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Transportation Planning for Floods - Phase I

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MATC

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16. Abstract
In the first year of this project, our team was able to develop a good understanding of how floods impact travel times and roads in Iowa. The analysis allows us to understand what areas will be more or less accessible after floods, which can help in making decisions for establishing evacuation centers and routing people outside the flood zone. We developed cyber tools and interfaces to recommend new routes in a flooding situation and used this tool to understand the impact of floods.

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Mid-America Transportation Center (MATC)
Nebraska Transportation Center (NTC)
Iowa Flood Center (IFC)

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Disclaimer

Abstract

In the first year of this project, our team was able to develop a good understanding of how floods impact travel times and roads in Iowa. The analysis allows us to understand what areas will be more or less accessible after floods, which can help in making decisions for establishing evacuation centers and routing people outside the flood zone. We developed cyber tools and interfaces to recommend new routes in a flooding situation and used this tool to understand the impact of floods.

Chapter 1 Creating Tools to Understand How Floods Impact the Use of Roads

In the first phase of our research, we worked to connect the flood maps developed by the Iowa Flood Center (IFC) with existing road maps. This helps us understand which roads would not be usable after a flood. We then developed a tool to find paths on these maps to understand how transportation between locations changes after a flood.

1.1 Combining Flood Maps and Road Maps

The Iowa Flood Center at the University of Iowa has established maps that represent the areas within counties in Iowa that would be flooded if different levels of floods occurred. These flood maps are based on combining the results of many different potential river flooding scenarios. Maps that are created, for example, are 100-year flood maps (maps reflecting events that have a 1% chance of occurring in a year) or 500-year flood maps (maps reflecting events that have a .02% chance of occurring in a year). Visuals of these maps are available on the Iowa Flood Information Website at http://ifis.iowafloodcenter.org. We selected Johnson County, Iowa as the example for our tests.

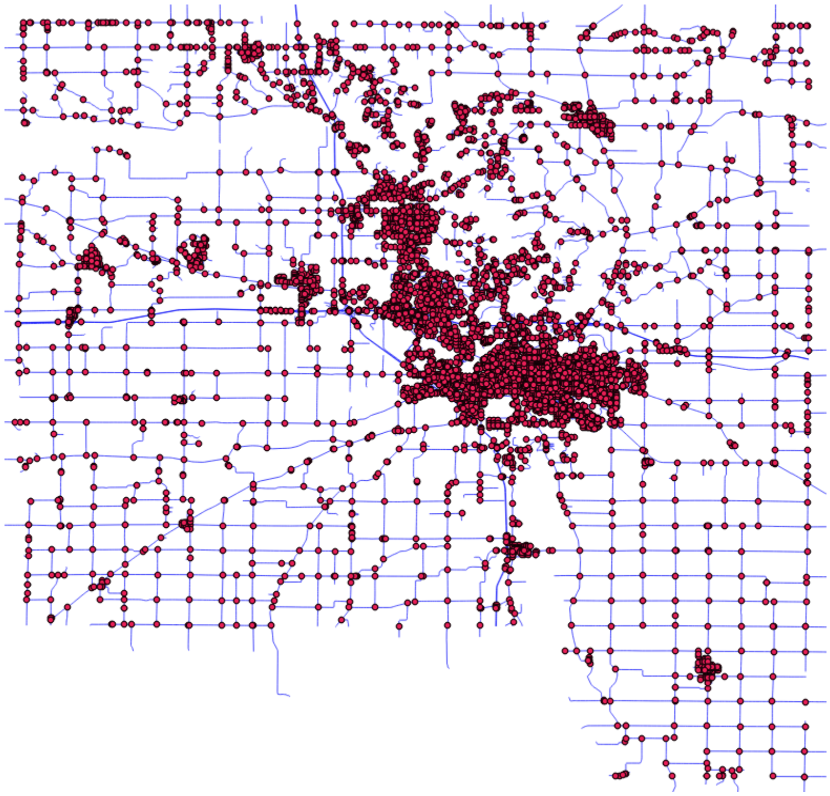

Figure 1.1 Road network nodes and segments

We next obtained publicly available road data (fig. 1.1) that contained information about the location of each road, designated speed, and the classification of the different road types. We combined the two data sources with the software QGIS so we could understand where the roads intersected the floods. See figure 1.2 for the combined map of Johnson County. We made the assumption roads that would be covered with water (as indicated by the flood map) would not be usable after the flood. With that assumption, we removed the road segments that intersect the flood map to create the "after flood" road network.

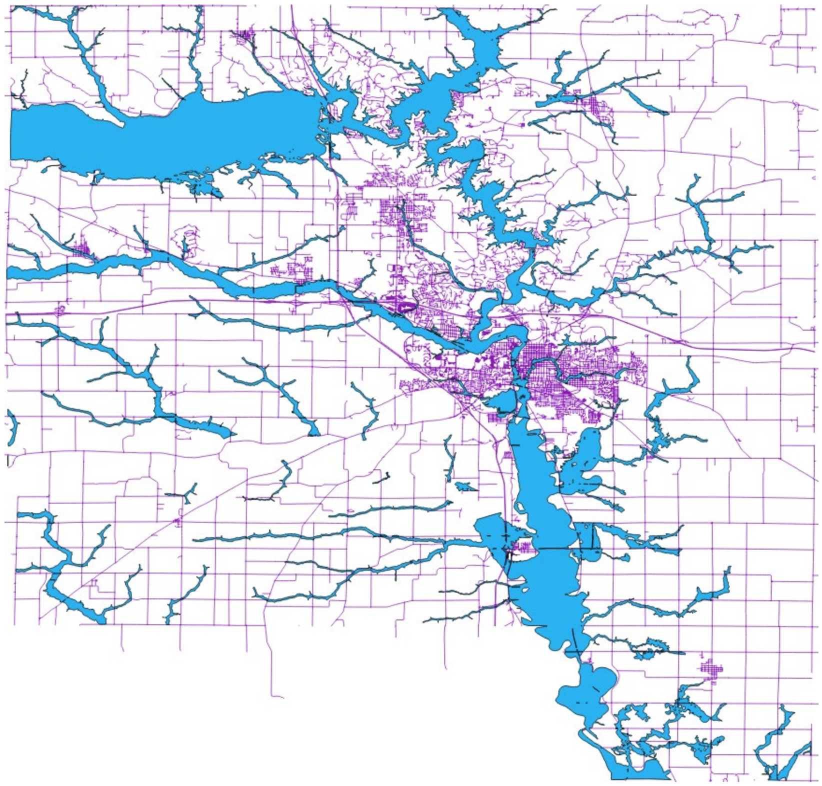

Figure 1.2 Merged flood and road map for Johnson County, Iowa

1.2 Analyzing the Changes in Road Networks

With the “after flood” network, we can analyze which roads are impacted by the floods. We also want to understand how the change in availability of roads changes how travel occurs between locations in the county. Thus, we examine how the best path between locations in the county changes from the “before” and the “after flood” network. We can see how it alters the types of roads used, the average distance, and average travel time between locations. This requires implementation of software to find the best path (in terms of travel time) in the road network as well as a system for deciding which origin and destination pairs in the county we want to use in our tests. Dijkstra’s algorithm is a well-known exact algorithm for finding the shortest path (here in terms of travel time) between two locations. But Dijkstra’s algorithm can be implemented in many ways, and the different choices can have a big impact on the run time. We did several experiments and improvements in our implementation so that the best path can be identified almost instantly. An example of a path found by our final implementation on a "before flood" graph is found in figure 1.3.

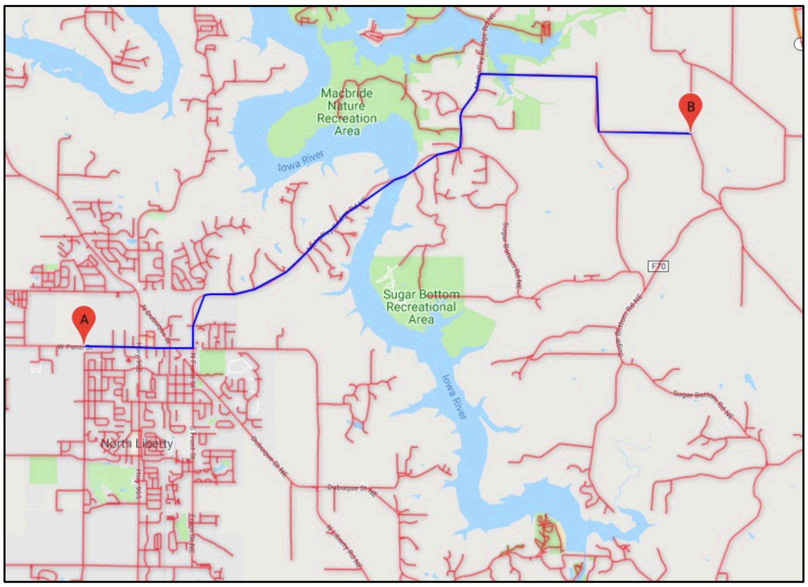

Figure 1.3 Interactive path finding tool

Once we had created this tool, we identified 10,000 pairs of locations and identified the best path between these pairs in the "before" and "after flood" road network. We observed the change in the type of roads used in figure 1.4 and the impact on travel time and distance in figure 1.5.

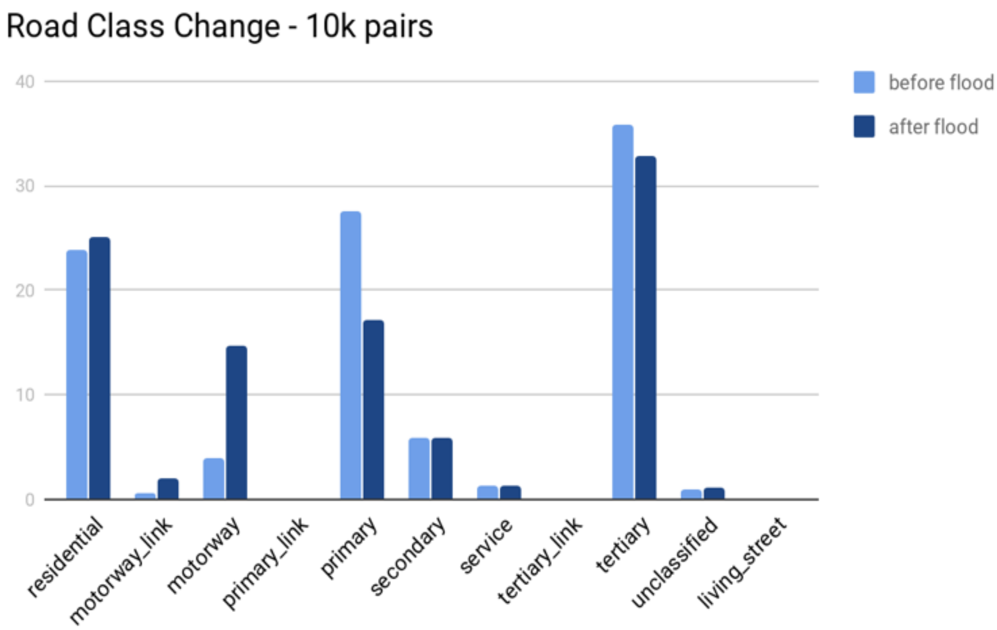

Figure 1.4 Analysis of Road Change

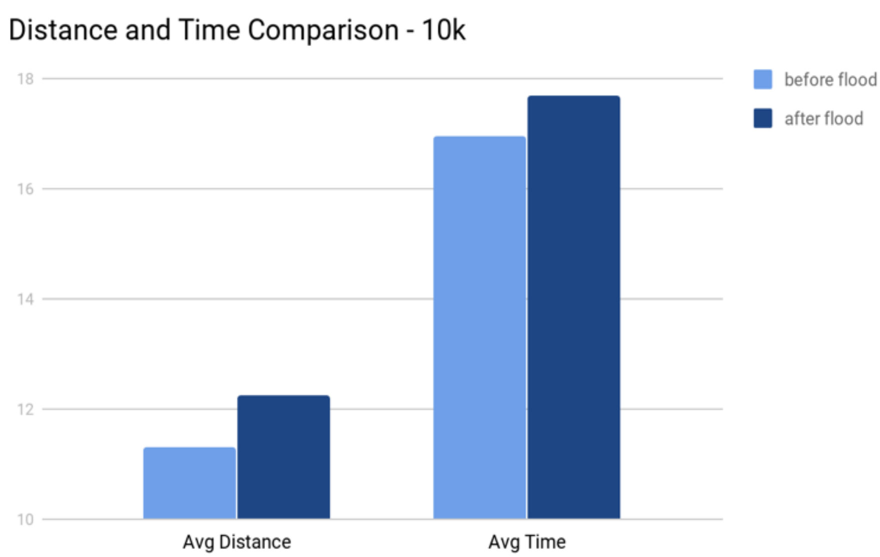

Figure 1.5 Analysis of Change in Travel Time and Distance

Chapter 2 Building on our Analysis

Once we had the results from our initial analysis, our second phase was to develop ideas of how these results could best be used in making planning decisions.

2.1 Heat Maps

Even though it is obvious when looking at an "after flood" map which locations are flooded, it is not so obvious to tell which locations require more time to reach. This is due to the roads available in the road network and revealed by the computed paths in the "after flood" graphs. How to convey this to a decision maker to decide on locations that are accessible for many is a challenging question. We experimented with the use of heat maps (fig. 2.1) where the color would reflect a measure of the accessibility of a given location after a potential flood. We experimented with several different accessibility measures and developed several different types of heat maps.

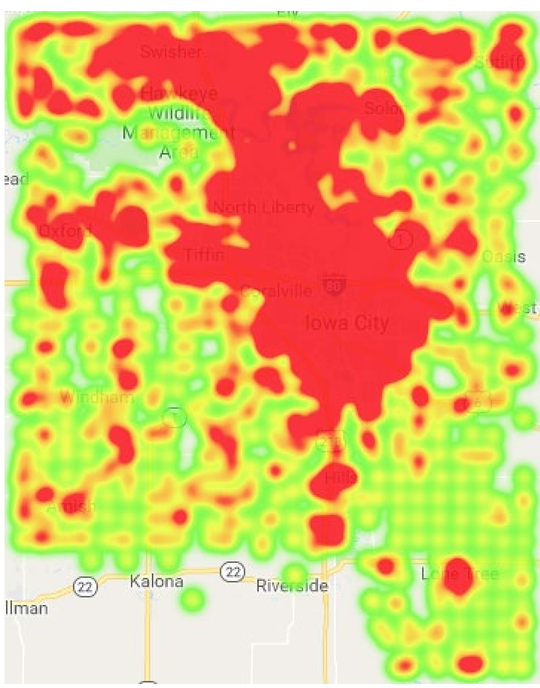

Figure 2.1 Heat map representation of the accessibility of the road network

2.2 Location Decisions

One use of this accessibility measure and heat maps is to help decision makers make location decisions for facilities that may be needed after a flood. This may include evacuation shelters or storage facilities for emergency supplies. To understand how to best use the accessibility measure in this way, research in this direction first involved a literature review of papers focused on locating emergency facilities. We found that few papers (1-3) focused on location decisions for flooding and none looked at the anticipated impact on the road network. Year 2 of the project is currently focused on modeling and solving these problems.

Figure 2.2 Web application for optimized routing algorithm for large road networks

2.3 Web Systems

We developed a web-based data analytics system that allows to visualize the road network and flooding on the map. The web platform provides interactive interfaces to visualize routing between selected points (fig. 2.2) before and after flooding and visualizes the accessibility of the regions in Johnson County using heat maps. The routing algorithm is optimized to run on the client-side to reduce the load on server-side processing of the data for host organization. The system can be used to evaluate the flood conditions and impact of road network and evacuation. It can help decision makers to interact with the road network and enable/disable road segments in the network before rerunning the analysis to understand the impact of road closures due to flooding.

References

1. de la Torre, L. E., Dolinskaya, I. S., & Smilowitz, K. R. (2012). Disaster relief routing: Integrating research and practice. Socio-Economic Planning Sciences, 46(1), 88–97.
2. Özdamar, L., & Demir, O. (2012). A hierarchical clustering and routing procedure for large scale disaster relief logistics planning. Transportation Research Part E: Logistics and Transportation Review, 48(3), 591–602.
3. Li, X., Zhao, Z., Zhu, X., & Wyatt, T. (2011). Covering models and optimization techniques for emergency response facility location and planning: a review. Mathematical Methods of Operations Research, 74(3), 281–310.