Optimizing the Evacuation for Eau Claire County, Phase III

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Introduction

In the event of a natural disaster or other related emergency, it is crucial for a city to properly and efficiently evacuate its citizens. Therefore, we have created a mathematical model that utilizes optimization techniques from Operations Research that was seamlessly integrated into ArcGIS, a Geographic Information System suite. Using Python, we created a script for ArcGIS that executes the evacuation process and Simplex Method algorithms. Specifically, the emergency management officers of the City of Eau Claire can obtain the optimal routes and times for an intended region that they may need to evacuate

The University of Wisconsin-Eau Claire's Math Department has been creating evacuation and optimization plans for the past five years and have had many novel results, such as:

- Dane County: Sandbag Distribution
- Clark County: Evacuation of Owen City
- Eau Claire: Luther Midelfort Hospital
- Eau Claire: Evacuation of Eau Claire City

City of Eau Claire, WI

This map of Eau Claire, WI shows the separate Traffic Analysis Zones (TAZ's) in which the city is divided. Each TAZ represents a district (or demand point) that could potentially be evacuated.

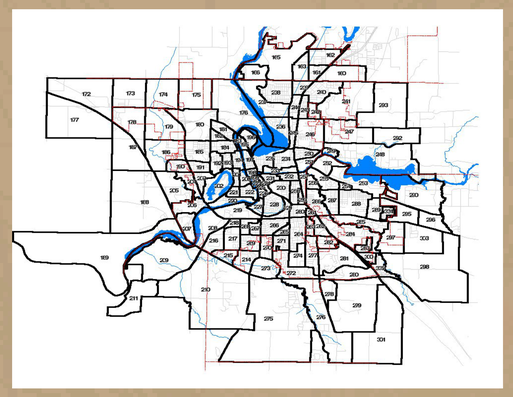

Figure 1: Map of Eau Claire, WI

City Information and Python Script

By implementing techniques from Graph Theory and Operations Research, we wrote a Python script for ArcGIS that executes the multi-step process shown in the figure to the right.

Eau Claire Information
- 237 TAZ's (Traffic Analysis Zones)
- 117,654 people in Eau Claire and surrounding area
- 26 city transit buses
- 28 business-owned buses
- Taxi services and other passenger services

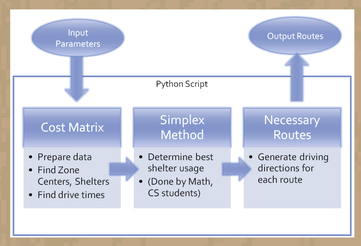

Figure 2: Diagram of program's process

Mathematical Model

Our coefficients, C_{ij}, in the objective function are calculated based upon

- s_H = Number of households
- s_B = Number of buses
- t_B = Time to load the bus
- t_S = Time to the shelter

The formula for C_{ij} is then given as

$$C_{ij} = \frac{s_H t_B + t_S}{s_H s_B}$$

We then have the following objective function:

$$\min Z = \sum_{j=1}^{m} \sum_{i=1}^{n} C_{ij} X_{ij}$$

This equation is subject to the following constraints:

$$\sum_{i=1}^{n} X_{ij} \leq A_j \quad \text{and} \quad \sum_{j=1}^{m} X_{ij} \geq B_i$$

- X_{ij} = the number of households evacuated from area i to shelter j
- C_{ij} = our calculated coefficient
- A_j = capacity of shelter j
- B_i = number of households in area i

Python Script and ArcGIS

A Python script is used to eliminate contaminated shelters as well as zone centers that do not need evacuation. Next, an OD Cost Matrix is generated to find the time it takes to drive from every source (zone center) to every destination (shelter). This process is crucial for generating the data used by the mathematical model. However, the actual roads to be used for a route are not known until after the math model is run. At that point, only the necessary routes are generated and returned as output from the program.

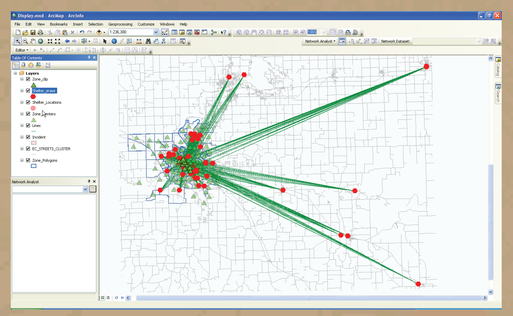

Figure 3: Screenshot of Cost Matrix Map

Input Script

During this phase of the project, we improved on the data input process. A feature dataset, used in ArcGIS, is the primary piece of data used and should contain such necessary features as shelter locations and zone centers. However, the user may choose to add or substitute different pieces of data, such as:

- Shelter locations
- Zone centers
- Travel speed changes
- System troubleshooting log

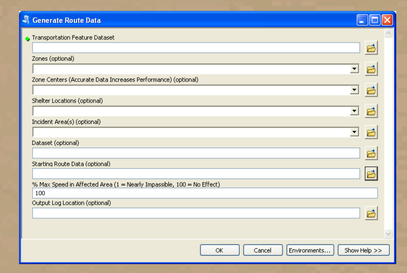

Figure 4: Screenshot of input script

References

[1] M. Phillipson and S. Tong, "Shortest paths and optimal solutions for evacuation in emergency situation," *Abstracts, AMS*, vol. 29, no. 1, 2008.
[2] W. L. Winston, *Operations Research: Applications and Algorithms*. International Thomson Publishing, 3rd ed., 1994.
[3] M. Bauer and R. Yohnk, "Optimizing the evacuation for the city of eau claire, wi," *UWEC Research Day*, 2010.
[4] M. Phillipson and T. Smeltzer, "Evacuation models for emergency situations phase 3," *Joint Mathematics Meeting Student Poster Session*, 2008.

Acknowledgements

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