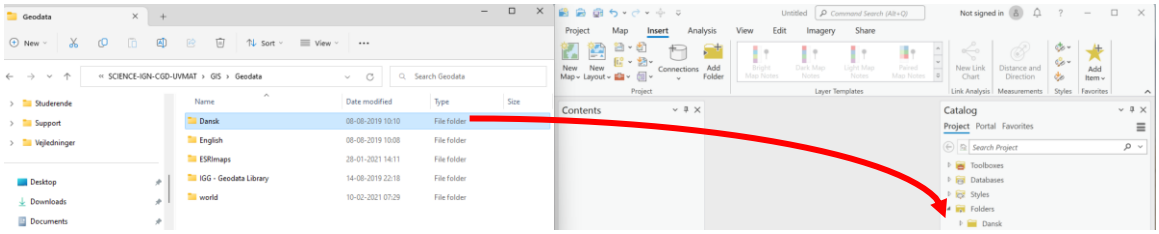

Figure 2 Drag & drop of folder from the I-drive tol ArcGIS Pro's Folders-section.

5) Next, in the Catalog Pane, right-click Folders -> **Add Folder Connections** and create a connection to the **Exercise_NetworkAnalysis-folder** you copied in step 1).

6) Assign default geodatabase: Expand your ***Exercise_NetworkAnalysis*** folder in the Catalog pane must look as shown in Figure 3. Now drag and drop ***Outputs.gdb*** to the **Databases** entry. Next, right-click the copied instance of ***Outputs.gdb*** in the Databases section -> **Make Default**. This trick ensures that when working with tools ahead, the ***Outputs.gdb*** is the default output location until changed.

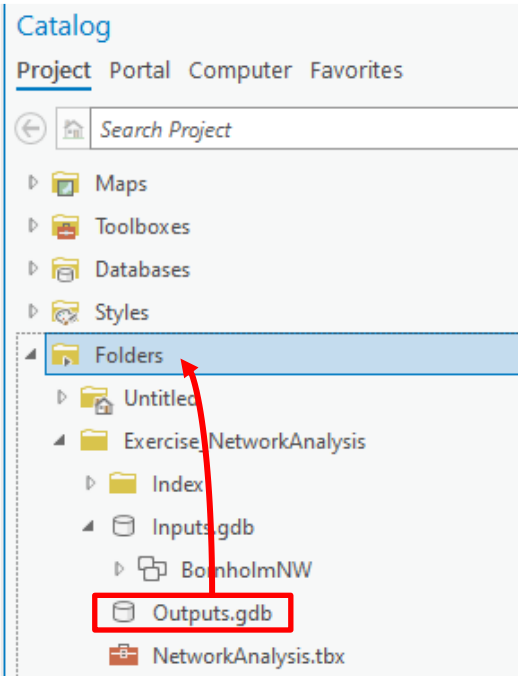

Figure 3 Catalog Pane

7) Save your setup by entering **Project** in the main menu -> **Save Project** and save the setup in the ***Exercise_NetworkAnalysis***-folder on the H-drive.

This ends your setup of ArcGIS Pro.

Inspect data

8) In the Catalog Pane expand the contents of your **Exercise_NetworkAnalysis\Inputs.gdb\BornholmNW** feature dataset. Highlight the 3 feature classes **Roads2017**, **Patients2017** and **Doctors2017** -> right-click and select **Add to Current Map**. Change the symbol for the doctors so it is distinguishable from the patients and move the doctors layer to the top of the Contents window. Notice that many patients' addresses are located at varying distances from the road network.

About the data

All data sets to build the roads' network, is saved in a so-called feature dataset named **BornholmNW** because a network can only be established when located there, see Figure 4.

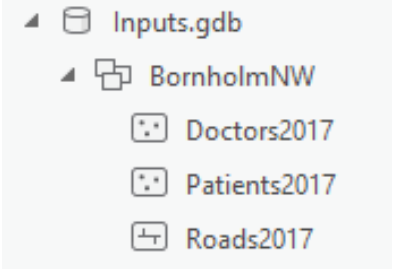

Figure 4 The Inputs.gdb's content.

Roads dataset:

The ***Roads2017*** feature class is adopted from the Danish Roads and Network Database (DAV) 2017, but you may extract subsets of nationwide roads datasets for other projects yourself. For example, you may use the Clip (Analysis) tool to derive a subset from the Open StreetMap dataset located on I:\SCIENCE-IGN-CGD-UVMAT\GIS\Geodata\English\14. OpenStreetMap\Road_line_10k_OSM_2017.lyr.

Patients dataset:

The ***Patients2017*** dataset was derived from all street addresses found in the Danish Address Register assuming that one patient is located per address. This is, off course, a rough generalization, but as true data on where patients live can be extracted from the CPR register, only, the 29,601 points here resemble the locations of Bornholm's approx. 40,000 citizens.

Doctors datasets:

The 13 ***Doctors2017*** addresses are picked from the Yellow Pages phone book, saved in a table and geocoded using the Geocode Address tool in ArcGIS Pro.

Create and build the network dataset

First, it must be specified which components the network dataset should be based on.

9) Right-click the ***BornholmNW*** feature dataset -> select **New Network Dataset** to open the **Create Network Dataset** tool. Set **Target Feature Dataset** to ***BornholmNW*.** For the **Network Dataset Name** enter ***Bornholm*** and for the **Source Feature Classes** check ***Roads2017***. For the **Elevation Model** select 'No elevation' and run the tool.

When the network is established, you can enable it to add directions including road names to route descriptions.

10) Right-click the ***Bornholm*** network's name in the **Catalog Pane** -> **Properties** -> **Directions** -> Check the ' Support Directions' checkbox -> select the **Field Mappings** tab -> set **Base Name** to ***VEJNAVN*** (=road name) -> **OK** and close the Properties window.

11) Now, to enable the direction guidance, right-click the ***Bornholm*** network dataset in the **Catalog Pane** -> **Build** and re-run the setup of the network's topology. When done, the network is automatically updated, added to the Contents Pane as ***'Edges'*** and saved in the feature dataset, see Figure 5.

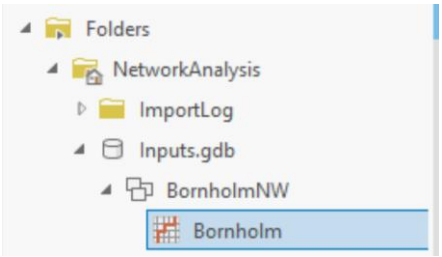

Figure 5 Network Dataset

Inspect the network

12) In the Contents Window, change the symbology for the road network's edges to a blue colour. Verify that there is a 1:1 match with the ***DAV2017_Roads*** layer. Next, turn off visibility of the latter. If you zoom into some forested areas, your network doesn't match your basemap because the roads are not publicly accessible. In the **Map** menu go to the **Basemap** section and change your basemap to **Open Street Map** instead that has a better visualization of public roads.

13) Right-click the network's name in the **Catalog Pane** -> **Properties** -> in the **Built** status section notice that the network has 20088 edges (road segments) and 8765 junctions (network nodes). Close the Properties pane before you proceed.

14) Add the network's ***Bornholm_Junctions*** from the Catalog Pane and change the layer's symbology so the points can be distinguished from the ***Patients*** layer.

Question 1: Where are the junctions located?

Route solving – the travelling salesman's problem

Now you are ready to create and evaluate a road trip with stops (locations) distributed around the island at some beautiful sites. For your inspiration, please look at this page with tourist attractions: Sites Bornholm.

First, add a new feature class named Sites to your BornholmNW feature dataset:

15) In the **Catalog Pane**, right-click the **BornholmNW feature dataset** -> **New** -> **Feature Class** -> for the **Name** enter ***Sites*** and set the **Feature Class Type** to **Point**. Click **Next** and check that the Spatial Reference assigned to the feature class is UTM 32N / ETRS89 and click **Next** to finish the new feature class.

    If you want to locate your starting point at the cozy Hotel Gæstgiveren, Theaterstræde 2, Allinge you may use ArcGIS Geocoding Service to locate it. Unfortunately, you cannot save the location to a feature class automatically unless you are signed onto ArcGIS Online, so instead you must manually digitize the location to the created feature class instead.

16) In the **Map** menu click the **Locate tool** -> select **Search** and type Theaterstræde 2. Right-click the match at Allinge and select **Zoom To**.

17) In the **Edit** menu, select **Create** - > click the **Sites** entry -> enter the map and click on the selected location for Gæstgiveren's location.

18) When done, re-use steps 16)-17) to enter at least 5 more locations to visit. For example, don't miss a visit to watch the Tretaspis shales at Øle Å close to Søndre Landevej 75 at Aakirkeby.

    When done digitizing, save your edits by selecting **Finish Sketch** in the lower part of your map frame, see Figure 6 and select **Save** in the **Edit** menu to save the features. **Clear** the selection and change the symbology for the **Sites** feature class so it stands out.

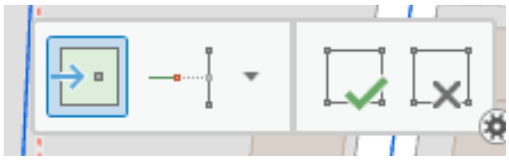

Figure 6 Finish sketch.

19) Prepare route analysis: Now comes a tricky part, see Figure 7, and try to follow the arrows inserted representing the work ahead:

In the **Analysis** menu select **Network Analysis** -> **Route**. Await that a new grouped layer named **Route** is added to the Contents Pane. Click the route's name (Route) -> click **Route Layer** in the upper menu. In the updated ribbon click **Import Stops** that opens the **Add Locations** tool. Fill in the menu as shown in Figure 7's left section by adjusting your Analysis Layer Name, select your ***Sites*** as **Input Locations**, expand the **Advanced section** -> set **Search Tolerance** to **500 meters, uncheck** the '**Append to Existing Locations**' checkbox, and make sure the **Search criteria's source** is set to *Roads2017* and **Snap type** to **Shape**. Hit **Apply** to add the locations to the Route layer. Ignore a warning saying that your input data are 3D but having an unknown Z coordinate system (this is because a vertical datum for the map hasn't been defined). Notice, however, in the results from the operation that all features have been located, and that they are available as numbered Stops in your Route layer.

To inspect the ***Stops***' attributes, right-click the sub-layer's name and open its attribute table.

20) If you want to return to your first location on your trip after having visited the last one, you must prepare an extra instance of the first point and add it to the table. So, repeat steps 16)-17). Next, clear the selection of the extra point.

Mark the group layer name **Route** in the Contents Pane -> in the **Route Layer ribbon** go to **Travel Settings Sequence** -> select **Preserve First & Last Stop**.

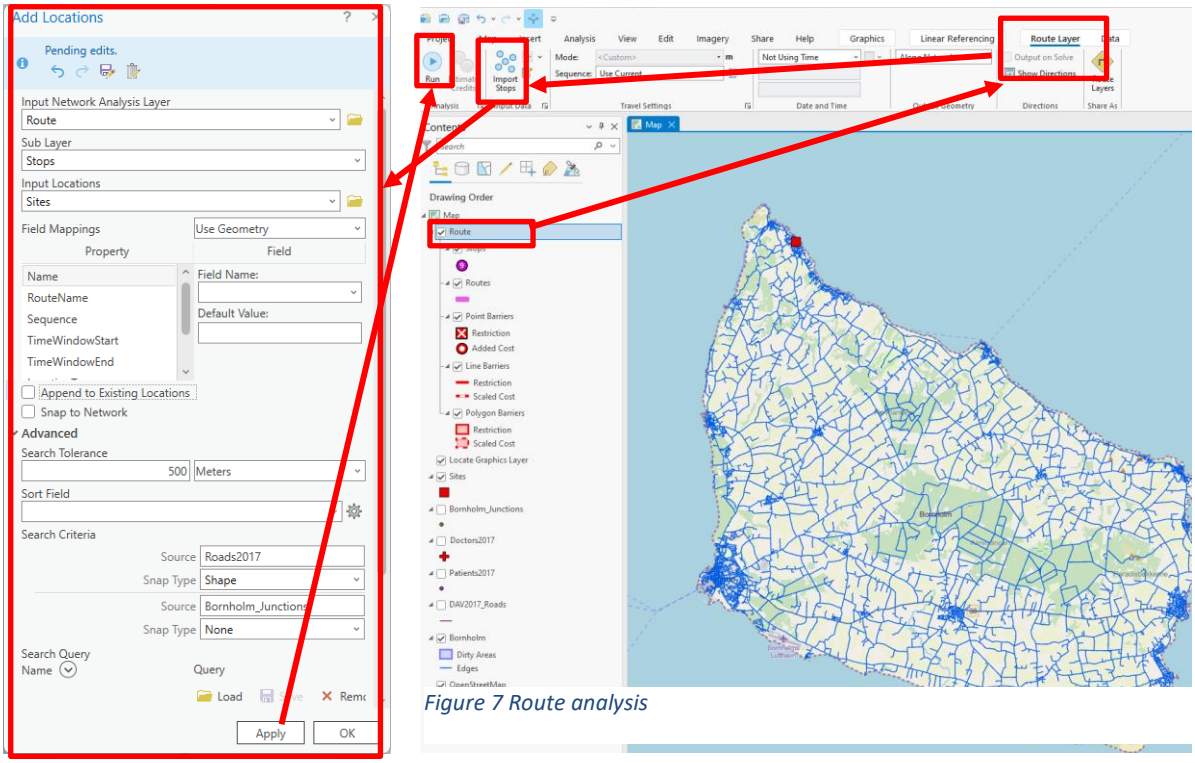

Figure 7 Route analysis

Also, make sure that the '**Output on Solve**' option in the **Directions** subgroup is checked, see Figure 8.

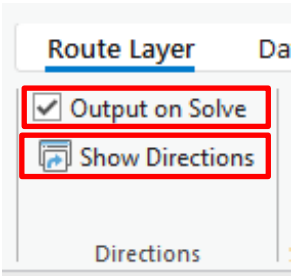

Figure 8 Enable Directions

In the **Route Layer** ribbon, click the **Run** button in the left side of the ribbon to solve the route. When done, press the **Show Directions**' entry in the Directions subgroup, see Figure 8 to inspect the route's directions in a new popup window.

Question 2: How long is your optimized route?

Notice that the stop's sequences are labelled in your map, but that location 8 overlaps location 1.

21) Rename map: In the **Catalog Pane** go to the top entry: **Map** -> double-click its name -> rename to **Route**.

22) Save: In the **Project** menu select **Save** Project.

Barriers

23) To simulate roadblocks, create a new line feature class named ***Roadblocks***, digitize a couple of line features along your route as blocks and save them. Remember to clear the selections before you proceed. In ArcGIS Pro's main ribbon -> Analysis -> Tools -> locate the **Add Locations** geoprocessing tool to add your roadblocks as **Line Barriers** (found among the Sub Layers) to your ***Route*** layer. Then re-run the route analysis and watch the altered route.

24) Before you proceed, open the **Route: Line Barriers** sublayer -> **select all roadblocks** -> go to the **Edit** menu -> **delete all selections** -> **Save**. If not, the roadblocks will affect the next steps.

Identify service areas

Service areas are used to identify locations within a specific driving distance from one or more facilities. In this case we want to identify areas within 5 and 15 km driving distances from doctors on Bornholm.

25) New map: Select **Insert** menu -> **New Map** -> rename the map: ***Service Areas*** and add your network data set **Bornholm** and the feature class ***Doctors2017***. Enlarge the Doctors point symbol, so their locations are easily visible. Open the ***Doctors2017***'s attribute table and notice the address fields. Close it afterwards.

26) Prepare service area analysis and load facilities: In the **Analysis** menu select **Network Analysis** -> **Service Area**. Await that a new grouped layer named **Service Area** is added to the Contents Pane. Click the **Service Area's grouped layer name** -> in the main menu click on **Service Area Layer**. In the updated ribbon click **Import Facilities** that opens the **Add Locations** tool. For **Input Locations** select ***Doctors2017***, expand the **Advanced** section, set **Search Tolerance** to **250 meters**, **uncheck** the '**Append to Existing Locations**' checkbox, make sure the Search Criteria source is set to Roads2017, **Snap Type** = **Shape** and hit **OK**. When executed successfully, open the **Facilitied** attribute table and verify that 13 doctor locations were added. Next, close the attribute table.

27) Set options and solve: Select the **Service Area's grouped layer name** (Service Area) -> in the upper menu select **Service Area Layer**. To identify 5 and 15 km service areas along the network from the doctors' addresses change the **Travel Settings' Cutoffs** to 5000; 15000 -> hit -ENTER- -> change **Output Geometry Standard Precision** to **High Precision**. Next, click **Run**. If necessary, adjust the service areas' symbologies to distinguish the two distance bands.

28) Patients' locations: Add the **Patients2017** data set that has fictional placement of potential patients' address locations.

Question 3: 13 doctors were allocated as facilities, but only 10 appears on the map. Why?

Question 4: How many potential patients' address points are located outside both service areas from any doctor? Are they found beyond the 15 km zone due to a distance criterion or for some other reason?

29) Clear your selection before you continue, save your project and turn off all Service Area layers.

Location / Allocation

Finally, we want to calculate which doctor is closest to the potential patients' address points when using a 15 km cutoff distance (which means that no patient should travel more than 15 km to reach a doctor). Also, we want the exact driving distance for the individual patients.

30) New map: Select **Insert** menu -> **New Map** -> rename the map: **Location / Allocation** and add your network data set **Bornholm** and the feature classes ***Doctors2017*** and ***Patients2017***.

31) Prepare location/allocation and load facilities: In the **Analysis** menu select **Network Analysis** -> **Location-Allocation**. Await that a new grouped layer named **Location-Allocation** is added to the Contents Pane. Click the **Location-Allocation** grouped layer's name -> in the **main menu** select the **Location-Allocation Layer**. In the updated ribbon click **Import Facilities** that opens the **Add Locations** tool. For the **Input Locations** once again select **Doctors2017**, in the **Advanced section** set **Search Tolerance** to **250 meters**, **uncheck** the '**Append to Existing Locations**' checkbox and hit OK. Notice that the doctor locations are now entered as **Candidate Facilities**.

32) Demands: In the **Location-Allocation ribbon** click **Import Demand Points** that once more opens the **Add Locations** tool. For **Input Locations** select **Patients2017**, set **Search Tolerance** to **1000 meters** as some citizens may be located up to 1 km from the edges in the network dataset[1], **uncheck** the '**Append to Existing Locations**' checkbox in the bottom of the tool, click **OK** and wait patiently for the many patients' addresses to be loaded.

33) Set options and solve: In the **Location-allocation ribbon** make sure the **Travel Settings' Cutoff** values are blanked, change **number of facilities** to **10**, set (problem) **Type** to **Minimize Weighted Impedance**, **Output Geometry** to **Straight Lines** and hit **Run**. This job may take up to 10 mins. to complete depending of your computer's health.

34) Visualize: When the calculations are done, right-click the **Lines** sub-layer -> **Symbology** -> **Unique Values** -> set **Field1** to **FacilityID** and select a rich colour scheme. Now it's visualized which doctors every single patient is closest to. To add labels showing the **Facility ID**s, **highlight** the sub-layer in the Contents Pane -> select the **Labeling** menu in the main ribbon, check the **Label** icon to the far left and change the text symbol's size and color.

35) Check facilities chosen: Open the ***Facilities*** attribute table. Notice the Facility Type field and that all doctors are set to 'Chosen' except 3 having a status of 'Candidate'. This is because those doctors are located at the same address location as doctors at other locations. This means that only 10 doctor locations out of 13 are flagged as chosen. If you want to change a location's status (Chosen, Candidate etc.) just go into that specific field, double-click its value, and change it to something different from the field' pop-down menu. Make sure that no records are selected before closing the attribute table and re-hitting **Run**.

[1] You may investigate on beforehand how far the most located demand point is from any closest road from using the Near tool.

Next, we want to calculate how many patients are assigned to each doctor.

36) Statistics: Search for the **Summary Statistics** tool and open it. Set Input Table to the **Demand Points** layer, set **Statistics** field to **FacilityID**, Statistics type to **COUNT**, **Case Field** to **FacilityID** and run the tool. The statistics output is added to the Contents window automatically.

Question 5: How many patients are assigned to each doctor?

Question 6: How may you get the travel length for any patient to a doctor?

Question 7: How to calculate statistics for the average and maximum travel lengths for patients allocated to each doctor?

37) Save your project and close ArcGIS Pro.

Thomas Balstrøm, Feb. 28, 2023