# Determination of an Optimal Bike Path Based on Slope & Distance Data

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## 1. Introduction

Many people bike in areas close to campus. Many of these are student who live nearby and use bikes as a quick and cheap method for travel in the otherwise cluttered campus areas. Hills in Austin can be a tenacious annoyance, providing more arduous journeys than in Houston, per se, where Qal is the topmost geologic layer for the city's full expanse and hills are not seen. The significance of this is compounded since single-speed fixed-gear street-bikes have come into vogue in recent years. These bicycles don't provide the extra assistance for traversing hills as other bicycles with multiple speeds would. Many bikers try to determine the best routes which avoid hills. The author finds himself in search of the optimal biking routes as well. One trip frequently made is between Bellevue Pl. and Harris Park Rd. (the abode of the author) and Genard St. and Leralynn St. (the abode of a very close friend).

## 2. Question

The purpose of this project is to determine the most optimal route from the abode of the author to that of the close friend. This must take into account not only a minimized distance, but a minimized slope as well.

## 3. Method

The only data needed are a DEM of the central Austin area and a shapefile consisting of streets. Using the DEM, a slope raster is generated which will give a higher number for a higher slope. An aspect raster is also generated, and then used to produce a new raster with the slope

raster which will account for slope in direction of movement. Next, this is combined with a rasterized version of the streets shapefile. The result is a slope raster which only contains data for cells in roadways. It will be used as a cost surface.

This cost surface can be fed into the 'Cost Distance' and 'Cost Backlink' tools. These tools are needed to use the final tool, the 'Cost Path' tool. This tool will produce a raster displaying the path which has the least accumulative cost associated with south-facing slope and distance.

## 4. Data Collection & Preprocessing

The DEM dataset was collected from the USGS National Map Seamless Server Viewer. While the DEM "cut out" did require the area between the two points, the size of the DEM was much larger and included much of central Austin. The associated metadata was used for datum/projection data solely. The file was unzipped using windows and extracted into a folder within the project's folder. The URL for the DEM is:

http://seamless.usgs.gov/website/seamless/viewer.htm

The City of Austin GIS Data Sets webpage was used to download 'Street Centerlines' and the associated metadata. The metadata was not used in this project and was not needed expect for basic datum/projection data. If the problem was able to be solved by 'Network Analyst', the metadata could have been used to create step-by-step directions for the biker. Again, the file was unzipped using windows and extracted into a folder within the project's folder. The URL for the centerlines & metadata is:

ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/transportation/STREETS.zip

## 5. Data Processing

Within the project's folder use ArcCatalog to create a new personal geodatabase called "Bike_Austin". Import the unzipped street shapefile as a feature class. Define the following feature classes (New > Feature Class):

- "Boundary", which stores polygons,
- "Destination", which stores points, and
- "Starting_Point", which stores points

Make sure all feature classes utilize UTM 14N for special reference and WGS 1984 for vertical reference. Also alter the DEM to reflect the same special reference.

Open a blank ArcMap document. Add the contents of the "Bike_Austin" geodatabase to the TOC. Also add the saved DEM to the TOC. Afterwards, change the data frame's coordinate system to reflect the feature classes. In the 'General' tab, change units to meters.

First the data had to be clipped. As the boundry class is already in the TOC, draw a box just inside the borders of the DEM. The symbology is specified as 'Hollow' and purple was chosen.
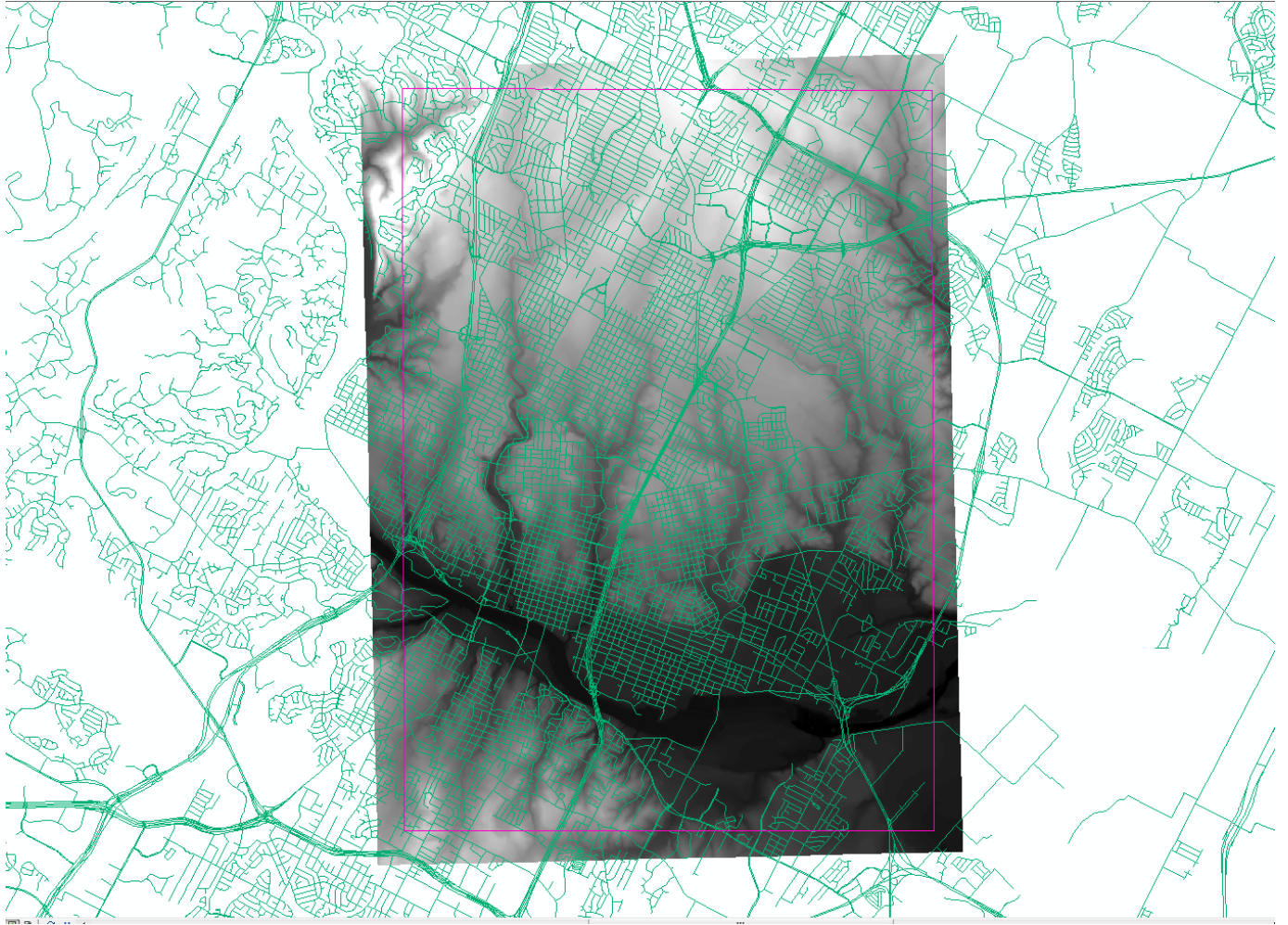
The boundary should match:

**Figure 1: Placement of the Boundary for Clipping**

Clip both the raster and the street shapefile to the bounding. For the shape file, use 'Clip' under Analysis > Extent. For the DEM, use 'Extract by Polygon'. This will give us a nice clean set of data to work with that will not slow down the processing to a great extent. Many rasters will be generated at this size. The result should reflect this:
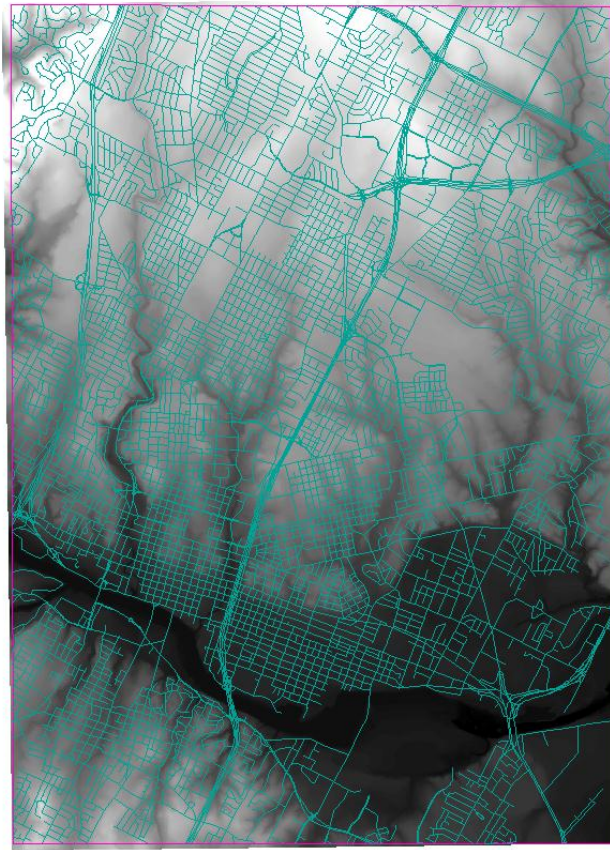
**Figure 2: Clipped streets and DEM**

 Uncheck the boundary layer and the other two unclipped layers, so that only the clipped street layer and the DEM are shown. These can be removed from the TOC to avoid clutter.

 Change the DEM symbology to precipitation and check the inverse box. This display symbology will be used exclusively when changing the symbology of a raster.

Now we will create point features for the starting and ending location. Turn on editing and select the 'Destination' feature class to edit. Uncheck the DEM and turn on snapping. Place the destination at the intersection of Leralyn St. and Genard St. Use Google maps to find the location. In a similar manner, create a point for 'Starting_Point" raster at Bellevue Pl. Harris Park Rd. This is where the trail will run.

Next, we must create a cost surface raster. This is no quick task. To do this, we will combine the DEM raster with the streets dataset. To do this, go to tools and under 'Conversion' select the 'Feature to Raster'

tool.  Use this to create a new raster. Select the field to be road_class, though this will be arbitrary. The raster will resemble a road but will have some different colors. We want all the values to be '1'.

Open the Raster Calculator and input the new raster. We want to make a '1' for every value and leave everything else as 'no data'. This is the calculator:
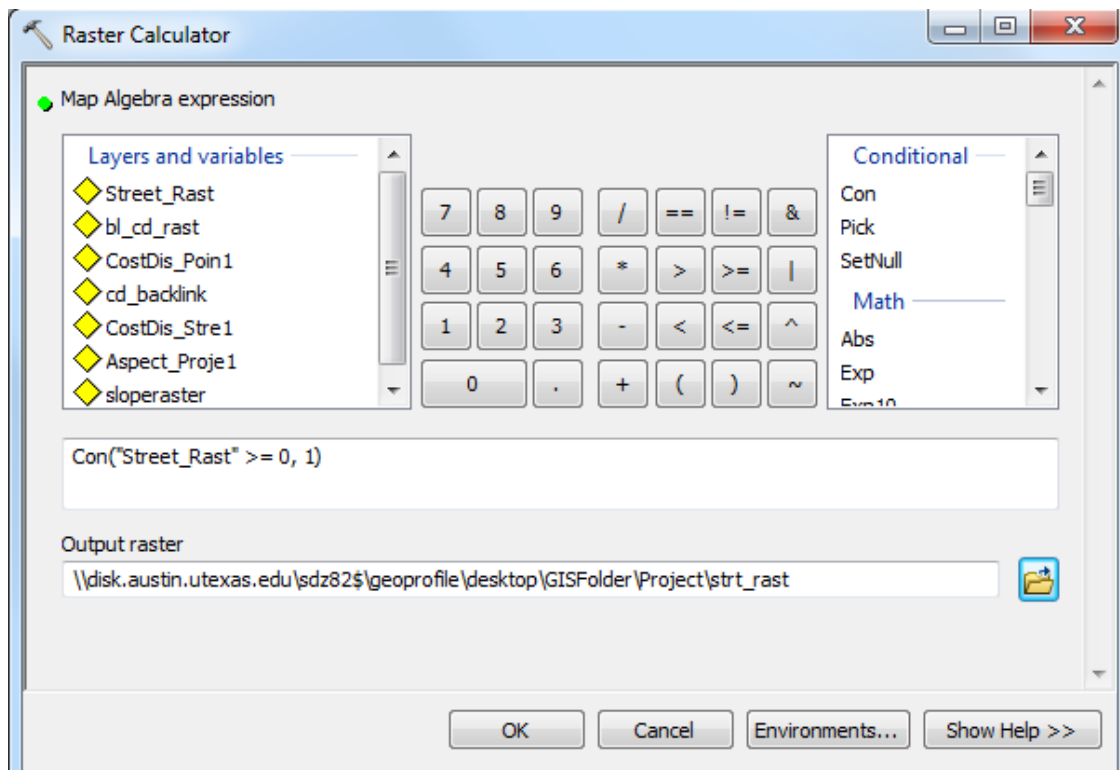


**Figure 3: Showing Raster Calculator Input**

The output should look like this (with the starting and ending locations displayed):

**Figure 4: Streets Raster with 'Starting_Point' and 'Destination'.**

We now have the streets portion of our cost surface. Now we must overlay slope information.

Next, a raster displaying slope will be generated from the DEM. This will give us a higher number for more intense slope and a lower number for more flat areas. Go to spatial analysis > Surface > Slope, Enter the DEM used into the input raster, change the output raster to a desired name, and specify degrees instead of percent change.

After generating the raster, change the symbology to 'stretched' and the color ramp to 'precipitation'. Check the inverse box. Click OK. The results should mirror this:
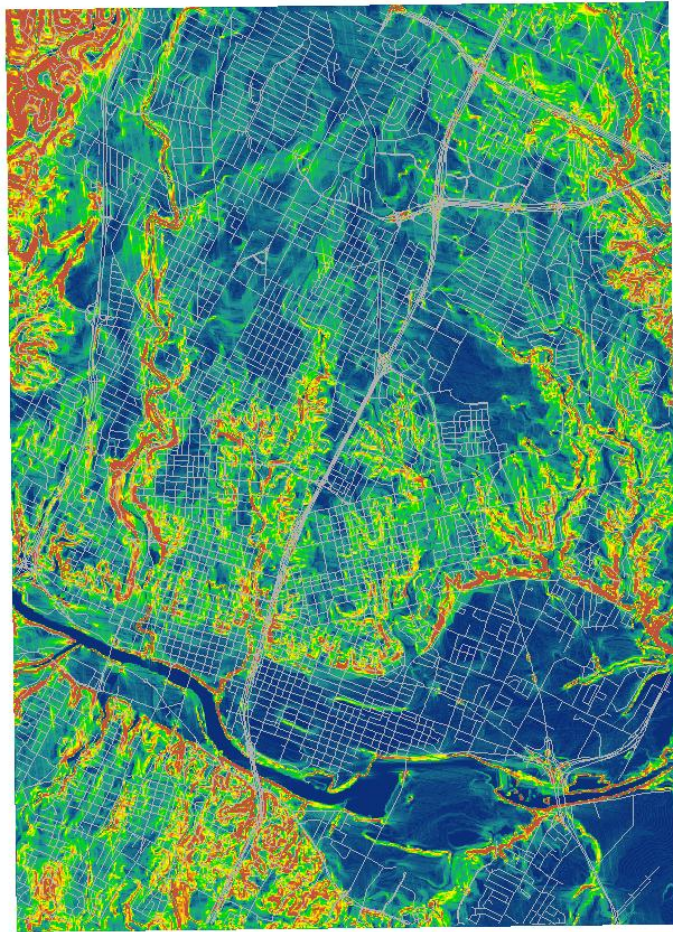
**Figure 5: Raster Displaying Slope Data**

This data isn't useful to us yet. The slope raster by itself does not take into account whether you are biking uphill or downhill. In order to take into account directionality of travel with slope, we will combine aspect information with the slope raster generated above. To generate an aspect raster, simply use the Aspect tool. As an input, use the clipped DEM. Select a desired file-name. Output should look like this:
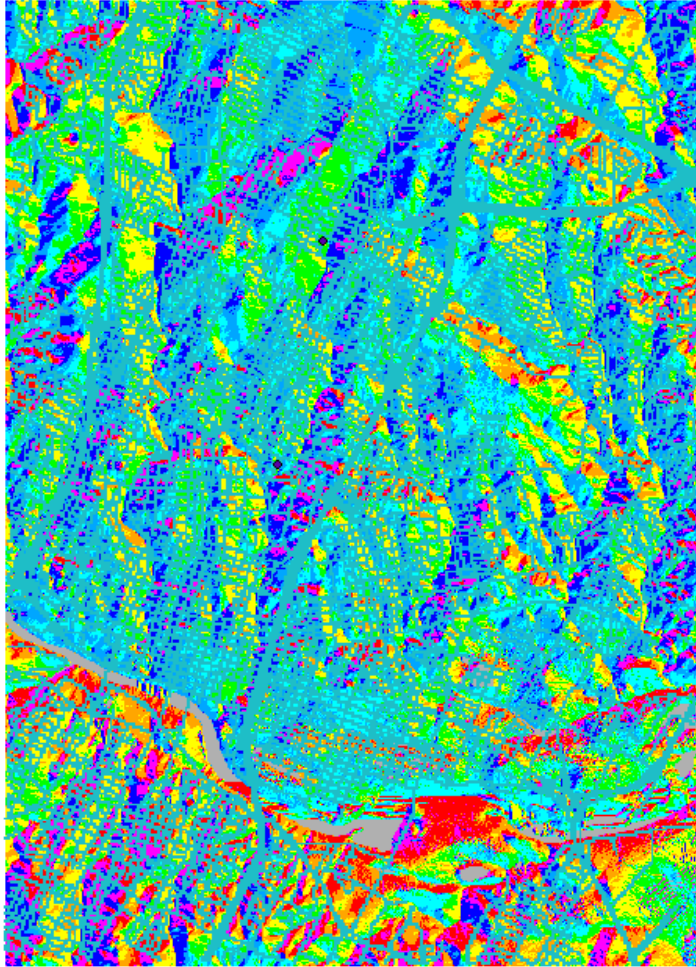
**Figure 6: Aspect Raster**

We now need to decide how we are using this aspect data. We will be travelling from South to North, so we will use the raster calculator to give weights to each of the 8 directions:
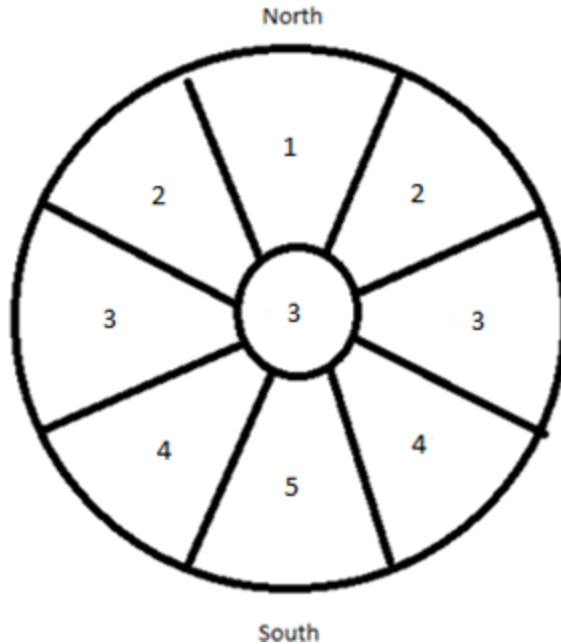
**Figure 7: Values used for the 8 Directions and 'Flat'**

In order to implement this system, the raster calculator will be used again to implement directional weights for the slope raster. With the raster calculator, create a new raster with these values. Use this input:

Con("Aspect_Rast" < 0, 3, Con("Aspect_Rast " <= 22.5, 1, Con("Aspect_Rast " <= 67.5, 2, Con("Aspect_Rast " <= 112.5, 3, Con("Aspect_Rast " <= 157.5, 4, Con("Aspect_Rast " <= 202.5, 5, Con("Aspect_Rast " <= 247.5, 4, Con("Aspect_Rast " <= 292.5, 3, Con("Aspect_Rast " <= 337.5, 2, Con("Aspect_Rast " <= 360, 1))))))))))

Where "Aspect_Rast" is the generated aspect raster.

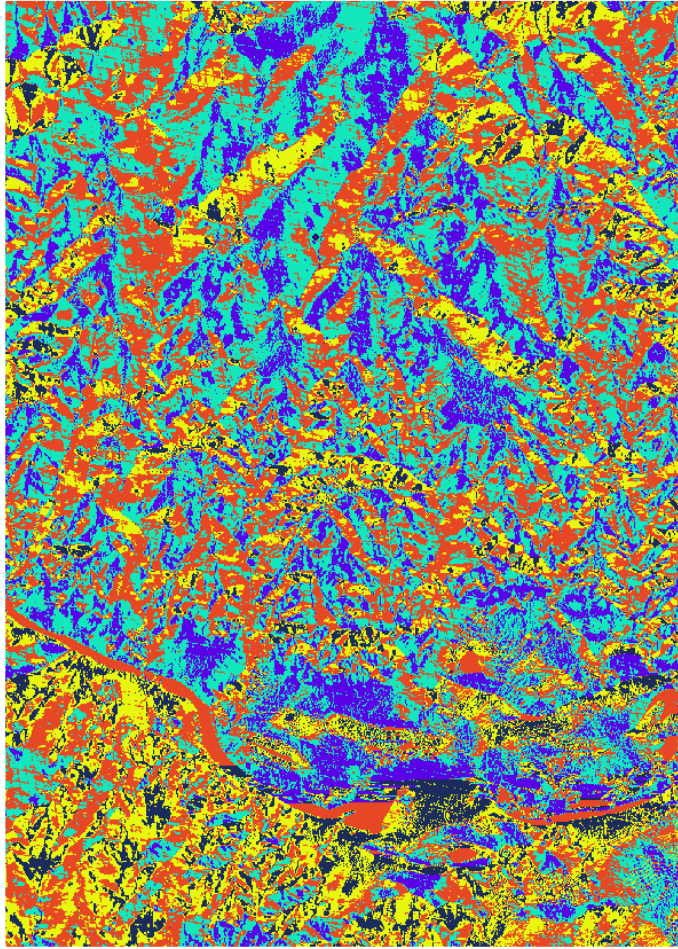The new raster will resemble this (without other layers):

**Figure 8: The Adjusted Aspect Raster**

With this new raster, we can use the 'Raster Calculator' again to multiply the values with the slope raster generated previously. The resultant raster will exhibit slope areas in the northerly direction with a different color than the southerly direction. Open the 'Raster Calculator', for input, simply multiply the newly generated aspect raster with the slope raster.

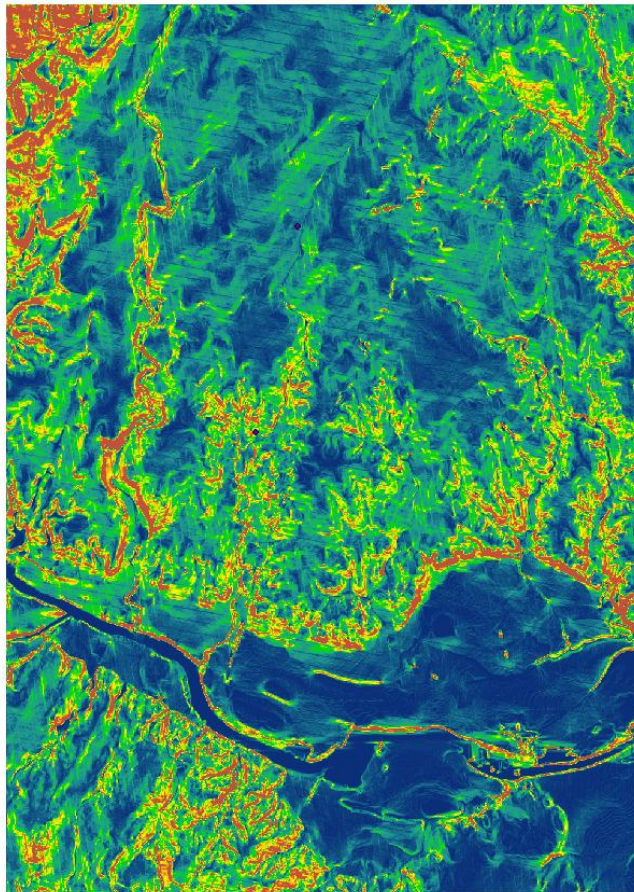The resulting slope-aspect raster should look like this (with specified symbology):

**Figure 9: The Slope-Aspect Raster**

Now, all the area outside of roads must be given 'no data' so the program does not try to use cells outside

roads to create the path. To do this we will use the 'Raster Calculator' again. This time, the street raster

will be multiplied with the newly generated slope-aspect raster. Areas of 'no data' on the street raster will

also be 'no data' on the resultant raster. For input, simply multiply the streets raster generated from the

shapefile with the new slope-aspect raster.

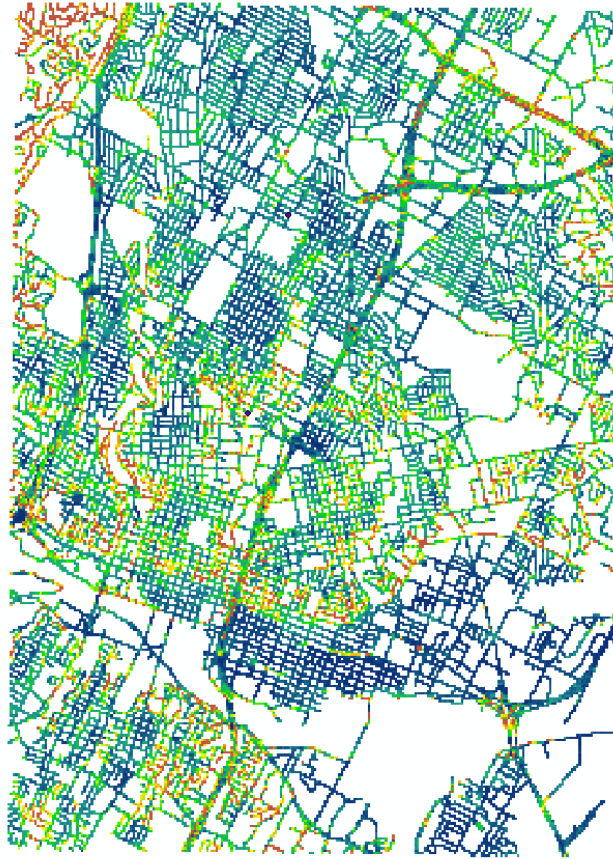The results should resemble this (with appropriate symbology):

**Figure 10: The Cost Surface Raster**

This gives us a visual representation of where it will be easy to ride northwards (blue) and where it will be more difficult (red). This is essentially our **cost surface** raster to be used in the 'Cost Distance' tool.

Open the 'Cost Distance' tool, for 'feature source data' enter the 'Destination' point feature class created above. For the cost raster, input our new cost surface raster. Choose a desired file name and address for the output distance and output backlink rasters. These will be used for the final 'Cost Path' tool. Overlaid, they should look like this (including the starting and ending point with an altered symbology):
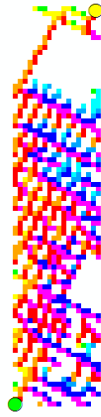
**Figure 11: The Cost Distance and Cost Backlink Rasters Overlaid**

Now, we have reached the last step. The 'Cost Path' tool with generate an actual path from our

'Starting_Point' to our 'Destination' Open the 'Cost Path' tool. For the first field, add the 'Starting_Point'

feature class. Input the Cost Distance and Cost Backlink rasters generated in the last step as well.

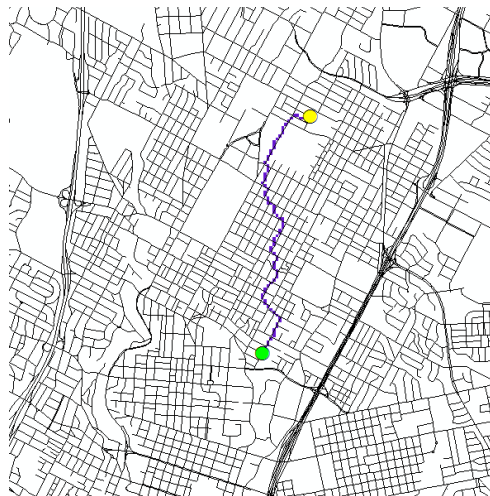The resulting raster, on top of the original clipped street layer should look like this:



**Figure 12: Cost Path with Streets**

Though the streets to take on the route are clear, the raster line is fuzzy and does not usually go through intersections. In order to fix this, it must be converted to a polyline and then edited to fit on streets. Open the 'Raster to Polyline' tool. Input the 'Cost Path' raster for the input and select a file name and address.

After loading the new route polyline, change symbology to "Highway" and turn on editing for that layer. Move the vertices of the polyline to fit the intersections of the street.

Afterwards, turn on labels for the street names and choose a symbology scheme for the roads in order to tell the difference between major and neighborhood roads. This will give us reference when viewing the map.

## 6. Conclusion

The author is satisfied with the product. Some aspects of the path defined are routes already known to be effective, while others suggested by the program represent areas which the author never thought to travel down, or didn't have time to explore. The result is different from the result gained from only doing a distance measurement. This other distance measurement was carried out using network analysis and was not explained in this write-up.

# Optimized Slope-Distance Bike Path from Bellevue Pl. and Harris Park Rd. to Genard St. and Leralyn St.



**End**

**Start**

**N**

| 0 | 0.25 | 0.5 | | 1 |
Miles

1 inch = 1,683 feet

## Legend

— Route
— Minor Roads
— Major Roads