Highway Planning Using Raster Data
Designing a Bypass for Hastings, Minnesota

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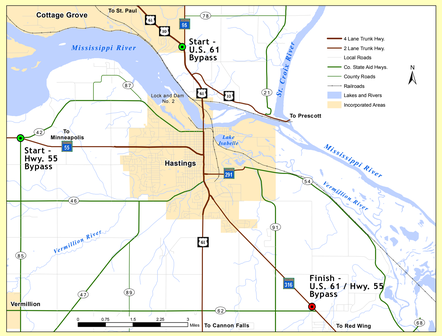
Background

The primary purpose of this study was to use raster data to determine the least-cost path for the design of a highway bypass for the city of Hastings on the southeastern edge of the Twin Cities Metro Area. Hastings is the meeting place of the primary highways linking the Twin Cities with towns along the Mississippi River in southeastern Minnesota, including Red Wing and Winona. Currently, the trunk highways entering Hastings (US Hwy. 61, plus State Hwys. 55 and 316) converge on Vermillion Street, Hastings's de-facto "main drag". Congestion during peak usage hours and multiple stoplights create major barriers to through traffic.

Vermillion Street in Hastings, looking south

Study Area:
Existing Trunk Hwys. at Hastings



Analysis Steps

Least-Cost Path Analysis was used to determine the alignment of possible highway bypasses for Hastings using the Spatial Analyst extension to ArcGIS. The steps in this analysis were as follows:

1: Reclassify selected raster data to a common subjective scale representing the "cost" of construction a highway through each raster cell.

2: Using map algebra, create a total cost raster for the study area by adding the cost of each data set together.

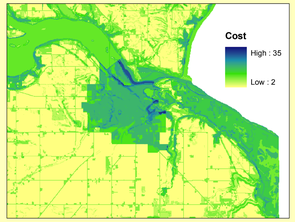
3: Create Cost-Weighted distance and direction rasters from a common end-point for the highway bypasses.

4: Create a least-cost path from the endpoint to selected start points for each bypass, using the cost-weighted distance and direction rasters from the previous step.

Creating the Cost Raster

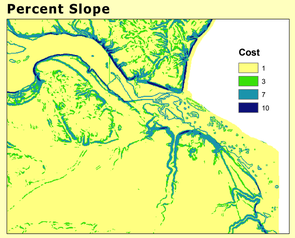
All data used for the analysis had a 30 meter resolution, and were reclassified with a common cost scale of 1 to 10, with 10 representing the greatest construction cost. In this case, the term "cost" is a subjective one, since it incorporates not only actual monetary costs, but also certain value judgments.

Total Cost Raster



After the data was reclassified using a common cost scale, the costs were added together to create the total cost raster for the least-cost path analysis. Note the high cost values clustered around the areas of high relief and open water in and around the Mississippi River, plus the sudden jump of costs in and around the city of Hastings. See below for the component parts of the total cost from each data set used in the analysis.

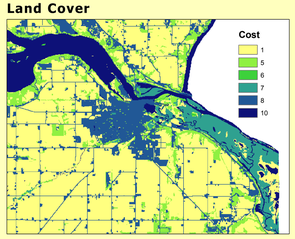
Percent Slope



Percent slope was derived from a USGS 30-meter resolution Digital Elevation Model (DEM). MNDOT construction standards give a 5% grade as the max. for a 70 mph hwy.

Slope: 0-5%, Cost: 1
Slope: 5-8%, Cost: 3
Slope: 8-25%, Cost: 7
Slope: 25-75%, Cost: 10

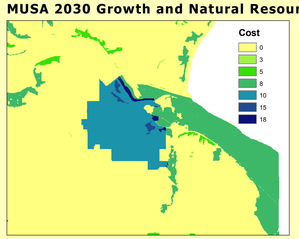
Land Cover



Twin Cities Metro Hybrid Land Cover, created by the DNR from the U of M 2000 Landsat land cover data by adding data from other sources (wetlands, roads, etc).

Cost Values:
1: Agricultural, grassland, shrubland, emergent veg.
5: Forests
6: Wetland Shrubs
7: Wetland Forest, Mudflats
8: Impervious (developed)
10: Open Water

MUSA 2030 Growth and Natural Resource Areas



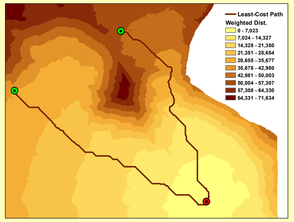
MUSA 2030 blueprint growth areas represent areas slated for development. The 2030 framework natural resource areas are rated on a three value scale. The map at left shows these values combined.

Cost Values:
MUSA 2030 Growth Area: 10
MUSA Nat. Resource Areas:
8: Outstanding
5: Excellent
3: Moderate

Least-Cost Path Analysis

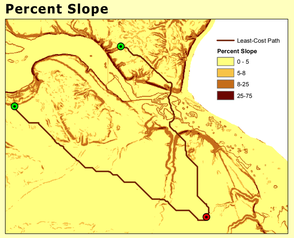
Once the cost raster was created, the end points of the proposed bypasses were used to create cost weighted distance and direction rasters that were then used to find the least-cost path for the proposed bypasses. In the four images below the resulting paths are shown overlayed on the source data used to create the cost raster for comparison and analysis.

Cost Weighted Distance



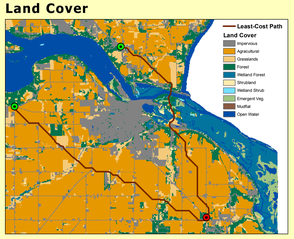
At left is the cost-weighted distance data created for the analysis. Notice how the results follow the paths of least resistance.

Percent Slope



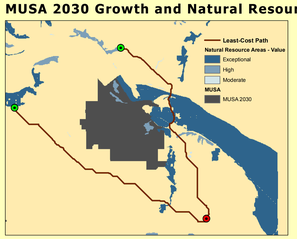
The resulting paths still pass through areas of high slope, but always avoid the highest slope cost category (25-75%). The south bypass follows no obvious features due to the relative flatness of the areas to the south and west of Hastings. The east bypass on the other hand had to navigate through the Mississippi River valley.

Land Cover



The land cover data seemed to be a major factor in the choice of the path for the east (US 61) bypass. It follows a path through the lowlands near the Mississippi River that takes it through a corridor of emergent vegetation, avoiding the areas of forest and wetlands to either side. The south bypass seems to try to avoid wider areas of impervious land cover along the roads to the south of Hastings.

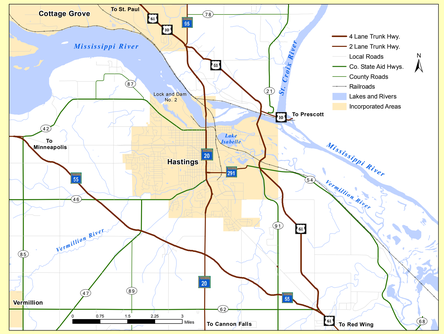
MUSA 2030 Growth and Natural Resource Areas



The east bypass avoided the natural resource area in the valley to the southeast of Hastings, and instead picked an area of the "exceptional" natural resource area that featured a few gaps and incongruities. Both resulting paths avoid the MUSA 2030 area entirely.

Results and Conclusions

Study Area:
Proposed Trunk Hwys. at Hastings



Above is a map showing the proposed Hastings bypass integrated into the trunk highway network. State Highway 20 has been extended north to take over on US 61's old route. State Highway 55's old route has been turned back to the city of Hastings. To create the features representing the proposed bypass, a great deal of simplification had to be done, including easing curves, and straightening small unnecessary jogs and errata. This seems to point out the limitations of this kind of analysis for actual highway planning.

The analysis can give a general idea of where the proposed highway should run, but more specific knowledge of highway engineering is still needed to actually design the road. The raw least-cost paths from the analysis, while instructive, could not represent the final alignments of the future trunk highways. Other important factors and design standards used in the actual engineering of highways could not be taken into account using the tools provided by spatial analyst, such as horizontal design standards, line of sight, intersection and interchange design, etc. Instead, the least-cost path analysis could be used as a starting point to guide right-of-way decision making. The areas avoided by the least-cost path can be as or more instructive than the areas chosen. They can highlight factors that due to the realities of highway engineering will need to be dealt with.

Sources and Contact Info

Data Sources:

Minnesota DNR Data Deli
http://deli.dnr.state.mn.us/

Metro GIS Datafinder:
http://www.datafinder.org/

Minnesota Department of Transportation, Transportation Data & Analysis Basemap
http://www.dot.state.mn.us/tda/basemap/index.html

Information Sources:

Brad Dragan, Scott Plenderleith, and Kyle Waldner. "Assessing the Impacts of Three Possible Highways Routes Between Kitchener and Guelph Using a GIS Based Model
http://www.geography.uoguelph.ca/research/geog4480_w2005/Group12/index.htm

West, James R. "Improving Highway Planning with the Help of GIS"
http://gis2.esri.com/library/userconf/proc99/proceed/papers/pap320/p320.htm

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