Comparative Analysis of Response Times between Actual Emergency Responses and Geographic Information Systems Developed Emergency Responses for Midland County, Michigan

Christopher D. Cantrell[1,2,3]
[1]*Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, MN 55987;* [2]*Midland County Services, Midland, MI 48640;* [3]*Midland County Central Dispatch Authority, Midland, MI 48640*

Keywords: Geographic Information Systems (GIS), Network Analyst, Response Times, Fire

Abstract

Emerging technologies allow antiquated emergency response coverage areas to be updated and improved upon. In Midland County the existing emergency response system has been in place for over ten years. Spatial technologies provide the means for analyzing current systems with anticipation of discovering areas of improvement. The current response coverages are not developed based on shortest distance to a location. Response coverages are developed according to township boundaries and in some cases multiple townships are one coverage area. Emergency response times are a measurable quantity; it is these times with which responding units work on improvement continuously. Through the use of geonetworking, response times are analyzed and modeled to develop an efficient and logical coverage for responding units based on spatial location.

Introduction

In Midland County, Michigan, emergency response coverages have not been re-evaluated since the early 1990's. Response coverage is the area that a response agency is responsible for. The county has a very distinct delineation between urban and rural areas. One relatively large city, the City of Midland, has 43,000 residents and the remaining residents live throughout rural Midland County. The combination of accelerating residential development and the introduction of new generations into the emergency response units require better dissemination of information during an incident.

Spatial technology can establish response coverages based on shortest distance or time to a location. In addition to logical response coverages, GIS technology can produce cartographic results quickly to aid responding units in the field. Decision making skills during incident response is dependent on access to information from several sources and GIS can fulfill this need. Geospatial data is a critical element that is utilized by emergency management. No other technology allows for the visualization of an emergency or disaster situation as effectively as GIS (Greene, 2002).

Emergency personnel are continually re-evaluating themselves to find ways for improvement. One

Cantrell, Christopher D. 2008. Comparative Analysis of Response Times between Actual Emergency Response Times and Geographic Information Systems Developed Responses for Midland County, Michigan. Volume 10, Papers in Resource Analysis. 8pp. Saint Mary's University of Minnesota Central Services Press. Winona, MN. Retrieved (date) from http://www.gis.smumn.edu

improvement that benefits everyone in emergency services is to have the quickest response time possible. GIS capabilities, specifically transportation information and analysis, assist in developing logical coverage areas for responding units based on shortest time of travel. The main data layer of the base map for public safety is the street centerline and the Public Safety Access Point (PSAP) boundaries; without having accurate and current street centerline data, emergency services cannot be efficiently dispatched (Berryman, 2002).

Project Scope

This analysis identifies inefficient coverage areas for emergency response units and originally was to include fire, EMS, and first responders, but due to the mass of data maintained for each department, the study focuses on the response of the rural fire departments in Midland County. In addition, times within the City of Midland are assumed to be relatively shorter; therefore the difference in response times should be very small. Because of this, the city response times are not a part of this study.

The study area incorporates the current response coverages for agencies located within rural Midland County, Michigan. Those agencies include the Coleman, Edenville, Homer, Hope, Jerome, Larkin, Lee, Lincoln, Midland Township, and Mills Fire Agencies that are located within Midland County (Figure 1). The additional four agencies, Breckenridge, Richland, Shepherd Tri-Township and St. Louis agency are located outside the county but have mutual aid agreements and respond when requested. The county has sixteen townships that are either 24 or 36 square miles. The county is 528 square miles and relatively square in shape measuring 36 miles north to south and 34 miles east to west.

Comparative analysis of the current response coverages to developed coverages through the use of spatial examination will allow the emergency response agencies in Midland County to improve the service that they provide. By identifying areas where distance and/or time of response can be reduced this analysis will create a safer environment for its residents.

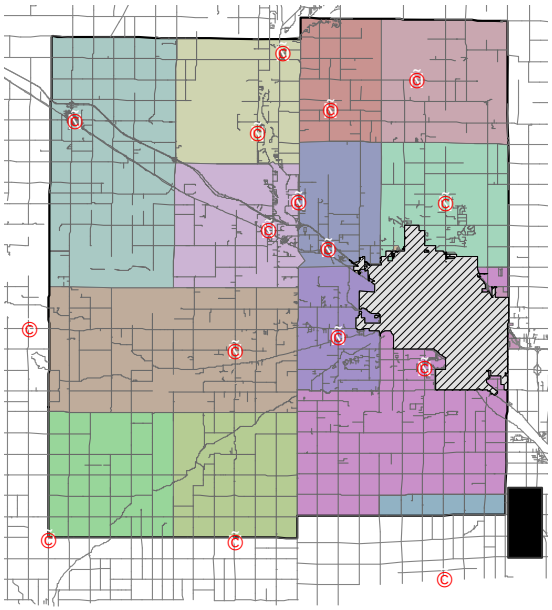

Figure 1. In this map of Midland County (22x36 miles in size), current fire response coverage areas and fire agency locations (red point symbols), each identified with an individual color are aligned with township boundaries. The City of Midland is the hatched area in the eastern side of the county and is excluded.

The analysis uses a network enabled transportation layer to develop coverages for each of the responding units from their base location to all areas of Midland County and out of county coverage areas.

Research questions this project addresses are as follows:

- Using the spatial relationship of emergency base locations to response calls, to what extent does emergency response coverage areas currently provide unrealistic or illogical response times?
- To what extent will comparative analysis of current emergency response times to GIS developed times yield improved services by the responding agents in Midland County?
- What factors influence response times among agencies beyond transportation types, traffic count, time of day, time of year?

Methodology

Technology

Software used in this study includes ESRI's (Environmental Systems Research Institute) ArcGIS 9.2 Suite including the Network Analyst extension. Microsoft Excel was also used to clean and format data for use in ArcGIS.

Data Collection and Preparation

The data was acquired from various departments in Midland County including Midland County Central Dispatch, Equalization, and the GIS Departments. Data from the County's Central Dispatch includes response times to each incident for a one-year period including the respective fire agency that responded to each incident. Transportation, addresses, political and fire agency boundaries in shapefile format, and orthophotography were acquired from the GIS Department. Additional data has been developed for this project such as emergency response base locations and resulting emergency response coverages from analysis. The response times acquired from Central Dispatch are provided in a text format including agency name, incident address and description, and the call, dispatch, en-route and on scene times. Excel is used to clean and format the project data. This process involves converting columns of data into rows to establish individual records of each incident. Using the Visual Basic module in Excel, a macro was created that combined several repeatable steps into one action and automating the steps to convert columns into rows. The macro included copying the data and the paste special tool with the transpose setting set to row and establishing the starting cells to create each respective record. The result was 1,991 records, or incidents, that were responded to in a one-year period.

New fields were added to the table to convert the time fields into measurable units that could be used for time calculations. Because the time was logged into the database for each call, and in order to calculate the difference between the incoming call times and the on scene times, the records required conversion to a common unit. Three fields were created for each time, one to convert the hour of the call to seconds, the minute of the call to seconds and finally copying the seconds into its respective field. A fourth field was then created that summed the previous three fields into a measurable form of time. Once that the two times were in seconds, the difference between the incoming call seconds and the on scene seconds represents the total time to respond to an

incident. The final table was named Response Information.

The transportation layer was topologically correct with connectivity between all features in the layer. The attribute table had many of the needed fields including speed (in miles per hour), class (used for establishing a hierarchy of road preferences), and length of each feature. Additional fields added to this layer included speed in feet per hour (Speed_FPH), hour, and minute. These fields were needed to calculate the time in minutes that it took to traverse each feature in the road layer.

The address point layer included points that were snapped to the centerline of the road at the intersection of the driveway and the road. There was one point feature for each address in the county with a total of over 38,000 addresses countywide. The attribute table included the needed fields, which were prefix, address number, street name, street type, suffix, and a field that included the above fields concatenated.

The political boundaries were the municipal boundaries of the townships and the City of Midland. There are sixteen townships in Midland County, and two cities, Midland and Coleman. Since the Warren Township Fire Agency responds to incidents within Coleman, its municipal boundaries are not required for this analysis.

The fire agency locations were developed by querying the address of each location and exporting the selected points into a new feature class called County Fire Stations. In addition to the address information, the name of each agency was added to the attribute table.

Additional layers were developed during the analysis portion of this project and are discussed in detail later in this paper.

Analysis

The analysis began with identifying the average time each agency responded to a call, based on actual times and then repeated in GIS. The results provide an evaluation of how current response times may be reduced to improve the response service of each agency.

The Response Information table of actual response times that was discussed earlier was related to the Address Point feature class using the address field. This resulted in 1046 matching records. The difference in matching records and total incident records is attributed to several factors; first, many incidents are located at non address locations such as intersections or on vacant property and secondly, there are records in which the agency has responded multiple times to the same address. The matching records are exported to create a layer of address points where an incident occurred.

The Incident Address Match feature class was then related back to the Response Information table using the address field for the relationship between the tables. The resulting table, RI Matches, contained records of incidents that had a corresponding address point.

To acquire the statistics on the actual response times, the agency name field was summarized with additional summary statistics generated from the response time field, Resp_Minutes. The summary table demonstrates that the average response times ranged from 7.76 to 29.88 minutes. The average response time county wide for 16 agencies was 11.94 minutes. Eight of the fourteen agencies had response times of less than 10 minutes (Table 1). The three highest averages are from agencies responding

from out of the county to only 4% of the total amount of incidents.

Table 1. Average response times, in minutes, derived from actual data acquired from Midland County Central Dispatch.

Responding Agency	Number of Incidents	Average Response Time
Breckenridge	21	29.8825
Coleman	157	8.3862
Edenville	119	8.9936
Homer	157	9.6240
Hope	43	11.3512
Jerome	210	7.7596
Larkin	113	8.9395
Lee	250	10.7209
Lincoln	87	8.0052
Midland Township	192	9.8094
Mills	72	10.1715
Richland	17	15.9049
Shepherd Tri-Township	3	8.3667
St Louis	23	19.3732

The Network Analyst extension in ArcCatalog was used to develop response times in GIS. The road feature class was used as the source in developing the network dataset. For the context of this analysis, the network definition was defined as a set of features that participate in a topology, which provides spatial intelligence to linear features. In addition, parameters were set in developing this dataset such as the time variable. During the setup for creating the network dataset, the minute field from the road layer was set as the default field used to define the cost to traverse a feature in the road layer. Analysis of this field was used to calculate the time to respond from a station to each incident. Adding the cumulative time over every feature between a facility and an incident calculated the total time to respond. An additional variable loaded into the development of the network dataset was the class field, which was used to establish a hierarchy of road use such as highways over local streets.

Once the network dataset was created from the road layer the facility and incident locations were loaded into the analysis layer. For the facility locations the County Fire Station layer was used and for the incident locations the Incident Address Match layer was used. The analysis was run to generate the routes from each station to each incident. One route was created for each incident and in the attribute table the time, in minutes, to respond was calculated and recorded.

To determine the average response times from GIS derived routes to incidents, the facility field was summarized with additional summary statistics generated from the minute's field. The resulting table of average response times ranged from 1.80 to 5.94 minutes (Table 2). The average response time countywide of GIS calculated routes was 3.37 minutes.

Table 2. Response times, in minutes, developed using ArcGIS's Network Analyst extension.

Responding Agency	Number of Incidents	Average Response Time
Breckenridge	27	4.7579
Coleman	90	3.4170
Edenville	76	3.6569
Homer	147	3.4119
Hope	34	2.5755
Jerome	147	2.7777
Larkin	112	3.2969
Lee	116	3.4737
Lincoln	58	1.7959
Midland Township	102	3.5199
Mills	51	3.3770
Richland	37	3.9559
Shepherd Tri-Twp	39	3.8546
St Louis	7	5.9376

Comparing the average times of actual responses, theoretical GIS response times have a lower average time by 8.12 minutes. The improvement in response times is a result of developing response areas based solely on shortest time to an incident.

Results and Discussion

This analysis of response times has yielded improvements in the theoretical time taken for fire responders to arrive at an incident. The comparison of response times from an actual incident and times generated using modeling in GIS, demonstrate improved average response times for each facility. By reassigning each incident to the closest facility that could respond, which was completed by creating boundaries based on closest facility, the times were significantly reduced. The resulting coverage delineation was unique because of the nature of how it was derived. The fire coverage boundaries were created using a logical method by determining the nearest fire agency location for each incident (Figure 2). Many of the greater response times were eliminated for each respective facility, as the incident had a closer facility that could respond (Table 3).

With these conclusions, many of the current boundaries are illogical if the sole issue of emergency response is to arrive at an incident in the shortest time possible. Depending on the incident, either injury and/or property damage can be significantly reduced. Another consideration is that less fuel would be used during each response thus saving money over time. Lastly, running multiple models in GIS as opposed to performing field tests also provides savings in time and money.

Though manually analyzing actual response times every so often can help to improve service, the ability of GIS to model and measure response times is the most efficient approach.

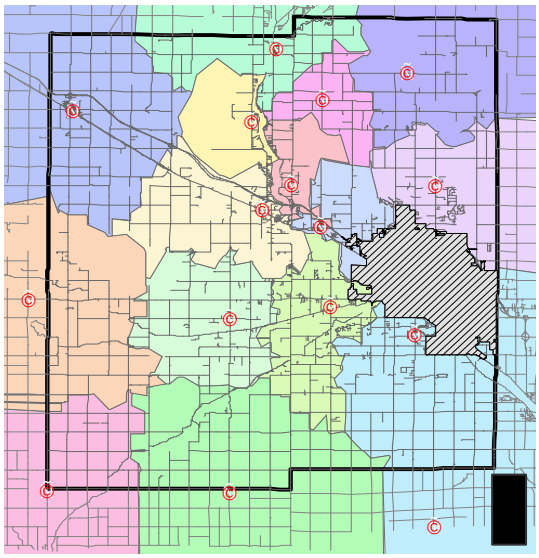

Figure 2. The theoretical response for Midland County is significantly changed through the use of shortest distance versus traditional township boundaries as seen in Figure 1.

Table 3. A decrease of average times was calculated for each facility.

Facility Name	Actual Average Response Times (Minutes)	GIS Derived Average Response Times (Minutes)	Net Decrease in Average Response Times
Breckenridge	29.8825	4.7579	25.1246
Lincoln	8.0052	1.7959	6.2093
Lee	10.7209	3.4737	7.2472
Midland Twp	9.8094	3.5199	6.2895
Edenville	8.9936	3.6569	5.3367
Coleman	8.3862	3.417	4.9692
Mills	10.1715	3.377	6.7945
Homer	9.624	3.4119	6.2121
Jerome	7.7596	2.7777	4.9819
Shepherd	8.3667	3.8546	4.5121
Richland	15.9049	3.9559	11.949
St. Louis	27.5667	5.9376	21.6291
Larkin	8.9395	3.2969	5.6426
Hope	11.3512	2.5755	8.7757

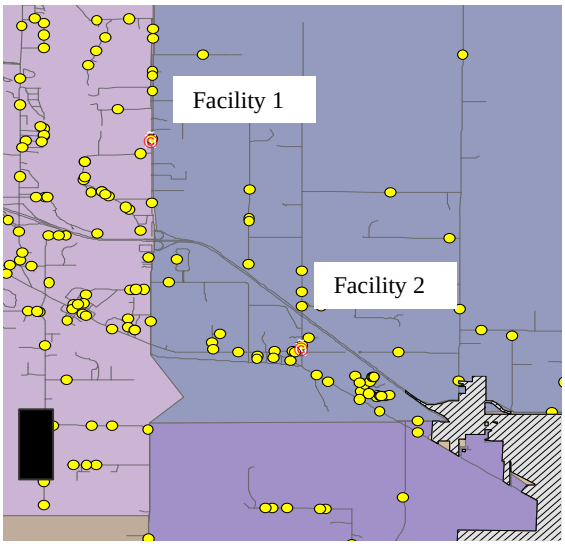

Figure 3. This map shows two facilities and a portion of their respective response areas and the incidents that occurred. Notice that facility 1 is closer to incidents to which facility 2 responds. Map scale is approximately 9 square miles.

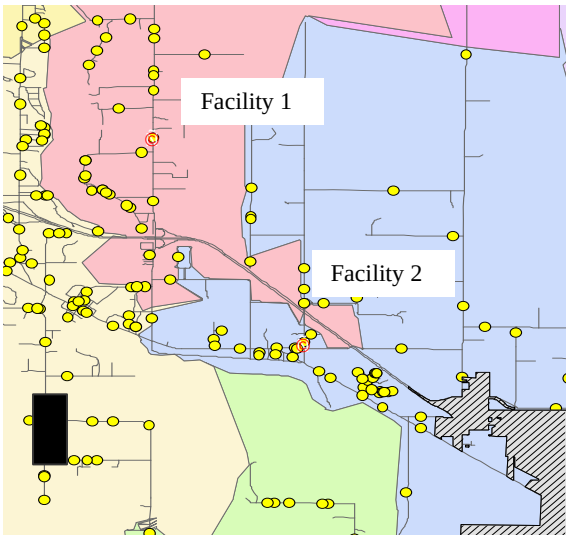

Figure 4. This map shows the same two facilities and incidents but the response areas are now the theoretical boundaries. Map scale is approximately 9 square miles.

The power of GIS is to model the real world and provide decision-making abilities before implementing a new idea. The completion of this paper has done nothing to disprove this. This analysis developed new response boundaries based on actual information provided by a local county and was successfully able to increase the potential for efficient fire response (Figures 3 and 4). Utilization of GIS during any of these phases of emergency management would result in an efficient and effective emergency management agency. To respond intelligently requires significant levels of spatial awareness only attainable through the use of a GIS (Johnson and Davenhall, 2005).

Limitations of Results

There are many factors that have not been introduced into this analysis that could influence the response times in varying ways. Weather conditions, road conditions, and traffic volume all have an influence on response times. In addition to these physical factors there are others, such as the use of political boundaries and lack of cooperation between neighboring jurisdictions that can negatively effect response times. Many of these could be included in a more in-depth study of response times and it is suggested that ways of including these variables could be used to further the analysis of response times in the future.

Acknowledgements

I would like to thank everyone involved with the Department of Resource Analysis at Saint Mary's University of Minnesota for their enthusiastic approach in assisting with my learning experience. I would like to express my greatest appreciation to my mentors; Patrick Thorsell for giving me those last momentous words of encouragement, Dr. McConville for encouraging me to take part in the master's program at

SMUMN and especially John Ebert for all the shared experiences from local government to education.

References

Berryman, M. 2002. Location Based Technologies and Emergency Response. Retrieved November 5, 2005, from http://gis.esri.com/library/userconf/proc02/pap0789/P0789.htm.

Greene, R.W. 2002. Confronting Catastrophe, Redlands, California.

Johnson, R. and Davenhall, B. 2005. Improving Emergency Planning and Response with Geographic Information Systems. Retrieved November 5, 2005, from http://www.esri.com.