Transportation Geography (Geo 310) Name: _____
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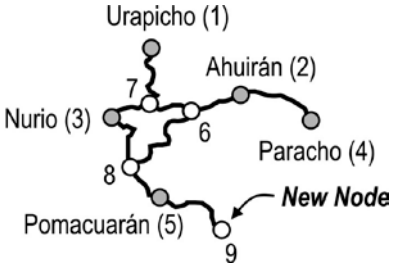
Exercise 2: Connectivity (T), 20 pts

Connectivity is a measure of the degree to which one location is connected to all other locations. We determine the connectivity of a place by reducing a transportation network to a series of nodes and edges. ***Nodes*** represent either places where roads intersect and other places of interest on the transportation network (such as towns). ***Edges*** are the links (in this case roads) that connect places (nodes). We can then use graph analysis to examine how connected places are to each other. ***Graph analysis*** is a technique in which we create a matrix of connections, where nodes that are directly connected are coded as a 1 and those not directly connected are coded as a 0, the result being a ***connectivity matrix***. By performing matrix powering on the connectivity matrix we can determine the number of steps (node to node movements) it takes to connect one node to all other nodes.

Example: First we need to examine the map and get it ready for our analysis. On the simplified map to the right there are several towns on a road system. Also notice that there are several places where the roads cross but there are no towns. We need to create a "topologically" correct map before we can begin the analysis. To do this we are going to add some nodes to those road intersections where there are no towns. We also need to add nodes to the road end points.

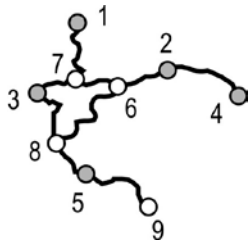


Notice that we have added 4 new nodes and numbered each of them, as well as the original 5 towns. These numbers are important, we will need them to build our matrix. Now the network is topologically correct: all nodes are numbered and there are no intersections or edge ends that do not have a node. Now we can build our connectivity matrix. Make sure to keep a list or map that shows you the number labels for the towns and new nodes!

	1	2	3	4	5	6	7	8	9
1	0								
2		0							
3			0						
4				0					
5					0				
6						0			
7							0		
8								0	
9									0

We are going to create a matrix by first counting up the number of nodes, in this example there are 9. We then create a 10x10 cell matrix using an Excel spreadsheet. There are several important things to note concerning this matrix. First, we entered the node numbers into the matrix. Second, the order is not important as long as the row and column headings are exactly the same. Finally, the diagonal is filled with zeros. Next we are going to fill in the matrix with the direct connections

	1	2	3	4	5	6	7	8	9
1	**0**								
2		**0**							
3			**0**						
4		1		**0**					
5					**0**				
6		1				**0**			
7	1		1			1	**0**		
8			1		1	1		**0**	
9					1				**0**



A connectivity matrix is an accounting of all of the ***direct*** connections on a network. So in our example Urapicho (node 1) has one direct connection, to node 7. Ahuirán (node 2) has two direct connections, one to node 6 and one to Paracho (node 4). We fill in the ***bottom half*** with all of the direct connections. Each direct connection gets a one.

The next step in the data base building process is to save the Excel spreadsheet as a comma separated file (.CSV). The process is not as easy as it sounds. First you must highlight the area that you want to save (highlight the whole matrix, including the row and column node numbers), then go to ***File > Save as*** and set the file type to .CSV. This is a text file and can be examined in Notepad. I suggest opening your .CSV file in Notepad and looking for stray commas at the bottom of the file. If there are any, delete them as they will cause problems later.

	1	2	3	4	5	6	7	8	9
1	**0**						1		
2		**0**		1		1			
3			**0**				1	1	
4		1		**0**					
5					**0**			1	1
6		1				**0**	1	1	
7	1		1			1	**0**		
8			1		1	1		**0**	
9					1				**0**

The computer will transpose the matrix (like the one above). Make sure that all of the links are accounted for or the program will issue an error. It is best to have a map so you can mark off the links that have been entered into the matrix. If the matrix is incorrect, your results will be incorrect, so it is very important to check for accuracy. One method is to sum across the rows of the matrix and then sum the resulting column. That number must be equal to the total number of ***links*** (not nodes).

	1	2	3	4	5	6	7	8	9
1	**0**	0	0	0	0	0	1	0	0
2	0	**0**	0	1	0	1	0	0	0
3	0	0	**0**	0	0	0	1	1	0
4	0	1	0	**0**	0	0	0	0	0
5	0	0	0	0	**0**	0	0	1	1
6	0	1	0	0	0	**0**	1	1	0
7	1	0	1	0	0	1	**0**	0	0
8	0	0	1	0	1	1	0	**0**	0
9	0	0	0	0	1	0	0	0	**0**

Finally the computer will fill in the empty cells with zeros to denote no direct connections (like the one to the left). This is our completed connectivity matrix, the one that will be used to determine the connectedness of each node.

Now comes the easy part… running the Connectivity program. Put a copy of your .CSV file and the program ***Network Analyzer Updated-xxxxx.R*** in a separate folder somewhere where you have write privileges (your thumb drive, a Zip disk, or C:\Geotemp). The ***Network Analyzer Updated-xxxxx.R*** program can be downloaded from the Transportation Geography webpage site

under *Exercises*. You will need to right-click on the ***Connectivity.R*** link and choose *Save Link As*… make sure to copy the program to the same location as your matrix (.CSV file).

From the Start Menu, select ***R > R2.6.0 (or the version on that computer)***. This will open the RGui and the RConsole. In the RConsole there will be a red cursor. From the ***File*** menu, first select ***Change dir…*** and navigate to the location where you have saved your matrix. Click ***Ok***. Again from the ***File*** menu select ***Source R Code…*** go to the bottom of the popup window and change the file type to ***All Files***… and then navigate to the location of the ***Network Analyzer Updated-xxxxx.R*** program. Click on the program and then ***Ok***. In the RConsole you will see enter the name of your matrix file (the program assumes that it has a .CSV extension, so you do not need to enter it) and hit Enter.

The program runs very quickly, and you will get four forms of output. The first output type is sent to the RConsole, an example of which appears below:

```
Input Matrix:  T1770          ← Name of the input matrix
Network Measurements          ← Various network measurements.
Vertices:            150
Edges:               222
Diameter:            23
Cyclomatic number:   73
Alpha:               0.00662071467440595
Beta:                1.48
Gamma:               50

CONNECTIVITY T-MATRIX RESULTS        ← The most and least connected nodes.
The least accessible node is 111 with 118661349984 connections.
The most accessible node is 114 with 103194692070728 connections.

Output files: T1770 Connectivity Results.csv        ← The results matrix.
              T1770 Network Measurements.txt        ← A text file with all of the screen output.
```

The other three output types are data files. The first is a .CSV file which can be imported into Excel. This file contains all of the connections between nodes and the total connections for each node. The R matrix output has to be edited slightly, since it adds an X to the column headings (which should be removed), and it shifts those headings to the left (they need to be shifted one cell to the right). The last row of the matrix is the column totals, which can be deleted. ***The last column is the most important***… it is the total connectivity results. It is this last column that you will need to map. The second output type is a text file containing all of the network measurements that appear in the RConsole. Save both of these files, you will be using them. The last file is a measure of link importance, and we will use that file later in the semester.

Assignment:

Using the map provided below, create a connectivity matrix. Make sure to keep a list of the town names for each node. Run the ***Network Analyzer Updated-xxxxx.R*** program on your connectivity matrix and map the total connectivity for each named town (disregard mapping the nodes you added). Use the three category legend to map the results putting approximately 1/3 of the towns into each category (Low = 14, Med = 13, High = 13). Color code the categories are

High = RED, Medium = BLUE, and Low = GREEN. Label the most and least accessible nodes (either populated or non-populated) on your results map. Color in the symbols in the appropriate manner based on your results. Make sure your map is neat and legible, poor looking maps will lose points. Hand in the following **stapled** together: your results map, your working map, the network measurements output, and a printout of the node numbers, town names, and their individual connectivity results.

Working Map


Cocucho
Urapicho
Cheranatzicurín
Cherán
La Mojonerá
San Jerónimo
Santa Fé
Ahuirán
San Andrés
Charapán
Nahuatzen
San Isidro
Quiroga
Nurio
Aranza
San Felipe
Sevina
Puácuaro
Paracho
Tzintzuntzan
Arantepacua
Corupo
Pomacuarán
Erongarícuaro
Quincéo
Ihuatzio
Pichátaro
Jarácuaro
Uricho
Turícuaro
Comachuén
Zurumutaro
Angahuán
San Lorenzo
Capácuaro
Ajuno
Tingambato
San Juan
Pátzcuaro
Uruapan

Name: _____

Ex. 3: Connectivity Results