EMERGENCY RESPONSE TIME AND A TRANSPORTATION MODEL TO IMPROVE EMERGENCY SERVICES IN HENRY COUNTY, INDIANA, USA

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BY

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ABSTRACT

THESIS: Emergency Response Time and Transportation Model to Improve Emergency Services in Henry County, Indiana, USA.

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Emergency services are very important in every society and that is why their activities should not be impeded by any avoidable barrier, especially with regard to transportation. One problem that is affecting the smooth running of emergency services in Henry County, Indiana is train movement across the county. The train tracks run through the county preventing road traffic flow when a train is crossing or has stopped. As a result, ambulances, police, or fire service vehicles have to wait for minutes or travel long distances to go around the train. This thesis focuses on developing response service areas maps based on the current response time and two models to generate shortest route around train obstructions. The data used for this thesis was provided by Henry County GIS Department, including shape files of police stations, police service areas, ambulance stations, ambulance service areas, fire stations, fire service areas, railroad and streets. The response service areas were designed based on the current response time. This was accomplished using ArcGIS network analyst extension which provides tools to design series of concentric circles based on the distance from the common center. Apart from the service areas maps for the emergency services which provide an idea as to where the services need to be extended in the county, the results of this thesis also include two models designed to generate shortest possible route as well as selection of a closest emergency facility to an incident site. The thesis could help improve the transportation aspect of emergency services.
ACKNOWLEDGEMENT

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LIST OF TABLES

Table 1: Data Layers .................................................................................................................. 20
LIST OF FIGURES

Figure 1: Indiana and Henry County ................................................................. 8
Figure 2: Ambulance and Service areas............................................................ 9
Figure 3: Fire Stations and Service areas....................................................... 10
Figure 4: Police Service areas........................................................................ 11
Figure 5: Flow chart of data refinement and processing................................. 22
Figure 6: New proposed locations for New Castle Ambulance Service Stations .... 24
Figure 7: 5 to 15 minute drive Ambulance Service Areas.............................. 25
Figure 8: 5 to 15 minute drive Police Service Areas .................................... 26
Figure 9: 3 to 10 minute drive Fire Service Areas ......................................... 27
Figure 10: Routing Model.............................................................................. 29
Figure 11: Closest Facility Model................................................................. 31
Figure 12: Geocoding with the "Find Tool" .................................................. 32
Figure 13: Routing Model Interface ............................................................. 33
Figure 14: Placing points on incident site and the emergency service facilities .... 34
Figure 15: Digitizing intersections to represent train barrier ...................... 35
Figure 16: Output of the Routing Model with barrier .................................. 35
Figure 17: Directions for Routing Model with barrier ................................ 36
Figure 18: Output of the Routing Model with no barrier ............................. 36
Figure 19: Directions for Routing Model with no barrier ............................ 37
Figure 20: Closest Facility Model Interface .................................................. 38
Figure 21: Digitizing barrier points and incident site .................................. 39
Figure 22: Output of the Closest Facility Model with barrier ........................................ 40
Figure 23: Generated direction for Closest Facility Model with barrier ........................ 40
Figure 24: Output of the Closest Facility Model without barrier ................................. 41
Figure 25: Generated direction for Closest Facility Model with no barrier .................. 41
Figure 26: Proposed Ambulance Service Areas ....................................................... 44
Figure 27: Henry County Sheriff department Jurisdiction map .................................. 45
# TABLE OF CONTENT

ABSTRACT ......................................................................................................................................................... i

ACKNOWLEDGEMENT ........................................................................................................................................ ii

LIST OF TABLES .................................................................................................................................................. iii

LIST OF FIGURES ............................................................................................................................................... iv

TABLE OF CONTENT ............................................................................................................................................ vi

CHAPTER ONE - INTRODUCTION ................................................................................................................... 1

1.1 INTRODUCTION .......................................................................................................................................... 1

1.2 PROBLEM STATEMENT ................................................................................................................................. 4

1.3 OBJECTIVES ............................................................................................................................................... 6

1.4 STUDY AREA ............................................................................................................................................... 7

CHAPTER TWO – LITERATURE REVIEW ......................................................................................................... 12

2.1 EMERGENCY SERVICES ............................................................................................................................... 12

2.2 MODELING .................................................................................................................................................. 14

2.3 GIS IN EMERGENCY SERVICES .................................................................................................................... 16

CHAPTER THREE – METHODOLOGY .............................................................................................................. 19

3.1 DATA COLLECTION .................................................................................................................................... 19

3.2 DATA REFINEMENT AND PROCESSING ...................................................................................................... 21

3.3 SERVICE/RESPONSE AREA DESIGN ........................................................................................................... 23

3.4 TRAIN- BARRIER MODEL DEVELOPMENT ................................................................................................. 24

3.4.1 ROUTING MODEL ................................................................................................................................ 28

3.4.2 CLOSEST FACILITY MODEL ..................................................................................................................... 30

3.5 TESTING OF MODELS .................................................................................................................................. 32
CHAPTER ONE - INTRODUCTION

1.1 INTRODUCTION

Emergency services are organizations which ensure public safety by addressing different emergency incidences. Many agencies engage in community awareness and prevention programs to help the public avoid, detect, and report emergencies effectively.

The availability of emergency services depends very heavily on the location of incidents and the fastest route to the destination. There are three services which are almost universally acknowledged as being core to the provision of emergency care to the populace, and are often government run. They would generally be summoned on a dedicated emergency telephone number reserved for critical emergency calls. They include police providing community safety and acting to reduce crime against persons and property, fire service fire and rescue operations, and may also provide some secondary emergency service duties, and emergency medical Service - providing ambulances to deal with medical emergencies.

The emergency services play a vital role in the public safety of every community. Their work should be as efficient as possible to save as many lives as possible. Jeopardizing the efficiency of the services by way of poor training, lack of infrastructure, lack of personnel and other impediments, being natural or man-made, would not only cause loss of lives but would also put the population at high risk. Incidents could occur anywhere in a county which gives rise to requests or calls for service. The times and
places at which these incidents occur cannot be specifically predicted in advance. In response to each call, one or more emergency service units (vehicles) are dispatched to the scene of the incident. The response time with which units arrive at the scene has some bearing on the actual or perceived quality of the service. Sometimes the heavy nature of their equipment contributes to the delay in arriving at an incident scene. Some of these tools may include fire engine and ladder trucks, police patrol cars, and ambulances, tow trucks for police, bomb disposal units, and emergency repair trucks for gas, electric and water services (Chaiken & Larson, 1972). Although all emergency service systems share the above characteristics, they may differ in certain significant details in Henry County.

Medical emergency or ambulance service has been provided to Henry County since 1944. The county has been divided into districts to ensure quicker response to incidents and service is available 24 hours a day, every day of the year. On average, the county’s ambulance services respond to 12 to 14 calls for emergency assistance per day. Ambulances are supplied stationed at different locations within the district to provide emergency ambulance service to the hospitals. The vast majority of requests for emergency services are recorded in summer and they are made by the public via telephone calls to the Police Department’s Communications Division. Upon receipt of a call, the patrolman on duty determines the type of call and acts accordingly.

Depending upon the nature of the incident, a helicopter may be sometimes requested to transport a patient or victim. In Henry County, for example, a helicopter is normally requested from the closest private helicopter company, such as PHI (Petroleum Helicopter Incorporated), in Anderson, Indiana. The problems with helicopters are
twofold. First, they are not good in an urban environment because they unable to land in the midst of traffic jams, high-rise apartments, and power lines. Their usefulness begins outside the cities. Secondly, they are too expensive for most agencies. Based on Hanlon estimates, a helicopter alone can cost over $300,000 without the crew's salary if an emergency service wants to own one (Hanlon, 1973).

Fire services have been in existence for over 100 years. The personnel respond to incidents from 19 stations in times of emergencies. The response time is not fixed but they can arrive at the scene from the time of being signaled to about 3-7 minutes depending upon their location with respect to the incident site. The county is divided into sections and each section is served by specific fire service groups. On average, the calls received per day range between 10 and 17. Because fire outbreaks are caused by a variety of factors, there is no peak season; it can happen at any time and at any location. However, some of the highest numbers of calls have been recorded in the summer period.

Henry County has 7 police stations. These stations are distributed throughout the entire county. The police service has been in operation since the county was founded in the 1850s. Since most 911 calls are received by the police department, their work is not only to fight crimes and make arrests of criminals, but also to report and direct ambulance services and fire trucks to emergency sites.

One pertinent problem that is impeding the smooth operation of emergency services is train movement across the county. The train tracks run through the county preventing traffic flow anytime a train is crossing or has stopped on the tracks for some reasons. This poses a great danger because an ambulance, police, or fire vehicle would
either have to wait for minutes or travel a long distance anytime the train crossing is blocked. This problem could be managed by either using a model that is able to generate alternate routes when the main streets are blocked or knowing the time schedule of the train company, which is difficult to have because of security reasons.

This thesis specifically examines developing service areas for police, fire and ambulance services and developing an interactive model that allows alternate routes to be implemented when the main streets are blocked by trains or other types of barriers.

1.2 PROBLEM STATEMENT

This thesis focuses on three emergency services: medical, fire and police. The work of the emergency services should not be impeded by any avoidable barrier, especially with regard to transportation. The Emergency Medical Systems Service Act (EMSS Act) of 1973 was passed by Congress to promote systematic planning and evaluation of regional emergency systems. The Act represented an attempt to coordinate a number of components in pre-hospital emergency cases, such as transportation, personnel, and facilities. One of the provisions of the EMSS Act is that 95 percent of all ambulance response times must be within twenty minutes in rural areas and within ten minutes in urban areas (Mayer, 1980). This means that the response and the service time should not be beyond twenty minutes in any part of the county. Response time is the time elapsed from the dispatch and the arrival of an emergency vehicle at the emergency
scene. Service time is the time from the dispatch of the ambulance to the arrival of the patient at a hospital (Daberkow & King, 1977).

Because it is an explicit assumption of geographical allocation models that short response times are desirable, a reasonable expectation is that the probability of a patient surviving an emergency should be a decreasing function of response time. Longer response times should thus have fewer patient survivals than shorter response times, other things being equal (Baker, Clayton & Taylor, 1989).

Emergency services fit within a more general framework of an overall emergency system. Such a system is composed of communication, transportation and medical treatment. The transportation subsystem includes the means for conveying a patient to the medical facility, or for transporting medical facilities (doctor, first-aid attendant, oxygen, resuscitation equipment, stomach pump, antidotes, etc.) to a patient. Elements within this subsystem include such factors as the boundaries of ambulance service districts, the locations of ambulances and hospitals, and the number of ambulances (Savas, 1969).

Railroad tracks that intersect with major roads in cities and towns pose a great danger not only to emergency vehicles but to all other vehicles. There have been many accidents involving emergency vehicles and trains which have claimed a number of lives. A railroad that passes through Henry County poses the same problems to emergency services. There is only one location where trains and cars can pass simultaneously in the county at this time. Anytime there is a train crossing, all cars, irrespective of their function, must stop and wait for minutes depending on the length of the train. The effect of this delay is an increase in response and service times. Preliminary studies show that
depending upon the distance, the average response times for police service range from 1 minute to 30 minutes; 5 to 8 minutes for fire services, and 3 to 15 minutes for ambulance services. If this time is extended because of train crossing or any other type of obstruction, then not only the EMSS Act has been breached but also the victim’s life is put in danger. The response times of the emergency services are used to compute the service areas covered by the police, fire and ambulance services in this study. In addition, thesis focuses on developing a model that would be able to calculate and display the shortest possible route from the emergency service centers to the emergency sites or find the best route when the main streets are blocked by a train.

1.3 OBJECTIVES

The objectives of this thesis are to help improve the emergency services of Henry County by:

1. Developing service areas for police, fire and ambulance services based on response time.

2. Implementing a network dataset to calculate the closest emergency service facility for emergency incidents.

3. Developing a model to find the shortest possible path when the main route is blocked by a train.
1.4 STUDY AREA

Indiana is located in the Midwest of United States and it is the home for about 6.4 million people, comprising 92 counties. This study covers Henry County which is located in the eastern central part of the state. Figure 1 shows the location of Henry County in the state of Indiana. Henry County population is approximately 46,947 and the county seat is New Castle with a population of 18,663 (2000 census). Henry County is within a relatively short drive from major urban areas such as Indianapolis and Cincinnati, Ohio.

With a population of almost 47,000, the County has three medical emergency service districts, with four ambulance stations. Figure 2 shows the location of the ambulance services and their assigned service areas in the county. Middletown and Southwest EMS have only one ambulance each. The ambulance services respond to any incidents over the entire county whether it is within its district or not. Distance from the ambulance station to the incidents is the primary factor in determining which ambulance service is called to the scene of emergency incident.

The county is divided into fifteen fire districts with nineteen fire stations covering much the entire county. Figure 3 illustrates the fire stations and service areas within the county. Even though the county is using a districting model in terms of administration, the closest fire station is always called to the scene of fire outbreak.
The county has seven police stations which are located in the major urban places. Figure 4 gives the perspective of the police and county sheriff jurisdiction in the county. The number of policemen in each town is proportional to the population of the town. The city police’s jurisdiction is confined to the city or town within which they reside. The county sheriff is the department that is responsible for the entire county. The county is divided into three sections, north, central and south with one car each for patrolling.
purposes by the sheriff department. During the day and afternoon, detectives are also available if needed to assist in any capacity.
Figure 3: Fire Stations and Service areas
Figure 4: Police Service areas
CHAPTER TWO – LITERATURE REVIEW

2.1 EMERGENCY SERVICES

There exist a number of journal articles, books and theses on emergency services, emphasizing mathematical methods of improving these services. One online article explains the relationship between emergency services and transportation and states that transportation and emergency services agencies have many shared and overlapping responsibilities in a myriad of situations, ranging from routine traffic incidents to large-scale events that threaten public health and safety (Transportation and Emergency Services, 2005). The importance of effective coordination among these groups has been heightened by the need to improve highway operations, ensure homeland security, and enhance all-hazards emergency management.

The work of emergency services requires more resources because the kind of environment within which they operate is risky and difficult to control. One of the articles published by US Department of Transportation explains that given an increasing number of vehicles on roads and intense highway environments, identifying and locating traffic incidents and the dispatching of response units requires far more than a single agency’s resources, regardless of how efficient that agency’s operations may be (Faster Response Time, 2004). It goes on to elaborate the importance of technology in emergency services. It is imperative to show police and fire departments the potential
resources in intelligent transportation systems that can help them do their jobs better. All the technology in the world would not help if the police officers on the street do not realize the full capability of the technology (U.S. Department of Transportation, 2004).

The complexity of the environment in which the emergency service systems operate and the impracticality of measurement of changes in deployment make their work a difficult one. In the work of Chelst and Jarvis (1979) on “probability distribution of travel times for urban emergency service systems” (Chelst & Jarvis, 1979), stated that the emphasis on emergency services has been on surrogate measures such as unit workloads, average travel times, costs, and imbalances in either workload or travel time. Thus, it is assumed that shorter travel times will lead to fewer lives lost and less property damage in a fire emergency, fewer lives lost and less crippling injuries in medical emergencies, and higher probabilities of arrest in crime-related emergencies. They found a relatively linear relationship between response time and fire fatalities.

A report of the United States Government Accountability Office (GAO) indicates that during disasters such as hurricanes, administrators of hospitals or nursing homes must make decisions about the best way to care for their patients or residents under such circumstances, including whether to evacuate if the facility becomes unable to support adequate care, treatment, or other services. At the federal level, the Centers for Medicare & Medicaid Services (CMMS) has requirements related to hospital and evacuation planning as a condition of participation in the Medicare and Medicaid programs. For example, CMS requires that the overall hospital environment must be maintained to assure the safety and well-being of patients. According to CMS guidelines for
interpreting this regulation, hospitals must develop and maintain comprehensive emergency plans, and when developing plans, they should consider the transfer of patients to other health care settings or hospitals if necessary (GAO, 2006). But the transportation or evacuation of people in times of disaster is primarily based on knowledge about human behavior and the emergency itself. This assertion seems to be inadequate for certain types of emergencies or accidents. One study conducted in the aftermath of the accident at the Three Mile Island nuclear-generating facility near Harrisburg, Pennsylvania in March 1979 concluded that the emergency plans developed according to criteria on human behavior and the emergency is likely not be adequate and effective for a major accident. (Johnson, 1985)

2.2 MODELING

In recent years numerous models have been developed to assist administrators in the deployment of emergency services. The general problem these models address is how to distribute emergency service units (police cars, fire trucks, ambulances) throughout a region. One probabilistic analytic model which has generated a great deal of research is the hypercube queuing model (Larson, 1975). The main advantages of this model with respect to performance measurement are: explicitly account for inter-district dispatching, allow emergency units to be on the move (e.g. police cars on patrol), and calculate average travel times for the region as a whole and for each district, sub-district and emergency unit within the region. There is also another popular model called
approximate analog (Chelst & Barlach, 1981). This model is based on a mathematical
approach to estimate the workload and dispatch of emergence services.

Most of the emergency services such as ambulance services use some kind of
model or procedure in their activity. These models are used in a variety of ways, ranging
from resource allocation to routing. In his work on the performance of urban emergency
service systems, Larson (1975) worked with a model that can be used to analyze a
number of resource allocation problems in urban emergency services including
districting, location, and work-load balancing problems. Given a region with a certain
spatial distribution of demands for service and given response units that are spatially
distributed throughout the region, he posed a question “how the region should be
partitioned into areas of primary responsibility (districts) so as to best achieve some level
or combination of levels of service?” In the context of a spatially dispersed emergency
ambulance service, a district for a particular ambulance would consist of a region in
which calls for ambulance service are handled by that ambulance, provided it is available
when the call is received. If the district's ambulance is unavailable, then an out-of-district
ambulance would then be assigned. Thus, in urban emergency services the analysis of
districting, location, and workload-balancing problems should include the possibility of
over-lapping, disjointed districts and mobile as well as fixed locations. Moreover,
because of the dispatcher's desire to avoid delaying calls in queue, any analysis of these
systems should include cross-district or inter-district dispatches as well as intra-district
dispatches.
2.3 GIS IN EMERGENCY SERVICES

Geographic information Systems (GIS) is defined as an organized collection of computer hardware, software, geographic data, people and spatial modeling for collecting, storing, maintaining, manipulating, analyzing, problem solving and displaying geospatial data and information (ESRI, 2006). Spatial modeling is the process of manipulating and analyzing geographic data such as roads and building locations, to find relationships between and among geographic features to generate relevant information for simple or complex problem solving. The results may be displayed as a map on a computer monitor or printed as a hard-copy. In the last few years, many attempts have been made to automate the route-planning process using GIS technology (Yildirim, et al, 2006). Many researchers have already used GIS to design many projects such as pipelines, school bus routing, and emergency management systems. These projects embodied complex intertwined elements that were evaluated and combined using GIS (Mackenzie & Walker, 2004).

Emergency services have the responsibility to protect lives and property but have a limited amount of resources. It is critically important that the deployment of resources is effective, efficient, and based on the best information possible. In the literature, GIS has been noted for its ability to help in the location of incident sites (geocoding) and displaying those incidents on jurisdictional base maps. The emergency services make use of such maps in their work (Spatial Thought, 2007). The report maintains that, emergency response services in India possesses no centralized 'call and dispatch' service that coordinate with police and medical facilities in one of the Indian cities, and the typical
response normally took hours, if not more. Today, the Emergency Management Research Institute (EMRI) is leading the way for state-of-the-art emergency response services in the state of Andhra Pradesh. Calling "108" from any cell or landline phone connects to a Communications Officer (CO) in a central dispatch facility. The most common GIS technique used in this application is finding the shortest route from the dispatcher to the caller using ArcGIS network analysis.

GIS contributes to the speed with which fire fighters, police and paramedics are able to locate, respond, and deploy to emergency scenes (ESRI, 2006). Many governments are now sharing geospatial information, that reduce the expense and improve the overall quality of geospatial data and information for public policy making (Baker, 2004). Response Time Modeling allows users to identify a station location, specify a travel time, and run a network analysis utilizing a fire station layer and a street layer (ESRI, 2006).

In his project on school bus routing and scheduling, Nayati (2008) arrived at an interesting conclusion (Nayati, 2008). His application was designed to help school transportation management to design shortest and fastest school bus routes which would help decrease fuel consumption and save time, and by using this system they can also allocate bus stops, which help them in selecting the pick-up stops for the students according to their concentration in the areas.

Much research has been focused on emergency services and management. However, few address the importance of transportation in emergency services. Most of the work concentrates on the theme such as allocation of emergency resources. It has
been realized from the literature, that there has not been any research specifically dealing with issues of transportation obstructions in emergency service and management. Because this can be a great challenge to emergency services, this thesis focuses on ways of mitigating against transportation obstructions in emergency service management.
CHAPTER THREE – METHODOLOGY

3.1 DATA COLLECTION

The geospatial data used for this thesis were provided by Henry County GIS Department. These data include police stations and service areas, EMS stations and service areas, fire stations and service areas, railroad tracks, streets and hospitals. Each layer and its attributes are summarized in Table 1. The data were already in a common State Plane coordinate system.

Current Henry County emergency services procedures were obtained through interview and questionnaire administration. The questionnaire for the emergency services is found in Appendix I. The other information about the county and historical background of the emergency services was obtained from other available sources such as books, journals and online resources.
<table>
<thead>
<tr>
<th>Layer name</th>
<th>Feature type</th>
<th>Main Attributes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police Stations</td>
<td>Point</td>
<td>Name, Address, City</td>
<td>Police station name Address of the station City of the station</td>
</tr>
<tr>
<td>Ambulance Stations</td>
<td>Point</td>
<td>Name, Address, City</td>
<td>Ambulance service name Address of the EMS City of the EMS</td>
</tr>
<tr>
<td>Hospitals</td>
<td>Point</td>
<td>Name, Address, City, Function</td>
<td>Hospital name Address of the hospital City of the hospital What type of medical service, e.g. hospital, clinic</td>
</tr>
<tr>
<td>Fire Stations</td>
<td>Point</td>
<td>Name, Address, City</td>
<td>Fire station name Address of the station City of the station</td>
</tr>
<tr>
<td>Streets</td>
<td>Line</td>
<td>Name, One-way, Speed limit, Drive time, Length</td>
<td>Road name One way street or not Allowed speed limit on the road Time to cover the segment The total length of the road segment in feet</td>
</tr>
<tr>
<td>Railroads</td>
<td>Line</td>
<td>Name, Districts, Status</td>
<td>Name of the tracks The district name for the tracks Either active or not active</td>
</tr>
<tr>
<td>Ambulance, Police and Fire Districts</td>
<td>Polygon</td>
<td>Name, Area</td>
<td>The name of the districts The size of the district</td>
</tr>
</tbody>
</table>
3.2 DATA REFINEMENT AND PROCESSING

The refinement and processing of the data are presented in a flow chart (Figure 5). The street data attribute was inspected to verify if it would support time-based networking. It was modified by adding the fields MILES, HIERARCHY, and FROM-TO (MINUTES) to make it useful in the calculation of accumulated time and distance for routing and service areas. These fields were calculated using a field calculator. The MILES field was calculated by multiplying the street length by 5,280 to obtain street distance in miles. The TO-FROM (MINUTES) and FROM-TO (MINUTES) fields were computed by dividing the product of MILES field and 60 by the street speed limits ((MILES*60)/SPEED_LIMIT). The HIERARCHY field was calculated based on the roads types (interstate = 1, U.S. highways = 2, state highways = 3, county roads = 4.).

Two feature datasets were created: the streets feature dataset and EMS feature dataset. The streets dataset contains only the street data while the EMS feature dataset is composed of police, EMS and fire stations as well as their service area layers. A Network Dataset was created using the streets feature dataset. The service areas for the emergency services were created using the Network Dataset with the respective emergency dataset.
Streets
Railroad
Police Stations
Fire Service
Ambulance
Police Districts
Fire Districts
Ambulance Districts

Add fields

Street Feature Dataset
Network Dataset
Service Areas
EMS Feature Dataset

Export

GDB

Closest Facility & Routing

Figure 5: Flow chart of data refinement and processing
3.3 SERVICE/RESPONSE AREA DESIGN

An emergency service-response area can be defined as the area over which the emergency service has been assigned in terms of jurisdiction. Although the emergency services operate within its respective allocated areas, the boundaries between these areas are very transparent. Depending upon where the location of an incident occurs, the closest emergency service is always contacted first to handle it. This could be either within the county or even outside the county. In the interview conducted in the pilot study, it was pointed out that the safety of the victim has always been the ultimate objective of the emergency service in Henry County. On the whole there are three main ambulance stations in the county. Two of them are located in the county seat of New Castle. The nineteen fire and eight police stations are distributed almost evenly throughout the county. Based on the road hierarchy, speed limit and one-way streets in the county, five to fifteen minute service area maps were constructed for all the emergency services. These service areas were designed based on the driving time it takes from the emergency service station to any other part of the county. Figures 7, 8 and 9 show the service areas for ambulance, police and fire services respectively. In the ambulance service area map, some areas are found outside 15 minute drive service areas. To make sure every part of the county is covered, new locations were proposed for the two New Castle ambulance stations which have overlapping service areas. Figure 6 shows the two locations on the aerial photograph. The proposed locations for the New Castle ambulance stations were chosen based on proximity to highways. The first
location is closed to SR 103 and US 36 while the other location is closed to SR103 and Interstate 70.

![Two Proposed Areas for New Castle Ambulance Stations](image)

*Figure 6: New Proposed locations for New Castle Ambulance Service Stations*

### 3.4 TRAIN- BARRIER MODEL DEVELOPMENT

Emergency vehicles normally use highways and good county roads to access incident sites as quick as possible. Without any obstructions such as construction or train crossings, the emergency crew typically does not incur any problems during their journey to and from the incident sites. One major source of road obstruction is train crossings. The train tracks cross most of the major highways in the county and the emergency vehicle crews have two alternatives to avoid being blocked by a train; they, either have to outrun the train, when the train is moving at a low speed or they have to wait until the
train passes because they only use paper maps and do not have any application or models to generate alternate short routes. To develop a model that would assist the emergency team in their decisions as to whether they should wait for the train to cross or find an alternate route, there are certain inputs required by the model.

Figure 7: 5 to 15 minute drive Ambulance Service Areas
Figure 8: 5 to 15 minute drive Police Service Areas
These inputs include, but are not limited to, the length of the train, road speed limit, road hierarchy, barriers (i.e., construction sites) and one-way streets. A train with few carriages, at the same speed, would cross the roads faster than the one with more
carriages. The length of the train is estimated to be about 1 mile long for the longest and 500 feet long for the shortest train. These inputs were used to estimate the time (minutes) and the distance (miles) from emergency service locations to the incident site and back to the hospital. In the model, the train is considered as a barrier across the major roads. If the location and the length of the train are known then the model would find a shortest possible route to go around the train.

Many assumptions were made to make these models practical and simple to use. The first assumption is the road speed limits. The speed limits for the roads are assumed to be fixed throughout the road segment which in reality is not the case. The reason for this assumption is that emergency vehicles normally do not obey the speed requirement of the roads. The model does not take into consideration any stop-over or delaying as a result of any circumstance. Information about the train with regards to train schedule, speed and length was also not known. This information was assumed to be constant and fixed in the model.

3.4.1 ROUTING MODEL

The routing model was developed to assist the movement of emergency vehicles throughout the county and beyond. The purpose was to be able to place beginning and ending points on any part of the map from which a connecting route, directions, distance and time could be generated.

This model was designed using ArcGIS model builder. The complete model is
shown in Figure 10. First, a route layer was created using the network dataset. This was done by connecting the making route layer tool with the already created Network Dataset. Then, the route layer was combined with input locations (incidents) to produce the route.

The incidents are the two or more locations or points selected in the map to represent the locations of interest such as fire outbreak, crime, accident, or any emergency site. Because trains are the primary source of barriers across major roads, points that coincide with the intersection between train tracks and roads were created and used to represent barriers across streets. The number of points to be selected would be based on the length of the train. To be able to store these points, a feature set variable was created. The selected points were used to clip the barriers layer to obtain the length of the train. The incidents, barriers, feature set (variable) and the model output were made model

Figure 10: Routing Model
parameters. The model was completed by adding the *solve tool* which computes a solution and produces a route.

### 3.4.2 CLOSEST FACILITY MODEL

A closest facility model was created to help in the decision of selecting the nearest hospital, fire service, ambulance and police service to the incident site. The completed model with all its required inputs is illustrated in Figure 11. The steps of how this model was created are described as follows. First, a route layer was created using the network dataset and make closest facility tool in model builder. The route layer was connected with the input facility layer (hospitals, fire stations, police or ambulance) to obtain the facility required by the model. The facility was also made a model parameter so it can be selected by the user and also able to be displayed in the map with the model output.

The Incident(s) is/are then loaded into the model by combining it with the selected facilities. If there is no barrier from the train or any construction, the closest facility route could be generated at this stage. However, if there is a train crossing at that very moment then certain streets would have to be blocked. A feature set variable was created to store the selected barriers and this was used to clip the barrier layer to get the actual blocked streets. The blocked streets were put into the model as barrier to block any passage across those intersections.
The facilities, incidents, feature set (variable) and model output were made model parameters so that the model could be interacted with and also its output could be seen in the map. The closest facility to the incident would be selected by the model and the shortest possible route, together with the directions would be generated to connect the selected facility to the incident site.
3.5 TESTING OF MODELS

3.5.1 SIMULATION OF THE ROUTING MODEL

Emergency responders attempt to arrive at the scene of a fire or other emergency as quickly and safely as possible. The time required for the emergency vehicle to travel to the incident scene should be factored into a response routing model. The routing model is designed to facilitate the movement of emergency vehicles in terms of navigation in the county, especially if there is a barrier that affects traversability.

Problem:

*There is an emergency at 105 S Cory St. and the New Castle 911 team has been notified.*

*Unfortunately there is a long train across the major street*

The problem is how to reach the incident site as soon as possible to save someone or property. The first thing to do is to find the exact place of the incident as most callers are able to give the address of the site. The find tool is used to geocode the address using Henry County Address Locator (Figure 12).

![Figure 12: Geocoding with the "Find Tool"](image-url)
After finding the incident location, the routing model is opened and the interface is shown in Figure 13. The input selector in the model is used to place a point on the location of the incident, ambulance, police or fire stations, and the nearby hospital. Figure 14 demonstrates how the ambulance, incidents site, and hospital have been added as inputs in the model using the input selector.

Figure 13: Routing Model Interface
Figure 14: Placing points on incident site and the emergency service facilities

Because there is a train on the tracks, the streets across which the tracks lie should be blocked. This is depicted in Figure 15. The barriers selector is used to digitize the length of the train (assumed to be 1 mile long) to select all those intersections of the train tracks and the street. These selected points would be used as the barrier in the runtime of the model. All the required inputs have been applied to the model. The model runs and evaluates all the streets based on speed limit, traffic direction, and street type to compute the shortest possible route connecting the ambulance station to the 105 S Cory St (incident site) and hospital. A route would be created to avoid the barrier caused by the train. The
outputs of the routing model with a barrier are depicted in Figures 16 and 17, while the outputs with no barrier are shown in Figures 18 and 19.

Figure 15: Digitizing intersections to represent train barrier

Figure 16: Output of the routing model with barrier
The step-by-step directions with inset maps would also be generated. This function is already inherent in the ArcGIS Network Analyst extension. The direction pane is shown in figure 17.

Figure 17: Directions for routing model with barrier

Figure 18: Output of the routing model with no barrier
3.5.2 SIMULATION OF THE CLOSEST FACILITY MODEL

The closest facility model is intended to assist in the selection of the closest facility (ambulance, fire, police stations or hospital) to an emergency incident. The goal is to reduce the response time to incident scenes.

Problem:

Assuming there is a fire in some part of the county, for example CR 325 E. How do we find the closest fire, ambulance or police station and the directions to the scene?

The address given by the caller has to be geocoded using the find tool. After the location is found in the map, the closest facility model is opened. The screenshot of the interface is shown in Figure 20. The interface looks similar to the routing model. There is an incident selector, which is used to place a point on the incident site on the map. Like
the routing model, the barrier selector is used to choose the barrier points by digitizing a polygon around the affected intersections. The only difference between the routing model and closest facility model is that the latter requires an input facility to be selected. This input facility could be ambulance, police, fire stations or hospitals.

Figure 20: Closest Facility Model Interface
Using the incident selector, a point is placed on the map to represent the incident location. Figure 21 shows the digitization of intersections as barriers. In the facility selection slot, the appropriate emergency service would be selected. In this example, a fire station would be selected for this scenario. The barrier selector would be used to digitize the length of the train to get the extent of the barrier. But if there is no barrier, then the barrier slot is left empty. In this exercise, we would create two scenarios one with a train barrier and the other one without any barrier, and then compare the two in terms of distance and time.

![Figure 21: Digitizing barrier points and incident site](image_url)

When the model is run, it evaluates the distance from each fire service station to the incident site in the map and then selects the one that is closest in terms of driving time,
taking into consideration the barrier, road hierarchy and speed limits. Figures 22 and 23 show the output of the model with a barrier in place.

![Map showing route and barrier](image)

*Figure 22: Output of the closest facility model with barrier*

![Map with directions](image)

*Figure 23: Generated direction for closest facility model with barrier*
How would the output be different if there was no train barrier? In this case the barrier section of the model would be left vacant. The generated route and the directions are shown in figures 24 and 25 respectively.

Figure 24: Output of the closest facility model without barrier

Figure 25: Generated direction for closest facility model with no barrier
CHAPTER FOUR – RESULTS/DISCUSSION

The objectives of this thesis are to design service areas and to develop models to facilitate the work of Henry County, Indiana emergency services. These objectives were achieved using the Network Analyst extension of ArcGIS 9.3. The two models and the three service areas were designed based on information from the questionnaires and interviews. In the service areas map, the service areas appear to be extended beyond the borders of the county. That is because the network dataset was intentionally created to cover parts of neighboring counties. Locations of emergency cases cannot be predicted in advance and therefore every necessary action possible needs to respond to emergency situation. Because time and distance are very crucial in emergency services, these models have been designed to select facilities closest to incident sites regardless of county boundaries. For example, if there is an emergency event on the Henry and Delaware county boundary, it would be technically unwise and unsafe to transport the victim to Henry County Memorial Hospital or wait for fire service or police from Henry County. It is reasonable to contact the closest neighboring county emergency service to take care of the situation (in this case Delaware County). The models have been developed to select any facility either from Henry, Delaware, Randolph, Wayne, Fayette, Rush Hancock or Madison counties, provided it is the closest one to the incident scene. This chapter focuses on the analysis of the results and discussion of the model simulation results as well as the service areas. Some limitations of the models
and the possible solutions relating to future improvement are also discussed in this chapter.

4.1 ANALYSIS OF SERVICE AREAS

The medical service areas were designed based on the current response time the ambulance takes to arrive at an emergency location in any part of the county. Currently, the maximum time an ambulance is expected to reach an incident site ranges between 10 and 15 minutes. In examining the service areas map (Figure 7), it is noted that most parts of the county are covered within a 15 minute drive from ambulance service centers. The northeastern and southeastern portions of the county are, however, not within 15 minute serviceable areas. This means that incidents in these parts of the county would not only put the victim’s life in danger but would call for a greater effort on the part of the emergency team to travel to the location. Fortunately, there has not been any problem with this current service area because according to the ambulance service representatives (S. Rifner, Interview. January 05 2009), there has not been any major incident in those areas. The representative added that it would be better to have all areas reachable within 15 minutes since emergencies cannot be predicted. One of the ways to resolve problems of this nature is to either build new ambulance stations or spatially disperse the existing ones to cover larger areas. The relocation of the existing ambulance stations was thought to be the best option to minimize cost, according to the ambulance emergency team representative. Figure 26 shows the new proposed service areas in which every part of the county is under 15 minute driving time from an ambulance station. But if relocation should be carried out, the two ambulance stations
that are the best choice to relocate are the New Castle ambulance stations. The reason is that they are so close to each other causing an overlapping of their service areas. So moving them apart would have little or no negative impact on the current service areas. After these stations were moved to new locations, the service areas expanded to cover the entire county.

Figure 26: Proposed Ambulance Service Areas
Like any other county in the United States, Henry County has a sheriffs department that possesses jurisdictional power covering the entire. Figure 27 shows the location and jurisdiction of the County’s Sheriff Department.

Figure 27: Henry County Sheriff department Jurisdiction map
The city police and their service areas seem to be located well in regards to the coverage and response time. It is evident in Figure 8 that the 5 minute drive covers most of the districts assigned to each police station. The areas that are not covered, however, do not create any problem because they are taken care of by the sheriff’s department. It is important to mention that there is an interdependency and interaction between all the emergency services in county. The reason is that if, for example, there is a robbery case reported, the police would need to be notified and in case of a victim present at the scene of the crime, an ambulance service would also be notified. Most of the time what we observe is that all the three emergency services (fire, police and ambulance services) report at the scene just in case they would be needed.

Naturally, fires spread very fast and cause much destruction if not extinguished early enough. This is the reason why there are many fire stations located across the county. The fire stations have been situated at different locations for faster response to emergencies in order to save lives and property. According to the response from the questionnaires, the maximum response time should be 5 minutes. But from the map (Figure 9), some areas are located outside the 5 minute drive zone. This not only puts pressure on the fire service team but it also puts affected people at risk anytime there is a fire incident in those areas. The service area map provides better idea where resources should be allocated as far as fire service is concerned.
4.2 ANALYSIS OF THE MODELS

4.2.1 ANALYSIS OF THE ROUTING MODEL SIMULATION

The routing model would assist in finding a shortest possible route connecting incident sites to ambulance or hospital locations. Because the travelling time to incident sites is more important than the distance, time is applied as a constraint in the model. The route analysis layer consists of different components:

- Stop feature layer (ambulance, incident, hospital).
- Barrier feature layer (congested or blocked areas where emergency vehicles cannot travel, in our case motionless train on the tracks).
- Route feature layer (generated route from the model, e.g. Ambulance-incident-hospital routing).

The distance between the ambulance station and the incident site, according to the outputs of the hypothetical routing model in Figures 16 and 17 is 22.7 miles with a travel time of 24 minutes. In Figure 16, we also see that state and U.S. highways were used instead of the county roads. The reason is that the roads have been categorized on a hierarchical basis using the road condition and speed limit as measures. The model begins searching for roads with high speed limits (interstates) first before U.S. highways and then state highways in that order. In the simulation, access to the closest highway (SR 3) was blocked by a train. This was done to mimic a real world event where a train has blocked direct access to SR 3. The model takes this barrier into consideration and searches for another nearby highway that has the same or higher speed limit as SR3. The model chooses SR38 over the county roads due to speed limits and the conditions of the
roads. The ambulance emergency team utilized the U.S. and state roads to access the incident scene and back to the hospital as quickly as possible. In the other scenario where there was no train and therefore no barrier in the model (Figure 17), the travel distance and time reduced from 22.7 miles and 24 minutes to 20.7 miles and 22 minutes respectively. The difference in response time for the two scenarios is not substantial because the model was able to find a shortest route around the barrier. Without using any model, the response time would be increased especially if the emergency service team decides go around the train to get to SR 3 or wait for the train to pass (i.e., if the train is moving). If the train is moving and they decide to wait for it to pass, then the response distance and time would be inversely proportional to the speed of the train. In that case the actual response distance and time would be 20.7 miles and 22 minutes plus ‘waiting time’ which would not be less than 2 minutes depending on the length and speed of the train. These scenarios suggest that barriers caused by trains actually increases the response time of the emergency services.

4.2.2 ANALYSIS OF THE CLOSEST FACILITY MODEL SIMULATION

Using the closest facility model, one can find the closest facilities such as hospitals and ambulances and the directions of travel towards or away from these facilities. After finding the best route to or from a facility to an incident site, the model would also display directions. This model allows you to perform multiple closest facility analyses simultaneously.
The closest facility analysis layer consists of different components:

- Facilities feature layer (ambulances, hospitals and fires stations)
- Incidents feature layer (incident sites)
- Barrier feature layer (congested or blocked areas where emergency vehicles can’t travel)
- Route feature layer (generated route from model)

Figures 22 and 23 display the results from the closest facility model simulation where the closest fire station is selected to travel to a fire outbreak site. Figure 22 is the output route when part of SR 3 was blocked by a simulated train while Figure 24 is when there was no obstruction from a train. In Figure 22, there are 5 fire stations around the incident site. Any of these stations had the potential to be selected for this case. The fire stations were evaluated by the model one after the other to locate the closest one considering speed limits, distance and road type. In the first scenario (Figure 22), the New Castle Fire Department was not chosen as the closest one because of the long distance the Fire Service team has to travel around the train to the incident site. The Middletown Fire Station was evaluated to be the closest one. The second scenario was created where there was no train or any obstruction. Figure 24 shows the output of the problem in which the New Castle Fire Station was chosen over the rest of the stations. Although US 36 occupies a higher level in the road hierarchy, SR 3 was considered as the best option to reach the closest facility because it is much closer and there is not much difference between the speed limits of US 36 and SR3.
In Figures 23 and 25, we observe that the response time is the same for the two locations (7 minutes) but the distance is different. The reason why the time is similar for both stations is because of the differences in speed limit between US 36 and SR 3. But the model considers New Castle Fire Station as the best option over Middletown because it was evaluated as the closest one.

4.3 LIMITATIONS OF THE STUDY AND THE MODELS

This study was carried out using available data from the Henry County GIS Department. The county’s road dataset lack certain attributes needed for this study. To develop models and effectively compute distance, route and directions, road information such as correct speed limits, road names, pavement conditions and one-way streets should be readily available. Since some of this information was lacking, they were assumed to be correct and constant. Again, due to security reasons information about trains which is the main source of the barrier was also not available. The speed and length of trains were assumed.

The models are exclusively based on ESRI ArcGIS Network Analyst extension. The geocoding of the address given by a caller is accomplished by using an ArcGIS tool (Find tool). To use these models, a copy of licensed ESRI ArcGIS software needs to be installed on the computer being used. Again, the use of these models requires some knowledge in ArcGIS software. The models are based on this software and it would be difficult for anyone who is not familiar with the software to use the models. For instance,
the use of “Find tool” to geocode and add a point to the location requires some general knowledge of the software.

The type of computer being used to run these models plays an important role in the effectiveness of the models as well. Computers with large Random Access Memory (RAM) would be better to use to run these models. This is because time is critical in emergency services operations, and therefore using a low RAM computer prolongs the execution time for the models which in turn increases response time.

The selection of intersecting points to represent the length of the train takes time and also needs careful attention. In order to save time this selection should be automated so that the user can enter the length of the train in feet or miles on the interface. This is something that will be looked into in future work.
4.4 POSSIBLE SOLUTIONS

This section discusses some potential solutions to the limitations of this study. To resolve the data issue, data collection should be more primary-based than depending on documented materials. The unavailability of road information from the Indiana Transportation Department made it difficult to obtain updated street information. The roads information in the transportation department needs to be updated periodically to reflect the current road information.

Because ArcGIS software is expensive, all the emergency services in the county may pull their resources together and purchase ArcGIS desktop and a server license so that these models are able to be published online for all to use at any time. Those in charge of dispatching emergency services should be trained periodically to keep them abreast of the use of the models and the new features of ArcGIS software. This would not only enhance the effective use of the models but would also introduce them to the other applications ArcGIS can offer to assist emergency services.

In the future, scripts could be written in any of the compatible programming languages to automate parts of the models to reduce manual inputs. For example, the selection of intersecting points to represent a barrier would be automated to avoid delay and also possible human errors.
CHAPTER FIVE – SUMMARY, CONCLUSION AND FUTURE WORK

5.1 SUMMARY AND CONCLUSION

The number of 911 calls seems to be on the increase according to responses from the questionnaires from the county police department. The peak season for emergency cases is primarily in the summer, because many people spend more hours outside. The emergency management services (ambulance, fire, and police) are equipped with the necessary tools to deal with such emergencies. However, there are problems that impede the smooth operation of their responsibilities. Among such problems include transportation of emergency services in the county or outside the county. On occasion, emergency vehicles are delayed or blocked as a result of road construction, accidents and other forms of obstructions such as a train on the tracks that creates a long barrier across the streets affecting the movement of emergency vehicles in the county.

This thesis posits three main objectives. They are to develop service areas for police, fire and ambulance services based on the response time; to implement a network dataset to calculate the closest emergency service facility for emergency incidents; and to develop models to find shortest possible paths when the main route is blocked by a train.

The thesis was begun by reviewing literature to understand the direction and how much research had been conducted on this particular topic. It was realized that much had
been accomplished on different aspects of emergency services or management, but little concerning transportation sector. Many classic mathematical models have been created to facilitate the services using different approaches, formula and software. Because only a handful of journal articles focused on the transportation dimension, this study was conducted to provide a different perspective of how emergency service transportation might be improved. One salient idea in the literature that motivated this study was the one put forward by Baker et.al (1989). They realized the critical relationship between patient survival and response time of emergency services. With all things held constant, the probability of a patient or victim surviving an emergency is a decreasing function of response time. In order to save more lives, the emergency response time should be reduced to the very minimum.

One of the avenues of helping to achieve this objective of response time reduction is to design service areas for emergency services. To design the service areas and the models, a network dataset was created after all the required data had been collected and updated accordingly. The service areas for the three emergency services were then created based on response time. The output maps illustrate different shades of concentric circles based on the distance and time from the emergency service.

Identifying the service areas for each emergency service provides greater clarity the distance to different parts of the county. In reality, the service areas provide an estimate concerning time to travel to different areas in the county. But any obstruction across the streets renders the service area estimate erroneous. This is where the routing and closest facility models are harnessed to provide ways around such obstructions.
Because the obstruction of emergency vehicles by train, road construction and accidents seem inevitable in both the short-term and long-term, two models were developed to route the shortest possible distance between emergency stations and incident sites, taking into consideration any obstruction.

The routing model was developed to provide the shortest route between two or more locations set by the user. The closest facility model selects the closest facility (hospital, fire or police stations) to incident scenes, and constructs a shortest route between the facility and the incident site. These two models were created using the network dataset in the model builder of ArcGIS. The routing model was initiated by creating a routing layer using the network dataset. The incident and barrier points were combined with the routing layer to produce an optimal route that connects an incident site to an emergency service station. After creating and combining the routing layer with the incident and barrier points similar to the routing model, the facility was added. The result of the closest facility model is not only a shortest possible route but the selected facility was the closest one to the incident site.

To test the usability of the models, two scenarios were created. In the first scenario, the routing model was used to construct the simple shortest route from ambulance station to an incident site and then to the hospital. The closest facility model was also used in the demonstration to select the closest fire station to a fire outbreak site, taking into consideration the obstruction created by a train. The step-by-step directions associated with the outputs of the models also reduce the response time of the emergency team.
The findings of this study show that the police and fire service areas appeared to be good in terms of coverage but there were parts of the county that are found outside the ambulance service areas. These areas are lacking easy accessibility to emergency services. The location of the ambulance services was adjusted so most of the county would be covered. This relocation of ambulance stations were merely proposed based on their current locations and service area coverage in the map and no feasibility study was carried out. This was done just to provide some ideas about how the entire county could still be covered using already existing resources (ambulance station) instead of building new stations. The models work perfectly as expected, but automating some parts of it would increase the efficiency of the models. For example selecting intersecting points as a barrier should be automatic to avoid delay and human errors.

The study was successful because it was able to achieve the objectives. It provided an insight into practical problems that might be associated with the service areas and the models. These problems are solvable and will be addressed in the future. The next section of this chapter discusses some of these challenges and how they can be overcome in the future.

5.2 FUTURE WORK AND RECOMMENDATION

This project was limited to the available data from Henry County and the Indiana atlas database. A project of this nature requires very current information. The attributes of the streets data was not current; the information about trains was not available and
therefore many assumptions were made. In the future, the street information such as traffic speed, pavement condition and one-way streets needs to be verified by driving through the study area. Information about trains must be obtained by developing a working relationship with the train company.

For faster identification of accident sites, we need a more detailed database of the landmarks and detailed major and minor roads information which would be developed over a long period of time.

The Routing and closest facility models are very useful in solving emergency service routing problems. However the models could be improved by:

- Making the barrier selection and address finding automated to reduce errors and also to save time.
- Develop the models using ArcGIS Engine so that any computer with ArcGIS runtime license is able to run the models.
- Finding ways of publishing the models online for easy access by any emergency service.

The best option for trains and emergency vehicles to cross each other simultaneously is to build underpasses. Instead of spending minutes waiting on trains or travelling long distances because of a train obstruction, these underpasses would be used to save time and energy.

From interview responses, Henry County emergency services provide exceptional service to county residents, considering the limited resources at their disposal. An
improvement in the service could be made possible by a careful planning and a high level of training. Planning could involve focusing on extending service areas to areas currently outside the respective acceptable service radius by improvement of road conditions. The use of models such as Routing and closest facility Models would not only improve transportation, but would also reduce the response time thereby saving more lives and property in times of accidents or fires in the county.
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APPENDIX I – QUESTIONNAIRES

Medical (ambulance service)
1. How long have been in operation?

60 years...(since 1944)

2. Do you use any model (guidelines)? How does the model (did you adapt the guidelines from there original form) work for you?

WE ARE PALE, FAKE, FAKE, DODGE, DODGE. HAVE NOT BEEN FRAUD. ACROSS NEW YORK, AUS.
We're out family work.

3. Average response travel time (time taken to travel to emergency site)

COUNTY RANGELY 8-15 DEPENDING ON DISTANCE

4. Does your department respond within a specific district or randomly selected? Please explain

SPECIFIC DISTRICT BUT WILL RESPOND ANYWHERE.
THE COUNTY WE ARE IN.

5. On average, how many calls per day?

12-14.

(2007: 6000/12=500)

6. Which, part of the year is the peak season for emergency calls and why?

JUNE-JULY. FIRST, BECAUSE OF THE MURDERS, BUT ALSO THE LOST WAGES. THIS YEAR STORM NEW YORK CITY.

7. What specific problems do you face in transportation concerning routes

WE ARE NOT ALWAYS THE SAME ROAD ARE CLOSED OR RESTRICTED,
KNOWING THE SHORTER ROUTE... HOWEVER, SOMETIMES NOT ALWAYS THE BEST.

8. Do or could trains impede or have any effect on response travel time? How?

YES. IN THE CITY THERE IS ONLY ONE TRACK. THERE ARE NO OVERTURNED TRAINS. THE COUNTY ARE NOT SURE. HAVE TO FIGHT OUT HOW TO GET AROUND THE TRAINS.

9. Any other general problems? List them

ANY TRAINS ARE KNOCKING ARE FLOW TO THE AREA.

BUT HAVE HAD WALKER UP BY CAR & MUST OR SIMILAR ADDRESS.
Police Service (Sheriff's Dept)

1. How long have been in operation?
   
   *Since county was founded. About 1823*

2. Do you use any model? How does the model work?

3. Average response travel time (time taken to travel to emergency site)
   
   *Depends on where the Officer is in reference to the call. Sometimes can take up to ½ hour.*

4. Districting or randomly selected? please explain
   
   *Districting. County divided in 1/3. North / Central / South. One car each area. The Central car is usually Shift Supervisor and will Assist in other areas. If need be all three can respond to any area as assigned. During the day and afternoon Detectives are available if needed to assist in any capacity.*

5. On average, how many calls per day?
   
   *80*

6. Which part of the year is the peak season for emergency calls and why?
   
   *Summer. More people are outside of their homes. Also school is not in session.*

7. What specific problems do you face in transportation concerning routes
   
   *Problems with road construction or anything that blocks all or part of the road. Most of the construction companies work with the Sheriff's Dept. to minimize this.*

8. Do trains impede or have any effect on response travel time? How?
   
   *This again depends on where the call is. There have been a few times when the train is broken down and has the crossings blocked until it is repaired.*

9. Any other general problems? List them
   
   *Costs associated with fuel, vehicle maintenance and downtime as well as the recent major cut to the property tax that funds our department that the State of Indiana passed.*
Fire service questionnaire

1. How long have you been in operation?
   a. over 100 years.

2. Do you use a model? How does the model work?
   a. Yes. 110 full-time paid personnel, with a minimum of 29 firefighters on duty 24 hrs a day, 7 days a week, 365 days a year. Which respond from 7 stations.

3. Average response travel time?
   a. 7 stations, can arrive on scene anywhere in the city from time of being toned, in 3-5 mins.

4. Districting or randomly selected?
   a. Districting, 5 zones or districts.

5. On average, how many calls per day?
   a. approx. 16.5

6. Which part of the year is the peak season for emergency calls?
   a. There is no real peak season.

7. What specific problems do you face, in transportation concerning routes?
   a. Train tracks, traffic, narrow roads and or alleys.

8. Do trains impede or have any effect on response travel time? How?
   a. Yes, because there are areas in the city that cannot be reach without crossing train tracks.

9. Any other general problems?
   a. Funding
      antiquated equipment
      aging facilities