Optimizing the Evacuation for the City of Eau Claire, WI

Mark Bauer and Ryan Yohnk

Faculty Mentors: Dr. Shyam Chadha, Dr. Daniel Ernst, and Dr. Simet Tong
University of Wisconsin-Eau Claire

Introduction

Natural disasters and other related emergencies are of major concern for communities. It is crucial for the city to evacuate its citizens from danger in the event of an emergency. Therefore, we have created a mathematical model based on Operations Research Theory and Graph Theory that can construct an evacuation plan to perform the optimal evacuation for a variety of emergency situations. We designed a program using the Java programming language that dynamically implements Dijkstra’s algorithm and the Simplex Method to efficiently calculate the optimal solution of evacuation with minimal user interface. Specifically, the Emergency Management Officers of the City of Eau Claire will be able to implement this software during times of emergency in the most efficient way.

The University of Wisconsin-Eau Claire’s Math Department has been creating evacuation and optimization plans for 5 years and has had many novel results. These are given in the following list:

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

Our coefficients, \( C_{ij} \), in the objective function are calculated based upon:

- \( n_j \) = Number of households
- \( x_{ij} \) = Number of buses
- \( t_b \) = Time to load the bus
- \( t_s \) = Time to the shelter

The formula for \( C_{ij} \) is then given by

\[
C_{ij} = \frac{n_j t_b + t_s}{x_{ij}}
\]

We then have the following objective function:

\[
\min Z = \sum_{j=1}^{n} \sum_{i=1}^{m} C_{ij} x_{ij}
\]

This equation is subject to the following constraints:

\[
\sum_{j=1}^{n} x_{ij} \leq A_j \quad \text{and} \quad \sum_{i=1}^{m} x_{ij} \geq B_i
\]

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

Mathematical Model

We suppose a disaster happens in the southwest corner of Eau Claire.

- Approximately 19 districts are affected.

- Numbers in red represent population in district.
- Numbers in green represent shelter capacity per district.
- Image represents shortest path tree.
- Program tells us how many to send on each path.

Evacuation Event

- Areas in red are the ones that need to be evacuated.
- We are evacuating them to the surrounding areas.
- Residential area.
- Numbers in green represents shelter capacity per district.
- We can see how many to send on each path.
- Program tells us how many to send on each path.

Java Program and Evacuation Result

- All information is stored in database.
- Program reads from database.
- Database can easily be updated to include current information.
- User clicks on area of evacuation.
- User can evacuate one or multiple districts.
- Program then prints solution.
- Solution is optimal.
- Interface is minimal and easy to use.
- Select start to begin evacuation.

References


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