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COLORADO TECHNICAL UNIVERSITY

RESPONSE TO CRISIS AND DISASTER MANAGEMENT THROUGH THE INTEGRATION OF TECHNOLOGY INTO A VIRTUAL CONSOLIDATED OPERATIONS CENTER

A DISSERTATION SUBMITTED TO

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IN CANDIDACY FOR THE DEGREE OF

DOCTOR OF MANAGEMENT

DEPARTMENT OF ARTS AND MANAGEMENT

BY

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COLORADO SPRINGS, COLORADO

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gave me the confidence to argue thoughts and ideas in an open forum. She stimulated my curiosity on why we, as members of society are not stretching ourselves to contribute to our communities. Her class project on establishing a community college curriculum for a eastern seaboard city, that would support adult learning and advancement helped me realize what we were capable of doing to help our nation, through our scholastic endeavors.

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ABSTRACT

This research explores problems that have been identified in response to crises, disasters, and incidents, by governmental and service organizations. There is a presentation of findings by the Government Accounting Office on how the Federal Emergency Management Agency can improve their response to crises. Additionally, there is a review of studies in the efforts of local and county government agencies to improve their responses to crises, disasters, emergencies, and incidents.

Identification of specific areas that need to be addressed in improving the response of agencies to these situations is given. There is a look at technology that is able to help improve response. The technologies researched are in present use and are proven entities. Further, there is research in how these technologies may be integrated in a different way and implemented into a new concept called the virtual consolidated operations center.

Data is compiled to look at the possible improvement in response times to incidents. This data covers two separate periods of time, with and without the use of the studied technologies. The data is historical and covers the emergency medical services organization operating in the El Paso County, Colorado region.

Research is also included on the benefit of response time. The research covered mortality and morbidity rates based on response times. Additionally, there is a look at research that discusses medical costs for emergency treatment and rehabilitation of trauma patients. The data from this area also discusses the lifetime medical costs and lost work costs.

Generic models are developed for looking at both the costs and benefits from using the integrated technology. These models will assist organizations in determining the impact of using the integrated technologies and the virtual consolidated operations center concept.

CHAPTER I

INTRODUCTION

The United States is both blessed and burdened with information from the media. When a disaster or crisis occurs, the media are quickly on site and provide us with the ability to see the damaged structures, broken bodies, and human suffering. As the population sees the media's reports on the disaster, the actions taken by the emergency response organizations come under critical review. FEMA (the Federal Emergency Management Agency) was chastised by the public and the Clinton administration for its poor performance during hurricane Andrew in 1992 (Sylves 1994, 1995). Articles also show that, in this same disaster, other organizations' images fared quite well with both their employees and the public at large. Specifically, BellSouth Advertising and Publishing Company was prepared to respond effectively due to its crisis management and disaster planning (Kruse 1993). In many articles, it is apparent that technology is one of the tools that permits quick response to the emergency situations that occur.

Looking further, it is certain that the United States is perhaps the most technically advanced society in the world. Every day there are spin-offs of new products from existing technology. At the same time, people are finding new uses for existing technology. One example is the miniaturization of the video camera, allowing people to carry this device in an unobtrusive manner, taking up little more room than the standard photographic camera that was common fifteen years ago. The advent of the personal computer and the variety of applications software packages have given rise to their use in many homes. This more common usage has helped to create even more innovative uses and an expanded reliance on the technology. The Global Positioning Satellite (GPS) receiver is yet another example of new technology that was developed for a specific reason and has flowed over into other areas. Obviously, the use of technology is only limited by people's imaginations.

Concomitant to this expansion in the development and use of technology, this country has seen a tremendous expansion in the presentation of information. The most common presentation is the daily news programs. These programs are also formatted as news magazines, where a program will have three or four specific topics covered in greater detail. An example is found in the evening national network news programs where there is a specific segment, such as "Eye on America." Additionally, news journalists frequently will do some investigative inquiries into a topic and reveal the findings to the public. The topics run the gamut from social problems to corruption. The programs, such as "20/20" and "Turning Point," are hour-long segments. A major result is a citizenry that is more informed and doing more questioning of its government and is expressing its dissatisfaction with fiscal expenditures and policies. In the elections of 1994, the country saw a significant change in control of the Senate and House of Representatives. The public seems to be looking for greater responsibility and accountability in government spending (Botner 1991, 444). Botner states that local governments are experiencing fiscal stress. Because of the stress, local governments are placing emphasis on efficiency and performance. Further, Botner states that taxpayers are becoming more resistant to tax increases. (1991, 443-444). Poterba and Rueben's study identifies taxpayers' resistance to higher taxes and their wanting improved local services. He also emphasizes the stress on local governments due to these factors (Poterba and Rueben 1995, 384).

As taxpayers look for better utilization of public funds, they are going to question the structure of public organizations and institutions. Where they see that an organization has duplication of effort and inefficiencies in operation, the public is going to be more demanding of change in those organizations. This will be manifested by the voting in of regulations that limit the expenditures and tax increases of the government organizations and elected officials or representatives. Public officials and municipal administrato·· are certain to feel this pressure and are going to look more carefully at what can be done. They will be concerned with making changes and doing so in such a manner as to minimize the impact on day-to-day operations.

The question is then, "What does all this mean?" This means that local governmental functions must be lean in budget expenditure, efficient in operation, and smart in application of resources. Those resources consist of facilities, equipment, and manpower. How can this be accomplished? Local communities can have more responsive, efficient, and effective operations through integration of newer technology. Additionally, through the proper integration of technology the negative impact on those public institutions may be minimized. Government leadership will be less susceptible to public criticism due to improvement in service and efficiency.

It is important for a government organization to be able to respond to crises and disasters. The response must be quick and directed to the resolution of the specific incident. As the literature indicates, there is a significant focus on communications and coordination between supporting organizations, especially those with mobile resources.

Further, the literature acknowledges that communications and coordination are especially important in the containment and recovery phases of crisis management.

As the above areas of concern have been identified, an integrated solution will be presented. The solution requires research in the following areas:

1. Identification of technology that can support crisis, disaster, and emergency response and management by improving communications and coordination in organizations having mobile resources,

2. Identification of costs to current operation of mobile resource dispatch, by modeling a current functional organization within a department of the city of Colorado Springs. This must be followed by the identification of projected costs in operating that department with the integration of technology through development of a model of the proposed operation

3. Development of a cost, performance, and benefit model of mobile resource dispatching to compare the current system to the proposed system.

Statement of the Problem

Organizations that involve the dispatching of multiple mobile resources appear to operate in a manner in which efficiency could be improved. This efficiency improvement would allow an organization to provide equivalent service for the same or fewer dollars per unit of service. For the purpose of this study, the term, efficiency, will mean the utilization of fewer resources while providing an equivalent level of service. Those resources include personnel, equipment, and funds.

Overview of the Study

In the overview, there will be an explanation of the purpose, scope, significance, contribution, hypothesis, assumptions, and limitations of the study.

The General Objective of the Study

The direction of this study will be both exploratory and descriptive. It will be exploratory in that there will be a look at an innovative solution to the problems identified through research. This study will look at a new way to coordinate and communicate the allocation of mobile resources to incidents, emergencies, and crises. This new way will bring into play the concept of Virtual Consolidated Operations Centers. In the course of this study, it will be determined whether the concept of virtual consolidation of operations centers can be accomplished and provide improved response time at reduced cost per unit of service. The exploratory nature of this study will look at the question of what can be done to improve communications and coordination of governmental agencies that dispatch mobile resources. This study will be descriptive by virtue of examining the practices of a specific organization. By examining this organization, an answer to the question of how they are improving coordination and communications will be provided. The question of why is answered early in this study by identifying the problems that have been delineated in the management of crises by government agencies.

Since this study is exploratory as well as descriptive and the focus is on contemporary events, Yin suggests that a case study, archival analysis, experiment, or survey would be appropriate research strategies. However, Yin states that an experimental strategy requires control over behavioral events (1994, 6). In this particular study, the researcher has no control over behavioral events. Therefore, an experimental strategy is inappropriate. That leaves survey, archival analysis, and case study as appropriate strategies. Since there is a particular organization that has recently integrated new technologies into its dispatch operations, the case study strategy is appropriate. However, data is available from the county archive that allows for comparison and analysis of data covering the time period involved. This data implies a combination strategy of case study with some archival analysis. (Yin 1994, 6)

The Virtual Consolidated Operations Center

An operations center is generally a location within a facility where an organization has personnel and communications equipment assembled to assist in the decision process of allocating resources to specific problems or incidents. For instance, a police department will normally have an operations center in which there will be a communications capability composed of both telephone lines and radios. The telephone lines allow people to call into or out of the operations center. Telephone calls into the center are normally requests for response from the organization. Telephone calls out of the center are for requests for additional information or for help from other organizations. Radios are used to make contact with mobile resources to dispatch them to an incident site or to determine their current status and location.

The consolidated operations center would be a location where all organizations that might be needed to respond to incidents are collocated. This collocation decreases the need to make telephone calls to other organizations for support since a representative of that supporting organization is present in the operations center. This allows for speedier response to requests for assistance. However, there can be some problems in establishing this consolidated environment since the managers might feel that they are losing control of their personnel.

The virtual consolidated operations center has the advantage of having representation of each organization available through computers. This will occur by having the organizations connected through the sharing of data and information. Each organization has its computer manned by a representative who has the authority to commit its resources to an incident when needed. Thus, information can be shared between organizations, yet its personnel remain within the organization's facilities. The strengths of having the ability to quickly communicate the need for resources, coordinate the providing of those resources, and commit resources from a variety of organizations are possible through this concept.

Scope of the Study

The study will specifically look at the dispatch operations of the emergency medical services organization serving Colorado Springs and El Paso County. This organization is an appropriate subject for this research since it is has multiple mobile resources that are scattered throughout its service area. Additionally, quick response is critical to the welfare of the local population. Any effort in dispatching, controlling, and monitoring of mobile resources that duplicates similar functions in other departments of the county or the city of Colorado Springs will be adequate to act as a transferable baseline. This baseline operation will then be studied and modeled for virtual consolidation. All modeling for cost, performance, and technology integration for virtual consolidation will be prototyped by using the emergency medical services organization's dispatch operations as the focal point.

Significance

It is apparent from the literature that there is a need to improve communications and coordination in order to contain and recover from a disaster or crisis. It is important to demonstrate that virtual consolidation is a viable concept that can be readily implemented by integrating existing technology. It is significant that improved efficiency and service response can be accomplished through this concept.

Contributions

The first contribution to the body of knowledge is in the modeling of a dispatch organization in its current form and in the virtual consolidated form. The model is generic and should offer broad application for other dispatch of mobile resource operations.

The second contribution of this study is the identification of specific technologies that can be integrated into a system that provides the virtual consolidation environment.

The final contribution will be in providing comparisons of the operational costs and methodology of the current organization to those of virtual consolidated operations.

Hypothesis

The use of state-of-the-art communications and technology, integrated into a virtually centralized dispatching facility, will provide an equivalent level of service without increasing costs of operation and without a significant increase in the response time of organizations having mobile resources.

Definition of Key Terms

ARGS – Automatic Route Guidance Systems. This is a system that determines where a vehicle is presently located, where it is going, and the optimal route, as well as providing guidance to destination (Karimi 1991, iii-iv).

ATIS - Advanced Traveler Information System. This is a system that provides mobile personnel with information as to the best routes to use to travel to a specific destination. The system constantly monitors traffic density and speed and is able to provide the information through radio or electronic boards along the main thoroughfares (Geehan and Suen 1993, 389).

ATMS - Advanced Traffic Management Systems. This is a system that monitors traffic density and then provides control over traffic flow devices, such as traffic lights, to control the entry of and movement of vehicles over particular routes (Boyce and Rouphail 1993, 65-66).

Crisis -- The Second Edition of the Random House Unabridged Dictionary, 1993, states, "1. A stage in a sequence of events at which the trend of all future events, esp. for better or for worse, is determined; turning point. 2. A condition of instability or danger, as in social, economic, political, or international affairs, leading to a decisive change."

DGPS -- Differential Global Positioning System. This is a method of providing greater accuracy to GPS signals by adding a reference receiver that transmits a corrective data signal to the mobile GPS receiver (Hurn 1993, 11-13).

Disaster -- The Second Edition of the Random House Unabridged Dictionary, 1993, states, "1. a calamitous event, especially one occurring suddenly and causing great loss of life, damage, or hardship, as a flood, airplane crash, or business failure."

GPS -- Global Positioning System. The GPS system works by means of a receiver measuring the time it takes for a signal to be transmitted from a GPS satellite. The GPS receiver has a program that computes the time into distance and through triangulation of multiple satellite signals is able to place the receiver in a three dimensional location (Hurn 1989, 12-21).

GIS -- Geographic Information System. This is an automated database that stores the geographic characteristics for display on a map.

IVHS - Intelligent Vehicle Highway Society. This is an organization that is a conduit for research involving new technology and methodologies in the handling of traffic.

LAN -- Local Area Network. This is a computer network that resides within a facility and allows for the sharing of resources.

Virtual -- The Second Edition of the Random House Unabridged Dictionary, 1993, states, "1. Being such in power, for, or effect, though not actually or expressly such...3. Simulated or extended by computer software." An example is virtual memory in a computer. What occurs in virtual memory is that the internal storage (memory) of . computer is finite in size. It might have 8mb (megabytes) or 16mb of internal memory. Through the use of software (normally within the operating system) it allows the use of peripheral storage devices (hard disk drive) to act as an extension of the internal memory. This technique allows the computer to perform as if it has a greater capacity.

WAN -- Wide Area Network. This is a computer network that ties together multiple facilities that may be located at some distance from each other.

Assumptions of the Study

The assumptions that impact this study are identified as the following:

1. The emergency medical service's dispatch operations are representative of dispatch, control, monitoring, and operations of other functional departments within a county or city.
2. The personnel costs for the studied emergency medical service's dispatch operation are representative of other organizations having to dispatch mobile resources.
3. The emergency medical service's users can be related to other county and city functional service users.

Limitations of the Study

This study will be limited to looking at the current technology that will allow for the virtual consolidation of operations centers. Additionally, there will be a focus on the response to incidents through use of technology and the virtual consolidated operations center concept. Any modeling of the concept will be through its application in the emergency medical services to the city and surrounding county area. This limitation is due to the fact that data is available reflecting the dispatch operations of this particular type of organization. The organization is called American Medical Response, Inc. Review of the available technology will be limited to those products that are currently being produced or that have been advertised or written about in professional or business journals. With the constant spin-off of new products, there has to be an imposed limit or this study can never be completed.

General Objectives of the Research

This section will describe the methodology of the study. It was stated earlier that this study is exploratory and descriptive in nature. It addresses the problems that have been identified in government studies as to what emergency response organizations need to do to improve their response to crises. At the same time this study examines how technology may be integrated to provide a possible solution to the problems. Since American Medical Response, Inc. is currently integrating that technology, that organization is the focus of the data that is collected for this study. Therefore, this study will take the form of case study of that organization's use of technology and the impact on the community. Since a case study appears to be the appropriate approach for this study, Robert K. Yin's book, "Case Study Research Design and Methods," Second Edition, (1994) wil' be used as a source to provide direction for the questions that must be asked to assure that the quality of the study is maintained. However, it is not the intent to follow a format that will not allow the practical implementation of the findings of the study In this section, the questions that must be answered, from a form standpoint, will be presented and help give the reader a sense of the rigor applied to this work.

Yin states that it is important for the case study to address three initial questions. The first is the type of research question that is posed. This was answered in the opening paragraph of this section where it is explained that this is both an exploratory and descriptive research. The second question looks at the extent of control that the researcher has over the behavior events that occur in the study area. In this study the researcher has no control over behavioral events and dispatch is a behavioral event, but not under the researcher's control. The third question looks at whether the study is contemporary or historical in nature. Yin defines *historical* as being when participants or observers are dead and can not be interviewed or surveyed. This study is contemporary.

Aim of the Study

Based on the answers to those three questions it is possible to determine the aim of the study. Since the questions being posed answer what the problem is and what a solution may be, and how technology may be integrated, the research strategy can take the form of a case study. Additionally, the researcher in this study has no control over behavioral events, the strategy cannot take the form of an experiment. Further, since the focus of this study is contemporary, an historic strategy is inappropriate. Therefore, it is determined that the strategic approach is a case study with some archival analysis (since there is archival data available for research) (Yin 1994, 6).

The aim of this study is to determine if the integration of technology by American Medical Response, Inc. has impacted their service. Additionally, this study will look at the service response prior to and after the integration of the technology. Further there will be a comparison between these two periods and an analysis to determine the amount of change. In this case study there will be development of the cost and benefits from the use of the integrated technology. From that point there will be an analysis to determine the differences in service from one time period to the other as well as cost. An additional method will be used to substantiate the findings from cost-benefit analysis. That method will be the use of queuing theory.

The significance of this study will be in identifying the amount of change in cost to the change in service response between a period when the emergency medical services was and was not using integrated technology for dispatch and control of its resources.

Design of the Case Study.

Yin states (1994, 18-19) that the difficult part of doing a case study is in the research design. For other strategies there are comprehensive guide books which have not yet been developed for the case study methodology. Yin points out that an action plan must be in place to show how the researcher intends to get from here to there. The here is the set of questions to be answered and the there being the conclusions from the data or information obtained relating to those questions.

In this study, the questions are as follows:

1. What are the problems that face governmental agencies in crises, disasters, and emergencies?

2. Can technology help governmental agencies in resolving crises, disasters, and emergencies?

3. What technologies may be integrated to assist governmental agencies in improving their response to crises, disasters, and emergencies?

4. How may these technologies be integrated to improve responsiveness of governmental agencies to crises, disasters, and emergencies?

5. Are the costs prohibitive for the benefits gained in integrating the technologies to improve responsiveness of governmental agencies to crises, disasters, and emergencies?

The propositions that are derived from the questions are:

1. Current technology is available to organizations to improve responsiveness to incidents.

2. The benefits derived from the use of the integrated technology will result in cost savings.

The unit of analysis for this case study will be the emergency medical services organization (American Medical Response, Inc.). This agency provides for the movement of individuals from an incident site to a medical treatment center. This organization has ambulances that are manned by two-person crews. The organization recently integrated technology into its dispatch operations and ambulances. Since data is available that provides information as to response to incidents before and after integration of the technology, this is a good subject organization on which to focus the study.

Yin states that the linking of data to proposition and the criteria for interpreting the findings has been the least well defined in case studies (1994, 25). He indicates that pattern matching can be useful and helpful to demonstrate similarities between pieces of information. Further, Yin has said that there is currently no precise way of setting criteria to calculate variance or to conduct a statistical test. Therefore, in this study, the means of providing the linkage will be through showing the data that is generated from a specific time period and comparing it to the data from another time period. Specifically, there will be the comparison of response times and cost before and after the integration of the technology. The criteria for interpreting the data will be comparison of the results of the data from before and after the integration of technology into the operations. If the change in the areas being compared (cost and service response times before and after technology) is 10 percent or less, the change will be determined to be insignificant, 11 percent to 20 percent will be determined to be moderate, and for differences greater than 20 percent will be determined significant. Yin's comments lend no advice on the area of determining criteria other than to say that this is an area that is not well developed.

Quality of the Research Design

The purpose of this section is to address the quality of the research design of this study by explaining how it was determined what data was to be collected. In order to determine whether technology helps to decrease response time, several elements were necessary. The first was to find an organization that conducted centralized dispatching of mobile resources. That organization was the emergency medical services organization supporting Colorado Springs and El Paso County. That organization is American Medical Response, Inc. The data they provided was actually rendered by reports from the El Paso County Health Services Office. Further, literature search revealed the various technologies that were available that could successfully be integrated into a solution. This data came from a variety of sources that included journals, newspapers, and interviews with vendors and personnel in organizations using the technologies.

Construct Validity

Yin gives a definition of construct validity as establishing correct operational measures for the concepts being studied (1994, 33). He states that the use of multiple sources of evidence is an important method to demonstrate construct validity (1994, 34). From the definition, if it is the intent to show a change in a specific area then the data that is collected must be able to support that intent.

The changes looked at in this study are meant to show that the integration of technology in operations that dispatch mobile resources provides a benefit. The data that provides that type of information would be response times to requests for support. It was determined that the actual data to be used to measure response times would best come from the El Paso County Health Services Office. That organization is responsible to assure that the county (to include the city of Colorado Springs) was receiving the level of support necessary from an ambulance service. The data came from monthly reports that were submitted to the El Paso County Health Service Office by the service provider. That data is available to any individual requesting it and is used to help monitor the support being provided. Further, that data is included, in the same form provided to the researcher, in Appendix A of this study. Additionally, interviews were conducted of personnel in the operating organization, vendors, as well as literature search. Based on these three sources of evidence the validity of the construct of this study is supported. (Yin 1994, 34)

Internal Validity

Yin's definition of internal validity is, "Internal validity (for explanatory or causal studies only, and not for descriptive or exploratory studies); establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships." (1994, 33)

Even though this is both an exploratory and descriptive case study and Yin states that internal validity is not a question to be answered for descriptive or exploratory studies, this section will discuss why this particular study answers questions concerning internal validity (1994, 33). The internal validity of this study can only be questioned due to possible alternate interpretation of the results and explanation (Yin 1994, 35), given in Chapter V of this study. It is clearly indicated that the decrease in costs was due to the use of the GPS, GIS, and wireless data communications. However, at the same time the reader is clearly informed that there is another possible explanation of the decrease: management making the decision to not provide as many ambulances in the period after the integration of technology. However, it must be pointed out that the data used in the computations did give specific indications of cost and resource reductions with minor decrease in service response, supported the conclusions found in each set of results. At the same time, it must be noted that one factor that will support the internal validity of this study is the pattern-matching that is discussed in the Chapter IV. In that chapter, Figure 15 shows the response minutes per miles. The analysis of the chart indicates no difference with or without GPS. That indicates that, even though there was a significant decrease in the number of ambulances after the introduction of technology, there was no difference in the response time per mile to be covered. The difference between the two measured periods was the introduction of technology in the form of GPS and GIS. Yin would say that this gives internal validity to the study (1994, 25-26, 35, 106-108).

External Validity

The definition of external validity is the establishment of the domain in which the findings of a may be generalized (Yin 1994, 33). It is the ability to take what has been found in a particular study and being able to apply it to another similar domain. It is suggested by Yin that there must be replications of the study in order to determine that the results are typical from one application to another of the same type domain (1994, 36).

When looking at the External Validity, questions need to be addressed to this work. The questions would be to the generalizability of the results of this study to other areas. It could be assumed that other ambulance services would have similar expectations of cost savings and response times (Yin 1994, 35-36). Since this was the study of just one city/county and its ambulance service, to gain confidence, it would be best to conduct another study of another city/county and its ambulance service. If the results showed similar indications, there would be greater indication of the generalizability of these findings Further, it is necessary to also look at the police department, county sheriff's office, the utilities department, as well as the transportation organization. The data for each of those agencies would be somewhat different. The finding that would be helpful for the police department would be that a relationship of the speed of response to a call and the diminished escalation of violence in a domestic violence call. There was found to be a lack of data and information in this area even though there was an indication of a belief that there is a relationship. For the utilities department the measure could be the cost of utilities lost (gas and water) by not responding quickly enough to a call for assistance. For the transportation department the data would probably concern the ability to divert its vehicles from congested areas or areas where emergencies are occurring. Possibly, the transportation department could move some of its resources to incident areas to assist in evacuating individuals.

Reliability

Yin defines reliability as being the demonstration that the operations of the study can be repeated and obtaining the same results (1994, 33). The objective of reliability is to assure that any later investigation that follows the same procedures as the one being studied should arrive at the same findings and conclusions (Yin 1994, 36).

The reliability of this study will only be determined when another investigator, using the data provided would come to the same conclusions. To help with this possibility, the data that was provided by the El Paso County Health Services Office is included in its entirety for other researchers. This data is located at Appendix A. At the same time and for the same reason, the interview questions and their answers are provided at Appendix B.

One of the problems in this study is the inability to obtain data on patients and their morbidity and mortality levels. With that data it would have been possible to compare those levels with the ambulance response times from the periods before and after integration of technology to determine if there was a difference. Even though that data was not available, the algorithms that would be used for analyzing that data were developed and are included in the study. This should be a point of assistance and departure for any further studies that might be conducted in the same general area of this study.

In summary it is the opinion of this researcher that this study demonstrates construct, internal, and external validity. The reliability question is open and will only be proven when other studies are conducted in the same area either in Colorado Springs or elsewhere.

Type of Case Study

Yin breaks the basic types of design of case studies into four types. The types of design are single–case and multiple-case studies. They are then broken into being single or multiple units of analysis. He further states that multiple-case designs have the advantage of providing more compelling evidence than do single-case studies. However, he does indicate that single-case studies are quite meaningful when they pertain to an extremely unusual situation or a one-of-a-kind case (Yin 1994, 38-46). Yin's comments on single unit of analysis compared to multiple units of analysis call attention to the problem of being drawn down a side issue and losing the focus of the study. He, therefore, has implied that a single unit of analysis is the preference. Summarizing Yin's comments, there is a preference for a case study that is a multiple-case design with a single unit of analysis.

Depending on interpretation this study could either fall under a single-case or multiple-case study. There is little question on whether this study has a single unit of analysis or multiple. Since the studied organization is a single organization and not two or more, then this must be a single unit of analysis. Additionally, this researcher looks at the study as being a multiple-case study. This is due to the fact that there are two clearly defined time periods that data has been collected from. The first time period is the emergency medical services with data from the time period prior to integration of technology. The second time period is the emergency medical services organization with data from the time period after the integration of technology. This clearly allows for the analysis of data for both periods and then a comparison of the two.

In light of this information, it is suggested that the evidence from this study should be considered compelling.

Case Study Method

The definition of what this case study intends to accomplish is previously discussed. The hypothesis, research questions, and propositions have been previously identified. It was also stated that this would be both an exploratory and descriptive study with some archival analysis. Further, reasoning was presented that this would be a multiple-case design with a single unit of analysis.

The determination of what data would assist in answering the questions is presented here. First there were multiple sources for the data that was to be collected.

The data came from documentation, archives, and interviews of individuals. The data that was desired covered the problems in crises management for governmental agencies, crises management theory, technology that was currently in use to help resolve the problem areas, and the costs related to the acquisition and operation of those technologies. Additionally, archival data was necessary to help define what the response times were prior to the agency's integration of technology as well as after. Interviews were conducted to determine costs associated with the operation of the technology and equipment. The interviews also identified the technologies that were currently in use after the integration effort. As this indicates there is a triangulation of evidence that helps to give support to indications and findings. Yin indicates (1994, 80) that documentation and archival records are very strong sources of data collection. He indicates that they are stable and may be retrieved repeatedly, are unobtrusive, exact, provide broad coverage, precise, and quantitative. Their weaknesses are that they may be difficult to retrieve, there is a potential for bias due to incomplete collection, access may be blocked, and privacy issues might be a problem. This study has attempted to eliminate the potential for bias due to incomplete collection by having gone through an extensive literature review. The evidence is included at Appendix D. In this appendix is a complete list of all documentation that was reviewed during this study. It is comprehensive and provides further sources of information for any subsequent research. The bibliography is based only on those elements that are directly referred to in the study presentation and considered to be the focal elements in the study. However, they were not the only sources used and the other documents do have pertinence to any researchers in this area and are available for their benefit. The archival records were both service and organizational records for the time periods involved (Yin 1994, 83).

As previously stated, the research for this study has been exhaustive. The evidence is in Appendix D. In that appendix a listing of all the documentation that has been reviewed is included. The documentation identified in Appendix D is relevant to this study and supports the conclusion and analysis. Further, the study and the referenced literature, as well as the references identified in Appendix D, give compelling support to the integration of technology as a means of improving response to incidents, coordination, and communications in operations involving the dispatch of mobile resources. Yin has said that exhaustive research is necessary. He states that it is important that the analysis has been made through the use of this research. Additionally, he indicates that the analysis was made through as much evidence as was available (Yin 1994, 123-124). The inclusion of Appendix D is in support of these comments from Yin and demonstrates the relevant evidence that has been examined.

Organization of the Study

Yin discusses the Linear-Analytic style of presenting the case study research. In that style there is a sequence of topics that must be covered. He states that the sequence is describing the issue being studied, a review of relevant literature, methods used, findings from the data collected and analyzed, and the conclusions and implications from the study findings (Yin 1994, 138-139). This study is structured in a Linear-Analytic style as evidenced by the organization layout presented below.

Chapter I presents:

- statement of the problem
- overview of the study
    - general objective of the study
    - explanation of what a virtual consolidated operations center is
    - scope of the study
    - significance of the study
    - contributions
    - hypothesis
    - definition of terms
    - assumptions of the study
    - limitations of the study
- general objectives of the research
- aim of the study
    - design of the case study
    - quality of the research design
    - type of case study
    - case study methodology
    - organization of the study

Chapter II searches the literature and background for the areas of concern to this study, while Chapter III analyzes specific and relevant information discovered during the literature search. Chapter IV presents a synthesis resulting from the discovery of information along with an analysis of the discoveries. In Chapter V there is a discussion of the results of computations obtained from the cost models and queuing theory algorithms. Chapter VI offers an implementation plan on how the concept may be put in place and made operational. In Chapter VII the conclusions and recommendations developed from the study are presented.

CHAPTER II

SEARCH OF THE LITERATURE AND BACKGROUND

In this chapter, there is a search of the literature involving problems in the handling of crises, disasters, emergencies, and incidents. This search suggests that specific attention needs to be given to the areas of communications and coordination. There is also a search of the literature on crisis management theory. This search emphasizes the containment and recovery phases of crisis management theory. Finally, the literature search includes current technology that can assist in speedier response to disaster and crisis. This part of the search is focused on technology that is specifically directed towards improvement in communications and coordination of mobile resources. Additionally, there is a search on the decision aiding theories with specific review of cost-benefit analysis.

In researching what has occurred and what is taking place in the area of consolidation of operations centers for municipalities, a significant absence of information was noted. There is a large amount of information available concerning the technologies that would be needed for implementing a virtual consolidation center. However, this is where it ends. There are essentially no published works on virtual consolidation and few on the consolidation of operations centers. The lack of research in this area caused concern that this might not be a workable concept and could prove to be a waste of valuable time. However, a number of individuals working in municipalities as the heads of departments and directorates uniformly agreed that there is a need for work in this specific area (Zelenok 1995, Weller 1995, Vernier 1995, Schalk 1995). Further discussion with other professional organizations brought similar results. In early discussions of the concept with people in academia, the same response was found (Anderson 1995, Greenwood 1996). Identification of the individuals and organizations, as well as their relationship or interest to the study, is provided in the section entitled, "Interviewed Individuals and Their Areas of Interest."

In addition to searching the literature, including several doctoral dissertations on pertinent studies, interviews with people managing and supervising work in the impacted areas have been conducted. These interviews were initially recorded on handwritten notes. These notes were then transcribed to audio recordings and important portions transcribed to hardcopy memoranda. The recordings and memoranda are referenced in this document and are appropriately identified within the bibliography and included in Appendix B.

Crisis Management

Management of a crisis occurs in either preparation for handling the complexities of a disaster or responding to a disaster that has occurred. Examples of crises are many, and the success in dealing with them and minimizing their effects varies.

Crisis Management Definition

A concise definition of what constitutes a crisis appears to be a point that scholars cannot agree on. The set of statements that best gives a sense of what is meant by the term *crisis* is in a study conducted by Wenger published in 1978. Wenger begins by saying that it is a concept that is used to describe the, "... state of a social system in a point of time." He goes on to say that the traditional institutional structure has been, to a great degree, rendered to a neutral state or destroyed. He further says that crises, "vary along at least two dimensions: intensity and scope." Intensity refers to the degree of traditional structure that is disrupted. "...By scope, reference is made to the inclusiveness of the social system disrupted by crisis." Figure 1 shows how government organizations are less impacted by lower level events than higher ones, and that an emergency is a lower level intensity event whereas a crisis is a very high-level intensity event. (1978, 26-27)

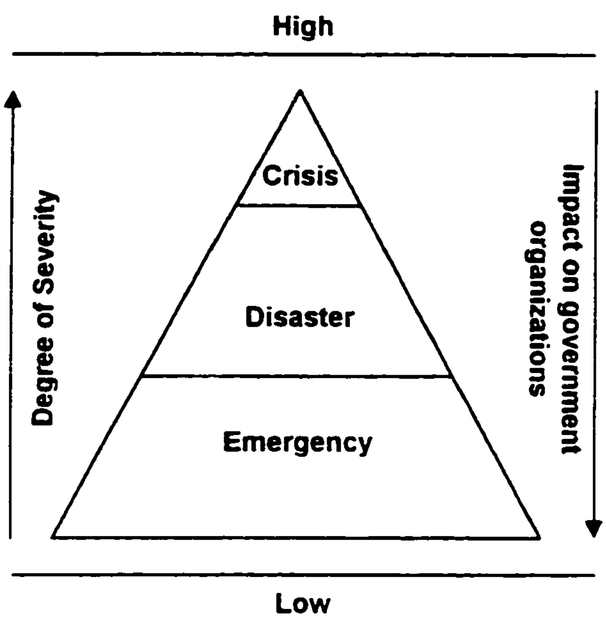

Figure 1. Raising of event levels in intensity and impact on government organizations.

Wenger explains that those things that are a crisis to a city might only be an emergency to agencies higher up in the government hierarchy. For example, the state-level agencies might see the crisis that is occurring within a city only as an emergency since its resources are not highly impacted. Additionally, he indicates that the better prepared an organization is for handling a crisis the more likely the crisis is to not have as serious an impact on the organization's ability to react and minimize the effects. Further, there is an indication that when agencies that make up a city have prepared for disasters and are accustomed to coordinating their efforts then, when a crisis occurs, they are better able to set aside contentions and cooperate in overcoming the crisis. Additionally, he asserts that technology has an impact on their ability to do so. At the same time, there is a centralization of power and this results in an improved ability to successfully react to the situation. (1978, 17-36)

Pearson and Mitroff conducted a five-year study of crisis management. In surveys they conducted of managers, there was a common thread in the definition of a crisis. Those managers said that it had high magnitude, there was an element of surprise, a need for immediate action existed, a requirement was present for immediate attention, and it was outside the complete control of the organization (Pearson and Mitroff 1993, 49).

The relevance of Wenger's work is to give an understanding of how the severity of an event is the measure of whether it is determined to be a crisis, a disaster, or an emergency. He has also identified that a crisis at a lower level in the governmental hierarchy is of much lower impact as you go upwards in the hierarchy. Further, he has found that minimization of the impact of an event occurs when agencies are prepared and have been accustomed to coordinating actions among the agencies. Wenger established that technology was found to have a positive impact on the coordination between agencies and the centralization of power. This is sufficient reason to look for methods to ease the coordination between agencies using technology. The work of Pearson and

Mitroff supports Wenger's previous study in that their surveys of managers found a concurrence of a crisis having a high magnitude, needing immediate action, and requiring immediate attention (1993, 49). This confirms the need for coordination between agencies and the fact that technology can improve the reaction time.

Crisis Management Problems

Just as there have been studies that identify needs for *preparation* for crises, there have been reports on the problems in *responding* to crises. FEMA (the Federal Emergency Management Agency) has recently been severely criticized by the Governor of the State of Pennsylvania. The State had experienced a harsh blizzard, followed by a thaw that caused flooding. Water and wastewater treatment plants were put out of action, and over 30,000 homes were flooded. During this same period 14 separate community water supply systems in West Virginia were damaged. Ice jams caused damage in New Jersey by raising the level of the Delaware River in one area. In Maryland, five counties received federal aid due to flooding caused by floodgates being raised. In all these cases, there was flood damage due to the melting of snow from a prior blizzard. The slow response of the FEMA in providing support has been criticized (Powers 1996, 11-12). In this case we see a natural disaster in the form of the blizzard followed by another disaster, the thawing of the snow and the floods, exacerbated by human-induced crises in the form of the floodgates being raised on the dams.

FEMA has also been under scrutiny by the congress, received criticism from the public, and been subject to reexamination by the Clinton administration. The Congress commissioned NAPA (the National Academy of Public Administration) and the GAO (General Accounting Office) to conduct an in-depth investigation of FEMA's poor performance during all phases of 1992s Hurricane Andrew (Sylves 1994, 303). A specific series of questions were addressed in the investigation:

1. Should FEMA be dismantled?
2. What is the role of the military in a disaster?
3. What is the role of FEMA and civil defense against nuclear attack?
4. How can federal emergency management functions be improved?
5. What needs to be done to build better FEMA relationships with state and local emergency management agencies?
6. How can FEMA improve its links to the White House and to Congress? (Sylves 1994, 303)

Mitroff says that, "It seems that hardly a day goes by without a major organization crisis," (Mitroff 1994, 101; Pearson and Mitroff 1993, 48). Pearson and Mitroff in their five-year research of crisis management say that there is a significant difference between human-induced and natural disasters. They indicate that the public reacts more negatively to the effects of human-induced disasters than they do to natural ones. They have found that managers also defined a crisis as an event or an incident that presents a threat to the reputation and viability of an organization. Additionally, there is a severe strain on the financial, physical, and emotional structures of the organization. The report stated that previous research had indicated that organizations were better able to respond to crisis when they were prepared and had technology and good communications (1993, 48-49).

Each state of the United States has some form of emergency management agency. Such agencies are expected to be able to handle local disasters and are expected to be well organized and to have updated plans, equipment, and facilities. The state agency interfaces with, promotes, and supports local emergency management organizations. It has been noted that the states vary widely in the level of preparedness for emergencies and disasters. FEMA should be assuring uniformity and increasing professionalism of the state and local emergency management agencies. One of the findings of NAPA and by GAO was that the local governments are the first organizations responding to a disaster, with the county often being the key agency. The county agencies work closely with the municipal organizations in responding to crises. The report from NAPA stated that FEMA needed to work more closely with police, fire services, emergency medical authorities, public works, and others (Sylves 1994, 306).

In the investigation of the FEMA, NAPA and by GAO found that FEMA was goaded into response to disasters because of comments made by the press. The investigators talked of the CNN Syndrome, which is explained as follows:

> One of the most dramatic contextual changes for emergency management is the greater intrusiveness and influence of news media. Disasters and emergencies provide dramatic news and the appetites of news media, particularly television, are insatiable. This means that emergency management agencies will have to perform under intense media scrutiny. It also means that few emergencies and disasters will remain local – most will be "nationalized" and politicized as a result of media coverage. This presents particular problems for maintaining emergency management's SOP's (Standard Operating Procedures) and the tradition that local and state governments are the governments with primary responsibility, while the federal government merely supplements their efforts. The media pressures reluctant local and state leaders to "ask for federal help," the president to dispatch such help, and representatives and senators to demand it on behalf of constituents. This "CNN Syndrome" or "camcorder policy process" disrupts and distorts normal procedures and response patterns. The best laid plans and procedures are now vulnerable to disruption, indeed destruction, by one dramatic "sound bite" that the media turns into political shock waves (NAPA 1993; 18. Sylves 1995, 8)

The NAPA - GAO study showed that FEMA had improved since the Hurricane Andrew incident. It was indicated that the improvement showed significantly in the actions taken during the January 1994 earthquake that occurred in the Northridge area of the San Fernando Valley. Additionally, it was determined that strong state and local emergency management organizations would reduce the need for federal intervention and there was better event response from such organizations. It further recognized the close relationship between county and municipal agencies in emergency and disaster response as being key to the support element (Sylves 1995, 27).

It was previously stated that "the populace is more tolerant of nature-induced disasters than human-induced," (Pearson and Mitroff 1993,48). This is significant since it puts a premium on minimizing errors during those events that have been caused by humans. This means that, in many cases, proper planning and training may decrease the number of disasters that are human-induced. A major portion of this elimination of errors is in the ability to contain what occurs and react quickly to resolve the problem. The use of technology and communications can have positive impact on elimination of these errors.

Further, the studies appear to state that good relationships between local, state, and federal agencies need to be established and maintained. This is again a coordination effort. The fact that crises are occurring on a daily basis, and the public is not reading or hearing about them means that organizations are responding in a timely manner and bringing successful resolution to the events. Findings that crises were placing both a financial and physical strain on the organizational structure enforce the fact that methods must be developed to improve the speed of response and resolution of the event. This is particularly true when public moneys are in use since they are limited and difficult to replenish. There was reinforcement to previous comments on the importance of technology and good communications.

These two findings again give pertinence to finding improved uses of technology to impact these areas. The research and problem identification suggest the need to have the significant technology and communications ability at the local government level since local organizations are the first to respond to a disaster event. Identification of the media impact on crisis management decisions again reinforces the imperativeness of excellent communications and coordination between local agencies. Such communications and coordination will help to demonstrate the control that local agencies have over the situation and can assist in alleviating the media's pushing to escalate federal involvement. The competency of strong local and state management organizations will reduce the need for intervention.

Crisis Management Theory

There has been significant study of the management of crises. A common thread in many of the studies suggested that there is a pattern that exists in crises and a theory on the phases of a crisis was subsequently developed. The five-year research of Pearson and Mitroff found that there were a series of phases or stages through which crises must pass. These stages are represented in Figure 2. The research shows that different opportunities exist in each phase and that organizations, "…increase their ability to manage crises by properly managing each phase of the process." (1993, 51-52)

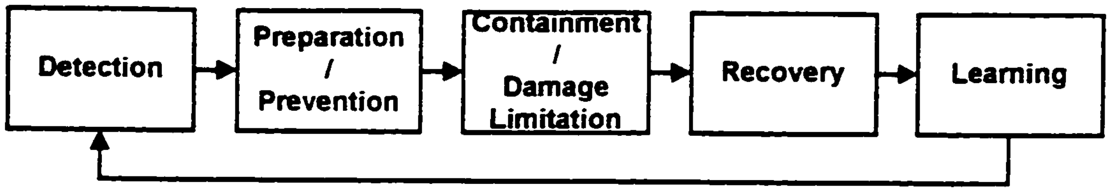

Figure 2. Phases of Crisis Management.

Pearson and Mitroff's 1993 study and Mitroff's 1994 study offer several insights, which are now discussed. In the signal detection phase an organization experiences difficulty in being able to separate those signals signifying a crisis and the standard signals that are constantly coming forward. Mitroff has found that crises that were preceded by early warning averted problems in responding to the crisis. This is the best crisis management. It is important for an organization to maintain explicit communications channels that are open. However, just having open channels does not assure that the receivers are listening and are really interested in hearing about problems. In the next phase, there is a requirement for the organization to be looking for areas that can cause problems and identify those areas that need to be fixed before they create a crisis. Their research also found that it is not possible to prevent all crises from occurring and that it is necessary to be able to respond to those crises with established crisis teams and plans. Recognizing that some crises will occur no matter how much planning takes place, the next phase is to contain or limit the damage. At this stage attempts are made to keep the damage from overflowing into other areas, to move personnel and vital equipment out of the area, and to limit the waste of time in responding to the incident. This is where effective communications channels are important in assuring that the impacted personnel and teams are kept aware of what is happening. In the phase of recovery, the organization commences its normal business albeit in a limited manner.

However, there is the need for procedures to identify the operations needed in order to recover and get back to normal operations. The learning phase occurs last. This is where the crisis teams and management review what has occurred and what was done well or poorly. This is where the existing plans are amended to incorporate those lessons that have been learned. Frequently, this phase is ignored since the crisis is past, business is continuing as usual, and money and time must be conserved. This is unfortunate since reviewing the actions taken immediately after an incident allows for better recall of what the reactions were (Pearson and Mitroff 1993, 53-54; Mitroff 1994, 101, 105-106).

There is recognition that a crisis unfolds from a natural or human-induced disaster. The human-induced disaster is due to the systems impact of the combination of technology, the infrastructure, human factors, cultural, and emotional/belief systems. The interaction of each of these subsystems can cause multiple problems to occur in the prevention of a crisis or the response to a crisis. The indications are that there is a significant need for managers and executives to understand the broad system impacts. The lack of this understanding can result in preventive actions or response actions that can, in fact, set off a chain reaction of other crises (Mitroff 1994, 108, Pearson and Mitroff 1993, 54)

The report on the five-year research effort made the following comments on effective crisis management:

> For effective crisis management, an appropriate infrastructure must be in place. This includes open and effective communication channels among levels and across divisions, as well as job descriptions which specify who is accountable for supporting crisis management activities and reporting bad news. It should be an integrative system which ties crisis management to major ongoing activities, roles, and responsibilities. Permanent crisis management teams must be

established in addition to conventional infrastructure systems. In the best cases, membership on such teams includes all functions and specialties required to deal with crises, such as the CEO and top executives from operations, legal, human resources, management information systems, security and safety, environmental health, public affairs, and finance. Ensuring that members practice their crisis management roles and responsibilities under conditions which simulate the informational and emotional overload that they will face during the heat of a real crisis strengthens this system (Pearson and Mitroff 1993, 54).

The results of the research produced twenty-nine action steps that typify the essential elements of the best program for crisis management. These steps are as follows (Pearson and Mitroff 1993, 58):

Strategic Actions
1. Integrate CM into strategic planning processes
2. Integrate CM into statements of corporate excellence
3. Include outsiders on the Board and on CM teams
4. Provide training and workshops in CM
5. Expose organizational members to crisis simulations
6. Create a diversity or portfolio of CM strategies

Technical and Structural Actions
1. Create a CM team
2. Dedicate budget expenditures for CM
3. Establish accountabilities for updating emergency policies/manuals
4. Computerize inventories of CM resources (e.g., employee skills)
5. Designate an emergency command control room
6. Assure technological redundancy in vital areas (e.g., computer systems)
7. Establish working relationship with outside experts in CM

Evaluation and Diagnostic Actions
1. Conduct legal and financial audit of threats and liabilities
2. Modify insurance coverage to match CM contingencies
3. Conduct environmental impact audits
4. Prioritize activities necessary for daily operations
5. Establish tracking system for early warning signals
6. Establish tracking system to follow up past crises or near crises

Communications Actions
1. Provide training for dealing with the media regarding CM
2. Improve communication lines with local communities
3. Improve communication with intervening stakeholders (e.g., police)

Psychological and Cultural Actions

1. Increase visibility of strong top management commitment to CM
2. Improve relationships with activist groups
3. Improve upward communication (including "whistleblowers")
4. Improve downward communication re: CM programs/accountabilities
5. Provide training re: human and emotional impacts of crises
6. Provide psychological support services (e.g., stress/anxiety/management)
7. Reinforce symbolic recall/corporate memory of past crises/dangers

The above action steps are suggested for businesses but, with minor tailoring, can positively impact governmental organizations and the communities in which they reside.

In previously identified studies, there was mention of the importance of certain activities. They are included in the above action steps. Chartrand presented a paper at a symposium conducted in 1985. The symposium was entitled "Theory and Application of Expert Systems in Emergency Management Operations" and the paper "Optimum Emergency Management: The Effective Use of Information Technology." Chartrand discussed the use of technology to assist in warning response organizations, locating mobile resources, and exchanging information in the emergency operations centers and between remote sites. Additionally, the study identified the need for interagency sharing of data through a communications network that was both flexible and durable. Chartrand also stated this same need existed for state and local agencies to provide mutual assistance through this same technological means. The study indicated that self-sufficiency of a municipality was extremely important (1986, 117-119).

The relevance to this study is found in the third and fourth phases of crisis management. The third phase, containment and damage limitation, and the fourth phase, recovery, are positively impacted by the use of technology and communications and focus on resources to apply to the event. Recognizing that no amount of planning and preparation can prevent all crises from occurring puts the impact on the containment and recovery phases. When Mitroff states crisis management attempts to keep damage from overflowing into other areas, moves personnel and vital equipment out of the area, and attempts to limit the waste of time in responding to the incident, this again supports the significance of communications and coordination as being important elements that can have a positive impact on a crisis event. The comment on the limiting of the waste of time emphasizes that time of reaction is an important element in the containment and recovery phases. Again, this leads one to look at technology as a resolution avenue for this problem. When addressing effective crisis management, there is an emphasis on open and effective communications channels. The perceived need for a system that integrates crisis management with major ongoing activities, roles, and responsibilities is a direct tie to the focus of this study: a virtual consolidated operations center. Pearson and Mitroff also stated that within local government there needs to be an integration of security, safety, and information systems. Security would be the police, while safety would be represented by the fire department and emergency medical response organizations. The identification of the twenty-nine action steps included specific areas that are germane to this study: computerizing crisis management resources, designating an emergency command control room, incorporating technological redundancy, improving communications with intervening stakeholders (police, fire, emergency medical, and public works), and enhancing downward communications. These again can be successfully brought about through the use of technology. Additionally, these areas support the rocus of this specific study. All this is then supported by Chartrand's comments on using technology in locating mobile resources, exchanging resource information between emergency operations centers and remote sites. His identification of the need for data sharing through a communications network directly supports the concept of a virtual consolidated operations center.

Local Response to Disasters

There has been a review of what crisis management is and the theory behind it. Problems in response to disasters have been identified. The importance of communications, coordination, and technology has been reported. At this point a review of how communities respond to disasters will be conducted. This is important since disasters are normally responded to by a local community's resources. Wenger's study gave a list of five normal functions of communities: 1) production - distribution - consumption, 2) socialization, 3) social participation, 4) social control, and 5) mutual support. Wenger's work is particularly interesting for this current study in three of the functions of a community: providing of goods and services to the locality, normative conformity, and support of needs arising from crises. He states that these five functions are carried out concurrently during normal times and that there is little consideration given to priorities during those normal periods. This implies that prioritization does occur when there is an emergency, disaster, or crisis. He additionally states that there are two significant factors relevant to a community's response to a disaster. The first is the degree of integration between the local units of response; the second is the degree of conflict that exists between them. Wenger says that a certain level of conflict will always exist. He indicates that the conflict comes from, "…antagonistic structural arrangement, scarce resources, divergent value patterns, and differential allocation of power, status and prestige; all community systems embody elements conducive to conflict" (1978, 23).

Where Wenger looks at the functions of the local community, Kreps discusses the links that must exist between community organizations. He states that community organizations such as police and fire departments are constantly needing to coordinate and exchange information on personnel, equipment, and other services. Further, it is important to maintain these links since the sharing of data is important to responding to an event in an organized manner. His studies have found that communities who have experienced a disaster or have planned and prepared for a crisis are able to handle the situation in a more routine manner. This then means that, through this preparation and planning, there is a mitigation of the significance of the impact on the community. This would translate to the idea that a crisis event would be handled as a disaster and a disaster as an emergency. This means that the preparation that allows an event to be handled in a more normal manner will result in less negative impact on the local community. Kreps also discusses the impact of communications between organizations and how the level of those communications can assure improved integration of processes between organizations (1978, 78-79).

Thomas Drabek's study on a disaster that occurred in the Coliseum in Indianapolis in 1963 was the foundation for many further studies. This study identified significant factors in the areas of mobilization, communications, coordination, and control. The study determined that organizations that were contacted quickly had fewer difficulties in reaching the disaster site. Kreps also indicated that formal organizations that were larger in size appeared to be able to respond quicker. There was no indication of what identified an organization as being larger. It was found that organizations not tied to a common communications link had intra- and inter-organization problems. This manifested itself in an overload in their separate communications facilities. Underlying all these problems was the lack of a central communications center and link. Since there is a communications problem, this can extend into a coordination problem. Additionally, Drabek states, "…the emergency response effectiveness of any single agency is directly dependent on the level of coordination within the emergent multiagency network" (1994, 28-33).

The significance of the above information to this study, is the continued support of the belief that there is a need for integration between local response units for successful event resolution. Additionally, there are strong comments emphasizing the need for continual data sharing between organizations. The finding that communities which have had prior planning and preparation are able to decrease the impact of an event because they are able to handle it in a more normal manner supports the idea of bringing technology to bear on the problem to allow for faster containment. The impact of communications on assisting the integration of efforts between organizations again supports the data-sharing aspect of virtual consolidation of operations. Drabek's comments also emphasized the communications and data-sharing linkage between organizations.

The common link between the sections on crisis management is that crisis, especially natural crisis, will occur no matter what level of planning and preparation pre-exists. Organizations that have communications links between them will be able to respond quicker to an event, and coordination will be better and faster. Technology can be used to assist in making these components more integrated and the sharing of data easier. It was found that the ability to identify resources and allocate them quickly to a situation allows for rapid reaction and better opportunity to contain and recover from a crisis or disaster. Further, there was identification that the more quickly an organization can respond to a situation the less likely it is to increase its level of intensity, and the overall impact to the locality will be less. It was also pointed out that the greater the improvement of communications, integration of effort, and coordinated sharing of data, the greater the opportunity to decrease the level of conflict that can occur between organizations. Information indicated that, through improved coordination and communications between organizations and agencies, there is an improved utilization of scarce resources. This can positively impact the use of public moneys.

Interviewed Persons and Their Areas of Interest

The next section covers discussions with individuals that work within the local city administration and with academicians having interests in the areas addressed in this study. The following individuals were interviewed or were presented with the purpose of this study. Each was approached based on his/her functional area of responsibility and experience. The identification of these individuals and their relationship to the scope of this study is described in the subsections.

Municipal Functional Departments

The functional departments that are represented in this study are from the City of Colorado Springs and El Paso County. The departments that provided data are emergency medical services and the county sheriff's department. Comments were also solicited from the police, fire, utilities, and transportation departments.

Department of Transportation

Mr. Zelenok is the director of the Department of Transportation. He expressed his concern over the paratransit operations being conducted by several different organizations. He identified a specific on-going situation where paratransit vehicles from as many as four different organizations are observed passing particular intersections of the city. They are observed to be carrying three or fewer individuals, traveling in the same direction, within a five-minute period. His opinion is that there is no coordination going on between the organizations, and that they are not operating in as effective a manner as they could (Zelenok 1995).

Mr. Schalk is the deputy director for the Department of Transportation. He has responsibility for budgeting the operations of the department, including paratransit. He provided paratransit data which are required for local and federal reporting. He indicated the same concerns as Mr. Zelenok (Schalk 1995).

The implication to this study, from these interviews, is that a coordination problem exists between several organizations within the department of transportation. The transportation department has data that may be used for modeling operations of the organization. The available data can be used to support any comparisons between the current transportation procedures and a virtual consolidation concept to see if there is an impact on the scarce funds and any measurable increase or decrease in performance between the two procedures.

County Sheriff's Office

Lieutenant Billiard of the County Sheriff's Office is looking into the possible use of GPS, GIS, and networking to improve the dispatching of the office's scarce and mobile resources. He has indicated that there is a recognized need to be able to quickly identify where resources are and determine which ones may be able to respond faster. Lt. Billiard is not certain of how best to show the benefits but has indicated a belief that there should be a decrease in fatalities, a decrease in rehabilitation time, and a lower escalation of violence. He does not have any data to support these beliefs (Billiard 1996). The significance of this interview is that the Sheriff's Department believes that technology will be important to the improvement of locating, dispatching, and controlling mobile assets.

Police Department

Captain Vernier is the officer responsible for information systems in the Colorado Springs Police Department. His responsibilities include radio communications as well as voice and data networking. He provided overviews and information relating to the current architecture and the future enhancements to the operational capabilities of the department's automated systems. He also identified new technology being brought into the police operations that assist in the dispatching, monitoring, and controlling of mobile resources (Vernier 1995).

The relevance of this interview to the study is that there is an attempt to bring in technology to assist in the control, monitoring and allocation of resources.

Fire Department

Deputy Fire Chief Weller has the additional responsibility of being the 911 Authority for Colorado Springs and El Paso and Teller counties. He is attempting to consolidate the efforts of the communities within these identified areas. The 911 operators are collocated with the Fire and Police dispatchers in the Police Department

Operations Center. This allows for conferring between the dispatchers concerning requests that come in on the 911 number. He has indicated that there is improved response from this collocation (Weller 1995). A local newspaper article also discussed the 911 collocated operations center and the improved response that occurred from this decision. (Zubeck 1995).

This interview was significant in that it demonstrates that there is a partial consolidation of dispatching functions for the local communities and the local and one adjacent counties. The use of data sharing and data communications are specific technologies being used by the 911 authority. The organizational impacts are on the rapidity of coordination of effort and allocation of resources to an event.

Summary of Interviews

The director and assistant director of transportation indicated concerns with the coordination between the departments that provide transportation support within the city. A lieutenant from the county sheriff's office expressed his belief that the use of GPS, GIS, and networking would improve the dispatching of their vehicles. He further stated that he was of the opinion that if sheriff's personnel were able to respond quicker there would be a lower escalation of violence. However, he had no data to substantiate his opinion. An officer from the police department indicated that his department was considering integrating technology to assist in control, monitoring and allocation or resources. The deputy fire chief indicated that there was an attempt to network the 911 operators from the nearby communities and counties and provide data sharing and coordination of service support. The significance of these interviews is that they demonstrate a need for improving coordination of effort and the sharing of data between organizations providing mobile resources. Further, there is a demonstration of a commonality of belief that technology can be used to improve service support.

Technology

In this section there will be a study of the current technology that might be integrated to support the virtual consolidated operations center concept.

Technology must be looked to as a possible means of solving the problems previously identified from crisis management research. Additionally, in order to have a virtual consolidated operations center, it is imperative to have technology to support the sharing of data and information. The technologies to be included must also be able to address those components previously identified as detrimental to good crisis management and response. Therefore, the technology must be able to assist in identification of current resources, location and status of those resources, the incident location, allocation of appropriate resources, coordination of organization response, and communications. The following areas of this section discuss the findings from the literature. The included illustrations show what the virtual consolidated operations center concept is and where the various technologies fit into the concept.

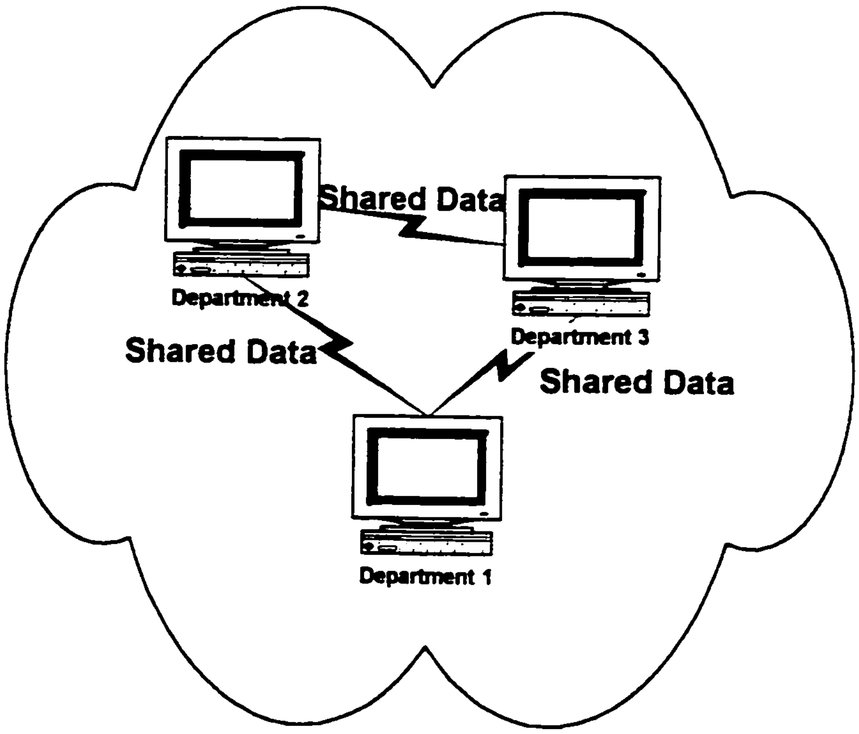

Figure 3. Shared data between functional element dispatchers.

The above figure, Figure 3, shows workstations within separate departments sharing common data. This data is used to communicate what is occurring within a department and is shared with other departments. The significance of data sharing is that it allows for communicating and coordinating actions between functional dispatching elements. This could be between the Fire Department and the Sheriff's Office, for instance. There could be the passing of incident data to various functional elements by the 911 operator so that each functional element is aware of an incident and its location. Then, as a functional element dispatches its mobile resources in response, that data could be passed to the other functional elements so each element is aware of other resources responding to the incident.

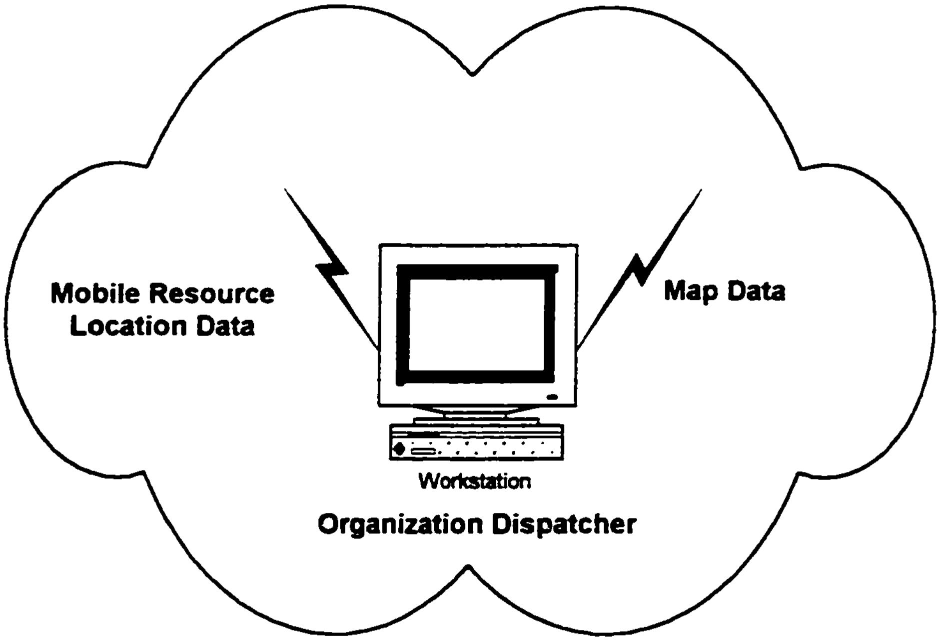

Figure 4. Data available on organizational dispatcher workstation.

Figure 4 shows dispatchers receiving a combination of location data from their mobile resources and map data. The map data can be a map of the area with the mobile resource locations identified as well as the incident location.

Figure 5 shows the multiple, mobile resources of a functional element sending locational data to its particular dispatcher.

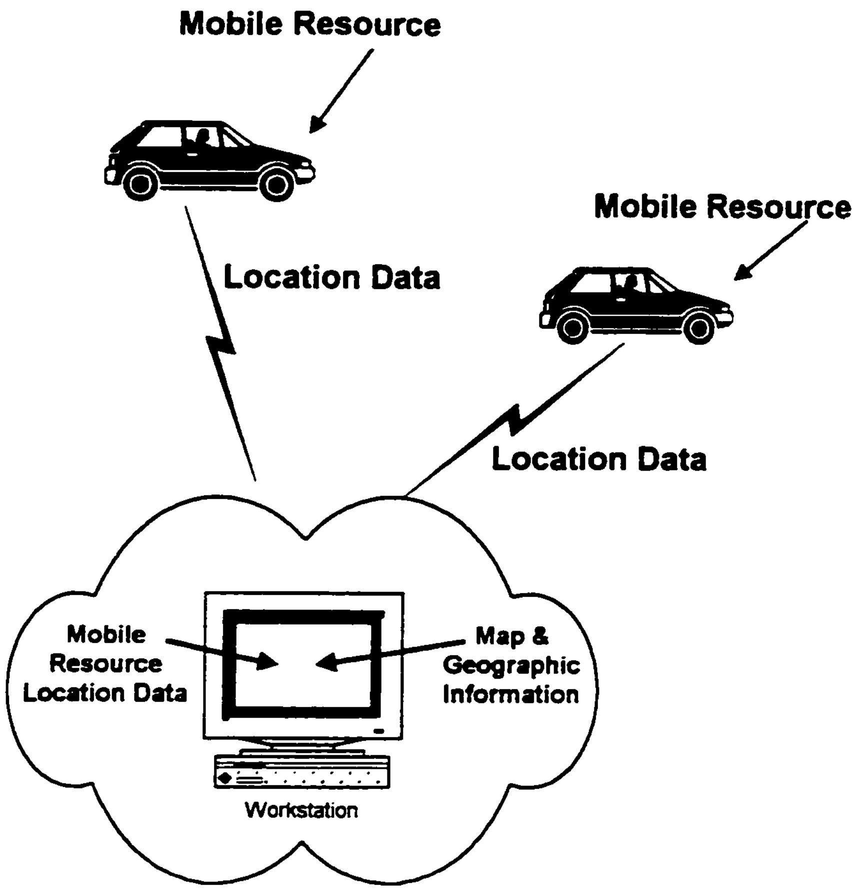

Figure 5. Integration of mobile resource location data and map data.

Position Location Technology

As identified in the crisis management section, there is a need to move mobile resources quickly to the site of an event. In order to do this, it is necessary to know where assets are at any particular point in time and their status. If the operator is not presently in the vehicle, there must be a method of informing the central authority of the location without interaction by the operator. If there is no ongoing means for a dispatcher to identify a resource's location, then the dispatcher will need to make verbal contact with each resource and request a report of its location. It will take some period of time to contact a number of resources to determine which can reach the incident site in the shortest period of time. Additionally, this has significance in positively impacting an incident by quickly dispatching the appropriate mobile resources to the site and, thus, providing an opportunity to keep the seriousness of the incident from escalating.

A variety of techniques exist that allow for determining the location of a vehicle within an area. The sophistication of the techniques has increased with the advent of new technologies. Unsophisticated techniques also exist. However, the emphasis will be on the most recent and more sophisticated techniques. The sophisticated methods use either LORAN or GPS. The unsophisticated techniques use dead reckoning methods or location transmission by IR (Infrared), in-street inductive-loop systems, or odometers. The following sections will discuss the various methodologies. The summary will single out a single option to be considered as a technology to be integrated into the problem solution.

GPS (Global Positioning System)

The GPS technology is currently in common use by the military and the aviation industry. Initially the military was intending to use the GPS system to allow for improved accuracy in applying ordnance to targets. Ground force units have used it to accurately determine and report their position. Miniaturization of the GPS quickly occurred. As the size and weight of the GPS receivers decreased, it became much easier for a soldier to have a personal GPS able to provide data that accurately and consistently gave positional information (Koorey 1995). The accuracy depends upon the GPS receiver and can be from within 100 feet to within a centimeter for survey equipment (Hurn 1989). Differential GPS (DGPS) provides greater accuracy with most GPS receivers. DGPS requires the use of two GPS receivers: one that is located at an exact location that is accurately measured and another that is mobile. The GPS receiver at the known location receives the satellite signals and compares the received location information with the known location. The difference between the two locations is the error that is then used for computations by the mobile DGPS receiver in calculating its location. This technique allows the accuracy to be within 10 feet (Hurn 1993).

GPS receivers have been miniaturized and are small enough to be installed in vehicles as either part of an add-in, separate component, or as a small PCMCIA card for a laptop computer. Through use of the GPS technology it is possible to track locations of moving items (such as containers or vehicles) and provide navigational information (Anonymous 1991, Bozman 1992, Eng 1992, O'Brien and Legg 1995, Sager 1993, Schine 1992, Scott 1994).

In his dissertation, Karimi looks at the technologies necessary for designing and implementing an ARGS (Automatic Route Guidance System). He looks at the requirements for both stand-alone ARGS and dispatch ARGS. The discussion in this current study is based on a stand-alone ARGS which Karimi helped to design and for which he selected the hardware. A prototype system is at the University of Calgary. In this system the GPS signals are received and sent to a laptop computer. The data used are the longitude, latitude, velocity, and time. Again, this is a stand-alone system that is specifically appropriate for use in privately used automobiles since it is self-contained (1991, 197-198).

When Karimi discusses the dispatch ARGS system he is looking at fleet operations. In this situation the specifics are that the fleet must be monitored and managed. The difference in this system as compared to the stand-alone is that, in this case, the location of the vehicle must be transmitted to a central location. The technology difference between the two types of operations is that in the dispatch system communications plays a significant role (Karimi 1991, 45-46).

The significance of the GPS technology and receivers is the ability to accurately determine the positional information of a unit carrying the receiver. The accuracy of the data is important when comparing locations of various mobile units in relationship to the location of an incident site. The further significance is that by being able to identify the closest available and appropriate mobile resource the quicker a decision may be made as to which resource to dispatch.

LORAN (Long Range Navigation)

Just as GPS is able to provide positional data of a mobile resource so can LORAN. Additionally, as previously discussed, in order to provide quick response to an incident, it is necessary to know where specific mobile resources are located at any point in time. LORAN can provide positional data. The LORAN system has been in use for many years. This system is under the control of the U.S. Coast Guard. It serves as a navigational tool for both aircraft and sea-craft. The accuracy of the LORAN system is to within a half-mile radius of a specific location. There are a number of manufacturers of LORAN receivers. However, the LORAN system will be phasing out by the year 2000. The reasoning is that the GPS system is capable of providing more accurate positioning data than LORAN. Additionally, GPS is a more stable signal source since LORAN is susceptible to distortion from rain and lightning. This distortion can cause an error rate that may be unacceptable and, thus, unreliable (U.S. Coast Guard Navigation Center 1995, 1994).

Other Positional Methodologies

Other methodologies exist, but their accuracy is questionable. There are dead reckoning navigational methods that use a combination of compass and odometer. The problem with this technique is that when a vehicle turns there can be an inaccuracy in the measurement of the distance covered. This is caused because a wheel will cover different distances depending on whether it is on the inside or outside of the turn. One way of correcting for this inaccuracy is by installing two odometers; one for each of the front wheels. Then, calculating a difference between the two and calculating the average distance that was traveled in the turn.

Other techniques would require the vehicle to pass over induction loops that are imbedded in the street. This method uses a receiver that picks up the signal from the loop which is then used to determine location. This method requires that the vehicle pass over the loops. The problem is that new areas of a city might not have the loops installed and old areas would have to be retrofitted. Additionally, there might not be coverage in outlying areas. Infrared techniques would have the same problems as inductive loops.

Summary of Position Location Technology

The technology that appears to have the greatest impact on resolving the positional location problem is the GPS. This technology can provide location information which can be transmitted back to the dispatcher. With a combination of GPS and a transmitter the locational data can be transmitted without human intervention. That provides for knowledge of resource location by the controlling agency without having to maintain voice communications with the operator of the mobile resource. The impact is that by knowing the current location of that mobile resource and knowing the location of the event or incident that needs that type of resource, the dispatcher is able to bring the proper resource to the incident in the shortest period of time with minimal human intervention. This specifically addresses the problem area of resource allocation to incidents, identified in the crisis management studies, as well as the need to prevent the escalation of an event to a higher level by cutting response time.

Additionally, GPS is a new technology and will have a greater remaining life cycle than that of LORAN. As previously noted, LORAN is only expected to be in operation until the year 2000. Both LORAN and GPS have the most versatility of the methods that have been identified. This versatility is due to the fact that inductive loops might not exist in areas in which the mobile resources are operating. Additionally, GPS and LORAN appear to have greater reliability and coverage. GPS is the least affected by weather and distance distortions. As a result GPS will be the technology that will be used for integration in the virtual consolidated operations center concept.

Infrastructure Mapping and Representation

The GIS (Geographic Information System) technology is basically a combination of the use of CAD (Computer Aided Design) and database methods. GIS systems are database systems that are designed to handle data relating to geographic characteristics at a specific location. These characteristics could be identifying a location as having water, rock formations, or man-made structures as well as identifying the road surface, soil, and vegetation types at the location. Some municipalities use a GIS to lay out the infrastructure for their locale (Anthes 1993, 81, 84). With GIS they are able to show utility control points, type of component, and depths for various utilities; this also applies to road networks and addresses (Ross 1996). Other cities are using GIS to assist in identifying crime areas (King 1996, 667-68)

There have been successful tie-ins between GPS and GIS (Dunn 1995, 16-21; Karimi 1991). Examples of the use of these integrated technologies was identified by several different studies and reports. Specifically, there has been the finding and identifying of problem areas for the railways during inspections. The problems could be out-of-gauge track, ties that are in need of replacement, or road crossings in need of repair (Anonymous 1994, Crow 1994). The problem is identified, data is input with a problem description, and the location taken from the GPS receiver. It is also possible to display a map on a laptop computer monitor and overlay the map with the present location that is determined by the GPS receiver. This is a frequently used integration of GIS and GPS (Crow 1994; Barbaresso 1994; Ben-Akiva et al. 1992; Radosevich 1993; Sager 1993, 91-92).

In Karimi's work with the ARGS it was determined that a system was necessary to reflect the geographic area of the locale. In the GIS database there is a need for the following element to be available to assist in location (Karimi 1991, 57-60):

1. Feature Code
2. Feature Type
3. Name
4. Street Type
5. Feature Direction
6. Longitude
7. Latitude

Massasati's dissertation specifically studies the ability to use remote sensing to define urban areas for modeling. This technique would have application in GIS in that it can give characteristics to land areas. The characteristics are then converted into data representation for insertion to the GIS database (Massasati 1991).

This technology is relevant for integration into the virtual consolidated operation center concept. Specifically, GIS addresses the problems of identifying resource and incident location. Additionally, it assists agencies in coordinating their efforts. With GIS an incident location may be placed on the map, displayed, and shared across many computer terminals at various locations. Further, by having vehicles and other mobile resources automatically forwarding their GPS locations through attached transceivers, that data may also be placed on the map and displayed on the computer terminals. In this manner impacted agencies are able to see on a map where various resources are located and, in a coordinated manner, allocate the closest appropriate resources to respond to the specific incident.

Computer Resources

Throughout the studies on crisis and disaster management there have been consistent comments concerning the need for communications. They indicate that accurate and quick communications are imperative in assuring timely allocation of resources to incident sites. This communication is also needed for good coordination between supporting agencies. Computers are used in most organizations today. Many organizations have accepted that there is a need for laptop computers being available to those personnel who are frequently out of the office. This allows the communication of e-mail and data between the individual and his/her office.

The use of laptop computers in police cars is a current practice. With a computer, a modem, and a radio transmitter, it is currently possible for the person in the mobile resource to obtain information and send and receive e-mail between the vehicle and other locations on the wireless LAN (Montoya 1995, B2). The fact that data can be sent to a vehicle through wireless communications with the operator able to read and respond has significance in that voice communications are not tied up. Instead, instructions are sent to the officer who has the laptop. He acknowledges receipt of message and follows instructions. The time to accomplish this is minimal, not taking the time of voice communications between the same organizational elements. On a voice network there could be several other individuals trying to use the network at the same time (Elsnor 1995), causing delays in information transmission. Wireless communications would take some of the load off voice networks.

One of the problems found in wireless communications between computers is that there can be an inordinate amount of time taken up by a single connection to the network from a laptop. This is due to the speed of transmission between the laptop and the network. There are two possible solutions: the use of coded messages that are decoded at the destination into full text, or the use of middleware. Middleware is software that acts as a buffer to receive the full data and then passes it into the network (Harler 1995, 30-31, 34, 39-40; Johnson 1995, 67-74). The middleware is used at the network connection point and collects the data (Frezza 1995, 65-67). Once it is received it is then passed to the network server (Johnson 1995, 49-52; Johnson 1995, 67-74; Fitzgerald 1995, 14).

The information in this section has direct implication for crisis management as per the comments on coordination, communications, and speed of response necessary to contain an incident. By having computers available in mobile resources it is possible to pass data between the mobile resource and their home organization. Additionally, data may be passed between the individual mobile resources. Further, there is an ability to establish preset messages that may be forwarded from the mobile unit to the home station through the press of a single key as opposed to having to assemble a whole message and transmitting it either verbally or through a data communications link. This information also supports the concept of the virtual consolidated operations center in that it is the link that can allow for message handling at the mobile resource site as well as communications with both the central authority and other individual resource units. Additionally, the center assists in improving the response time due to faster passing of data between mobile units and home organizations.

Communications

Communication is the focal point for all elements of disaster and crisis management. It is also the hub for handling routine emergency procedures on a day-to-day basis. In that there has been an identified need for improved coordination to handle the special cases of disasters and crises, it is recognized that there must be a solid communications link both between agencies and among mobile resources under those agencies. Providing communications between agencies is a relatively simple matter since there can easily be connection by telephone. However, what means is available for communicating data between computer systems? This, also, could be accomplished through telephone lines, separate lines connecting the computer systems, or radio waves (wireless technology) (Carlson 1995, 36-41). For agencies to maintain contact with their mobile resources, radios are frequently used for two-way voice communications. The new technology that exists and the possibility of having computers in each vehicle obviates the use of anything short of wireless technology to allow the passing of data between the vehicles and their central authority (Garry 1995, 43-45), (Harler 1995. 30-34, 39-40).

Wireless Technology

Throughout the crisis management research there is a continual identification of communications within an agency and between agencies as being a source of failure in incident response (Pearson and Mitroff 1993, 57-58). Additionally, there has been a perceived need for communications to exist between a central authority and its resources (Drabek 1994,28-33; Kreps 1978, 76-79). Previously, there has been discussion on the impact of being knowledgeable on resource location so there might be proper dispatch of the appropriate available resource closest to the incident. Therefore, there must be a means of communication between the resource and the central authority. It is obvious that this must occur by some sort of wireless means. Additionally, for the concept originated in this study to work, there is a need to communicate data between vehicles and a fixed location. The technology that allows this to occur is wireless data transmission. There is current use of this technology, and standards are being developed that will allow for many different products to be interconnected in a wireless manner (Frezza 1995, 65-67; Garry 1995, 43-45).

The dissertation by Peeta, studying the assignment of vehicular traffic on congested networks, discusses the importance of wireless communications between a central computer and a moving vehicle. Peeta looked at the advances in ATIS (Advanced Traveler Information System) and the IVHS (Intelligent Vehicle Highway Systems). The study identified that real-time information and data had to be sent to vehicles from a central traffic control center. The information would provide drivers with the status of various routes and their congestion. Drivers would then be provided with instructions on route selection from their current location to a selected destination. This capability is operational. (Peeta 1994, 1-9)

Ching-Sung Chin's dissertation looks at integrating traffic controls and metering of traffic onto freeways and at the same time providing route guidance. Chin's work develops a control scheme to provide guidance to traffic through a commuter corridor. ATMS (Advanced Traffic Management Systems) is included in Chin's solution. There is discussion of providing route guidance information for both specially equipped and unequipped vehicles. The equipped vehicles have the capability of receiving data through wireless data communications techniques that are processed in the vehicle with messages being provided to the driver as to routes that may be taken and specific directions for getting from the present location to a specific destination (Chin 1993).

In Karimi's study the prototype that was developed was referred to as a PCG (Position, Communications, GIS). That study looked at the communications technologies that were most suitable for the ARGS applications. It was determined that three technologies were suitable: private based radio, cellular phone, and satellite systems. Characteristics of the three communications methods were compared. Table 1 identifies the characteristics with the state of the technology at that time.

Table 1. Characteristics of communications links in research completed in 1991.

Feature	Technology		
	Radio (VHF-UHF) Urban	**Cellular Urban**	**Satellite regional**
Communications Links	1-way, 2-way	1-way, 2-way	1-way, 2-way
Number of Mobile Units	Limited	Limited	Unlimited
Broadcasting Coverage	Urban area	Urban area and corridors	Wide area
Data Rate in bps	2400-4800	300-1200	2400-9600

In the prototype he developed, the actual communication between the mobile and base units was accomplished in a simple fashion. A transceiver is placed in the mobile unit and another at the base station. In the mobile unit, there is a modem between the GPS receiver and the communications transceiver. At the base station there is a communications antenna connected to a transceiver, a modem, and then to a computer (Karimi 1991). Figure 6 portrays the architecture from Karimi's prototype. The relevance of Karimi's work to this study is that it demonstrates the practicality of integrating these different technologies for communicating positional data between a mobile resource and a central base. Additionally, that study compared the capabilities between different communications links in a wireless environment.

Wireless communications networking is experiencing a lack of standards and, as a result, there is slow movement to this technology (Johnson 1995, 49-52). However, that is for horizontal markets. Where the communications are internal to a single organization, wireless begins to look better since there is improved speed over standard LAN networking (Blodgett 1995).

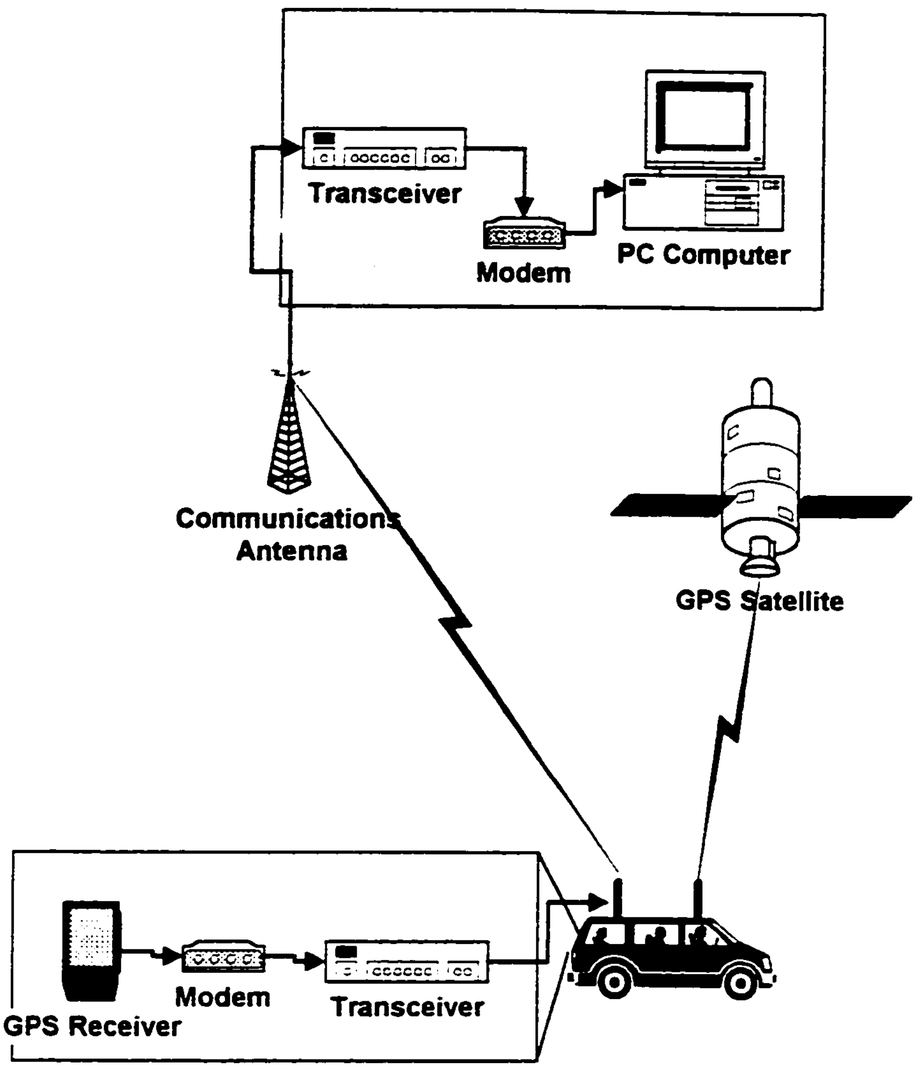

Figure 6. The PCG communications link for ARGS

LAN

With the increased capability of the personal computer and significant numbers of them operating within an organization, it was universally realized that these needed to be connected so that they could share resources. These resources are printers, software, and data. This is accomplished by connecting the computers into networks or LANs. The LAN connects the computers over relatively short distances, perhaps within a building (Whitten, Bentley, and Barlow 1994).

In wireless LANs there are two types of solutions that are dominating the market. There is the fixed location that connects PCs and desktops that are stationary to the network. The second solution allows for a PC to be movable in that, if the computer is small, there could be connections being made even while the PC is being moved around the building. Radio and laser infrared transmissions are two of the technologies that are presently in relatively common use. Radio appears to be the dominant of the two technologies. In the radio technology there are two breakouts: microwave and spread-spectrum. Microwave has certain strengths in that it is able to penetrate walls and is very fast in comparison to its competing technology. However, microwave uses bandwidths that require licensing, its equipment is bulky. Spread-spectrum is slower than microwave but does not require licensing for use. It is also less expensive to implement than microwave (Blodgett 1995). The relevance of this information is that the technology exists, which will allow PCs to be connected to a network while not being in a static or fixed location. Additionally, the relative expense and licensing requirements of the various approaches has been identified.

Wireless technology is allowing United Parcel Service (UPS) to have real-time package tracking on an across-the-country basis. Additionally, UPS is able to conduct real-time vehicle dispatching and rerouting. This capability is connected through the cellular phone network into their LAN for central database management. At the same time, the American Red Cross determined that its need to be able to move from disaster to disaster and provide support required portable LANs. Through these portable LANs, the Red Cross has an inventory control, tracking, and reporting system that is able to move with agents to the field. By using wireless technology they do not have to lay and pick up wire. (Harler 1995)

Summary of Communications

The ability to transmit data to and from mobile resources is imperative to successfully coordinate and control an organization's mobile resources. This ability is also important for the success of the virtual consolidated operations centers. Additionally, the fact that it helps to respond to the problems identified in the crisis management studies is significant. The actual use of these communications technologies in current applications helps to assure that it is not a high-risk item being integrated into the concept.

Summary of Technology

It is apparent, from this overall section, that technology is available and proven in its use in a mobile environment. This is important since this study is looking at the ability to integrate technology in a manner that will improve the coordination of municipal organizations as well as improving the ability to communicate between mobile resources and their parent agencies.

It is apparent from the literature that technology is available to provide accurate positional information through the use of GPS. It is evident that there has been successful integration of GPS data to the mapping capabilities of GIS applications. Joining these technologies with laptop computers and wireless networking capabilities allows for the sharing of data and information between mobile resources and their parent organizations plus other agencies, as may be desired.

The ability to track mobile resources, obtain data pertaining to other agency resources, and quickly allocate the closest asset to support an incident is available without creating new hardware devices. The tools exist, and the fact that there has already been successful integration of these technologies in supporting areas suggests the viability of a virtual consolidated operations center. Most importantly, it answers the need for improved communications and coordination between resources, their parent organizations, and other emergency organizations.

Cost and Benefit Modeling

The search of the literature for this study has identified problems that exist in crisis management, the phases of crisis management impacted by the problem areas, and the technology that may be used to help resolve the problem areas. If there is to be a successful application of a new concept in a municipality's method of operation, then there must be a way of measuring how that concept impacts cost and what benefits it provides. The cost side measures the amount of money needed to acquire a new system, operate that system, and provide the services in its charter. When an agency provides an increased level of service and the proportion of money spent is lower than the benefit received, then there is an apparent improvement in the utilization of resources. The performance or benefit side looks at the needs of the community, service demand, and the workload on the agency. The demand identifies what needs to be done, based on community requests or requirements. Workload is defined as, "The amount of work to be performed or actually executed on a given activity for a specific period of time," (McKinney 1995, 262-263).

In a survey conducted by O'Toole and Marshall it was determined that local governments looked to their own staffs for estimates and forecasts of expenditures and revenues. They found that among the tools used by the local governments were the following (1987, 13):

1. Staff expertise based on their experience with the jurisdiction,
2. Projections that were based on historical data, and
3. Statistical techniques in looking at the correlation between economic variables.

In the survey it was found that the budget request required some level of measurement of the output. The output measurements were of workload, efficiency, and effectiveness. Workload measures were defined as being those that measure the amount of work accomplished. The efficiency measures relate to the amount or cost of units of output on a per unit basis. The effectiveness is the degree to which the service goals and objectives have been met. The expenditures are a major concern within 98 percent of the jurisdictions that were surveyed (O'Toole and Marshall 1987, 15).

In the following sub-sections there will be a review of literature pertaining to decision-aiding theories, cost modeling, and benefit modeling.

Decision-Aiding Theories

There are three decision-aiding theories: cost-benefit theory, decision theory, and social choice theory. It is necessary to review these to determine which would best meet the needs of this particular study.

Cost-Benefit Theory (CBT)

This theory is the result of economic research that was conducted in the nineteenth century for public works construction projects. Cost-benefit theory looks at the advantages and disadvantages of a project in terms of benefits and costs. The benefits are judged by individuals against criteria that pertain to a social value of a set of consequences that result from the application of the reviewed system. In turn these consequences are aggregated to determine the total value of the benefits and are valued as to a total social value. One of the aspects is that there should be an economic value applied to the social value. This is to be in the form of a willingness to pay for the service by members of the impacted social organization (Merkhofer 1987, 60-62).

The issue on the willingness to pay is addressed in an article in *The Ecologist*. In the article entitled "Cost-benefit Analysis: The Problem, Not the Solution," there was discussion on the validity of the willingness to pay for a benefit as being a means to place value on a benefit. Specifically, there was questioning of how value is placed on certain benefits. For example, what is the value of clean air and clean water. Discussion proceeds in questioning whether it is even moral to place a monetary value on certain benefits. However, there is difficulty in determining and applying any other standard to valuing a benefit (Adams 1996, 2). A specific example was given of an individual in Frankfurt, Germany and that individual's willingness to value a clear view from her window. In Frankfurt there is a law that allows residents, living within a 45-degree angle from the top of a proposed structure to withhold consent prior to start of construction. Initially the resident was offered DM 1 (DM stands for Deutsches Marks, the .nonetary denomination of Germany), which she refused. This resident began to understand her ability to veto the project. The resident was then offered DM10 million and again turned it down. This individual proposed DM20 million since it was her birthplace and the blocking out of the sunlight would spoil the place where she was born.

Two things have occurred here: first, there is the ability to pay by the construction company, and second the willingness to accept the amount by the recipient. Is that a fair establishment of the value of a benefit or is it greed? Establishing the value of a benefit is difficult since there must be an evaluation of the motives of the recipient or the payer of the fee. There can be a willingness to pay an amount but also an inability and this skews the value. There is an expressed concern, in this article, that responses to the question on what the respondents would pay would be unrealistically high since the respondents don't actually have to make a payment for the benefit. It is agreed though that the most conservative choice is to base the estimate on the amount that the respondents are willing to pay (Adams 1996, 2-4).

Another issue that is addressed is of cost-benefit analysis being used to compare alternatives. This comparison might be between solution choices for solving a particular problem or between solving different problems. An example of this latter element is a comparison of the cost and benefit of the seat belt law to the cost and benefit of an environmental law. In these cases, there is an attempt to look at the social impact and costs. (Stiefel 1990, 35-37)

Decision Theory (DT)

Decision theory was developed in the eighteenth century. It is used for making decisions when uncertainty is involved. Decision theory is based on the fact that choices are dependent on the probabilities of the consequences of a decision and the worth of the consequences in the eye of the person making the decision.

The criterion that is used in decision theory to find the best alternative is based on mathematical principles that define rational behavior. This rational behavior would be that, if you have three possible outcomes, A, B, and C, and if the person making the decision has a preference for A as opposed to B, and to B as opposed to C, then that person must prefer A to C.

The person making the decision is required to establish a value to the various components of the alternative. Additionally, that individual must establish a probability of the risk associated with that alternative. This is a subjective process and is dependent on the information available to the individual, his/her experience, and the theories of that individual (Merkhofer 1987, 63-64).

Initial review of this decision-aiding theory does not appear to be appropriate for use in this study. This theory attempts to compare alternative solutions against each other. In this study there is only a single solution being considered. Further discussion of the selected decision-aiding theory will be conducted in the chapter on methodology.

Social Choice Theory (SCT)

In the social choice theory the view is that the appropriate criterion for decisions is not based on the preferences of a single decision maker but rather on a synthesis of the preferences of all individuals affected by the decision. Merkhofer states that this is evidenced through the election and legislative processes. He further states that the individual aspects of game theory are less important in social choice theory than ethics. He states that game theory pits individual self-interest and values against other individuals doing the same thing. However, ethics involves the rational pursuit of the interests of the group as a whole.

In taking the ethical approach certain problems occur. There has been investigation to derive ways of aggregating the preferences of individuals into a social utility function. Another approach is analysis of how group decisions are reached through a process like voting. Where the problem exists is in trying to determine the weighting of choices between options. The best example of this is that it was shown that in developing a set of alternatives there was no way to assure that if A was preferred over B, and B was preferred over C, that A would be preferred over C. This was an evident contradiction. There was found to be further contradiction in that just because an individual would prefer a specific choice, that the group would also have the same preference. Further research proved that there was no procedure for quantifying a group's preference structure that does not include interpersonal preference comparisons (Merkhofer 1987, 66).

In reviewing use of this decision-aiding theory it is apparent that there is an attempt to bring in what the impacted society would select as a solution or outcome. From that standpoint it does not appear that this theory would be useful for this study. This study looks at a solution to a problem and the benefit that would be provided to a municipality. To use this theory necessitates conducting information sessions on the concept to the public. After conducting these sessions there would be a requirement to survey the public to determine its perception of the usefulness or need for the implementation of the concept. Therefore, consideration of this theory indicates that for purposes of this study it is not pertinent. However, further discussion will be conducted in the chapter on methodology.

Summary of Decision-Aiding Theories

The three decision-aiding theories vary on their approach and applicability to studies. The significance of the literature on these three theories is that quantification of benefits is important in determining problem solution. From initial review it appears that the cost-benefit analysis theory will be of most use in this study since it places a cost on a solution and compares that cost to the expected benefit. Those benefits can actually be reductions in costs resulting from implementation of a particular solution. The remaining two theories use probabilities and social consensus as a means of determining the impact of a solution. The actual determination of which decision-aiding theory will best suit this study will be discussed in the chapter on methodology.

Cost

In determining a solution to a problem one of the considerations is cost. This study is concerned with the use of a new concept to solve problems that have been previously identified for response to crises, disasters, emergencies, and incidents by local governmental agencies. As previously identified, communications and coordination improvements are needed to properly and effectively respond to the situations involving dispatch of mobile resources. Further, it is important to identify the costs of implementing a solution since the cost could be prohibitive and moneys not available to render that solution viable. In order to determine costs it is imperative to determine the cost elements that are looked at by municipalities.

The model of cost for a municipality must include the basics of labor and equipment. What is included must be of such a level of detail that it is realistic to the organization that it represents. The areas of labor and equipment are different in that labor has several categories of employees based on skill and how payment is determined. When looking at equipment there are the acquisition and operational cost elements to be considered (Brudney and Duncombe 1992).

Brudney and Duncombe have defined the costs of operating a government agency. They have established that there is a grouping of costs into labor costs (LC), equipment, and facilities (KC), and other costs (MC). The other costs include materials, support services, supplies, and utilities. They further state that labor cost has the components of wages and salaries (WC), pensions and fringe benefits (FC), and the recruiting, training and supervising costs (RTC). McKinney identifies a further element to the labor cost: Cost of Living (1995, 248-249). The representation of the total costs is (TC_p) which establishes the formula as follows (Brudney and Duncombe 1992, 475):

$$(TC_p) = LC + KC + MC$$

where $$LC = WC + FC + RTC$$

This above formula is certainly easy to model and is simple in form. However, labor costs must include the occupational skill, the payment rate basis, labor category, and pay increase determinants.

From interviews with managers and accounting personnel from the functional organizations, the following information was obtained. The occupational skills in the areas using mobile resources such as vehicles are varied. First, there is the management level. At this level an individual will have responsibility for a variety of functional areas.

A manager will only spend a portion of his/her time on duties expressly relating to the dispatch, monitor, and control of mobile resources. Manager responsibilities will be involved with planning, organizing, allocating of personnel and moneys, and problem solving. The manager will be in a salaried position that will usually not pay overtime for time worked beyond the 40 standard hours. Pay increases will usually be based upon merit or longevity (Taylor 1996). The dispatcher is the next skill area to be considered. Normally the dispatcher will have been promoted to the position after having served as a driver. The dispatcher can be either salaried or paid on an hourly basis. Overtime pay is normally made when work extends beyond the standard 40 hours. Increases for this position are normally made on a longevity basis unless this is a contract position (Taylor 1996, Hill 1995). The driver skill area is an hourly pay basis. Overtime is paid for any hours beyond the standard 40. These rates are normally based on organizational policy or contract rates. Any pay increases are normally accomplished through policy or contractual agreements. The maintenance personnel normally are paid on the same basis as the drivers except for rates. The maintenance supervisor is tasked with assigning work and overseeing the quality of that work. The pay rate for the maintenance supervisor will be the same as or greater then the dispatcher's. Administrative support will be paid on hourly or salaried basis with overtime payment. (Smith 1995, Taylor 1996, Hill 1995, Krushaar 1995).

When there is a look at costs, there are two elements which must be considered: present costs and future costs. The present costs include the initial acquisition plus the operation costs. The future costs do not include acquisition except where there is the need to incrementally expand the existing hardware if additional units will be necessary.

Additionally, inflation factors might have to be considered when there is a use of consumable materials and supplies or personnel rate increases.

Gianakis and Frank discuss a variety of issues in the addressing of forecasting models. One area they looked at was the aggregation of sources resulting in a loss of overall accuracy. Their conclusions indicated that there was no statistically significant relationship between forecast error and the level of aggregation of sources. Their study indicated that revenue forecasts were more accurate when the forecasts were applied to the aggregate total than when applied to separate sources and those estimates summed to arrive at a total forecast (1993, 140).

The Community and Organization Research Institute of the University of California at Santa Barbara has an Urban Economics Program. In this program students conduct research and develop reports. In one of their studies they determined that the cost of services such as police and fire could be related to the size of the city in square miles and density of population. They also determined that federal grants had an impact on the expenditures since the city could provide for increased manpower above what it would have without the grants. This would mean that provided service would be lower in cost since the city was not paying the total bill (Ryff 1978, 39-48).

The elements that will be used in the cost model will be discussed in the chapter on synthesis. It is apparent that it is important to have a certain level of detail in a model. However, the literature indicates that it is important to consider aggregation of model elements.

This section looked at the subject of costs and their modeling. The next section will review the area of benefits, which is the other aspect that must be looked at in problem solution.

Benefits

There needs to be some consideration given to a definition of a benefit, from the viewpoint of this study. Benefits, for the purpose of this study will be defined as reduction of costs. There might be some confusion between a cost and a benefit but each outcome resulting in a cost reduction will be identified as a benefit. Other benefits will be decreases in response time to incidents and non-duplication of efforts.

In reviewing benefits of use of the virtual consolidated operations center concept it is evident that benefits would have to be measurable or address one of the shortcomings that have been identified in the crisis management research. Earlier in this study there was a significant amount of attention given to the need to improve communications and coordination between functional organizations having a support mission during crises. Measuring the benefits of improved communications and coordination is not an easy task, but there must be a means of measurement. One such means can be through the relationship of time response to an accident injury and the mortality rate.

Research shows that trauma is the third leading cause of death for persons between the ages of one and 35. This statistic has persisted and is the reason for attempts to upgrade trauma treatment on a national basis. One of the recent developments has been the basing of helicopters at hospitals and staffing them with advanced medical treatment crews. This allows for moving trained individuals to the site of the injured and providing care intervention both at the site and during movement to the hospital (Baxt 1983, 3047).

The first major use of helicopters for medical evacuation was during the Korean conflict. During World War II battlefield deaths were 4.5 per 100 casualties. In Korea there were 2.5 deaths per 100 casualties. Research shows that this was partially due to the rapid evacuation of the casualties to medical treatment facilities. The study by Baxt and Moody indicated that a portion of the reduction was due to the introduction of front-line surgical hospitals. During the Vietnam War, there was a further reduction in deaths to 1 per 100 casualties. This was due in part to the helicopter but also to definitive enroute treatment. The study admits that it is impossible to totally attribute this reduction to the helicopter. In the 1970's, hospitals in the United States began using helicopters with trained medical crews to move injured and seriously ill patients. It was found that the helicopters were able to move the patients at two to three times the speed of land-based ambulances. In the study there was a comparison of survivor rates between land transported patients and those moved by helicopter. One of the problems with the study is a valid comparison of the results. This is due to the fact that even though all the patients were treated by the same hospital, those that were moved by ambulance were located in the urban area, whereas those moved by helicopter were located in the rural areas surrounding the city. Additionally, there was a requirement, by the supporting trauma units, that movement by air would be beneficial to the patient. This means that there had to be an existing medical determination of the patient's condition prior to dispatching the helicopter. As a result there is a time skewing of the data. However, it was found that when comparing the results of the two groups, those moved by land had a prediction of 15 deaths with actual deaths being 19, whereas those moved by air had a projection of 21 deaths with the actual deaths being ten. When looking at the differences the combination of timely movement and emergency medical team composition were the important factors (Baxt and Moody 1983, 3048-3051).

A 1996 study in the United Kingdom involved research on memory impairment and rehabilitation of people having suffered cardiac arrest outside a hospital. In this study the researchers were concerned with the nature, prevalence, and severity of memory deficit in patients resuscitated after a cardiac arrest. The researchers were trying to determine if these deficits were related to the duration of the cardiac arrest. There was a control group against which to make the comparison. The control group was composed of patients who suffered acute myocardial infarction and never experienced cardiac arrest. The significance of this study was that there was evidence of moderate to severe memory impairment in 37 percent of the study group, which occurred outside the hospital. There was also a significant correlation between severity of impairment and the duration of the cardiac arrest. There was no evidence that this depended upon age or sex. In this study, the researchers concluded that improvement in response times of emergency services could reduce the severity of the memory deficits and rehabilitation (Grubb and Keith 1996, 143-146). However, there was no indication the amount of decrease in severity that could be expected from timely response.

A recent study in Canada looked at the costs associated with gunshot wounds. The costs that were looked at were medical care, mental health care, public services, productivity losses, funeral expenses, individual and family pain, and lost quality of life. The efforts of the study were aimed at gun control issues but the information applies to other areas as well. The medical costs included both in-patient and out-patient care. The out-patient care reflected rehabilitation and nursing home costs. In the mental health area there was focus on the cost of therapy and related social services. In the review of productivity losses there was a broad spectrum of activities that were included. The costs here were not only concerned with the victim's productivity but also that of the employer, family, and social groups. These costs were related to time that people would talk about the incident and not concentrate on their own work responsibilities. The study showed that the per capita costs were $235 in Canada (1991) and $595 in the United States (1992). The researcher found that the medical care cost per individual survivor was $16,597 and a lifetime medical care cost was $28,879. These gunshot wound costs calculated out to $2,252 in average daily costs as compared to $1,664 for the average daily costs for all injuries. In the conclusions of this study there was a cost comparison between gunshot wounds due to violent acts, accidents, and suicides. As an example there was a comparison between suicides and homicides. "...it would be useful to estimate that preventing 250 suicides is as important as preventing 100 homicides; that is, the value of preventing a suicide is 40 percent of the value of preventing a homicide." The significance of the Canadian study is the fact that costs of medical care and productivity loss due to injury have been identified (Miller 1995, 1261-1268).

From the literature, there is indication that the reduction in time required to respond and arrive at an incident site has potential to decrease the rates of mortality and levels of morbidity. Hence, timeliness in responding to an incident is a benefit. This is significant since it gives support to solutions to problems that allow for speedier dispatching of mobile resources to an incident site.

Performance

Performance for the purpose of this study is an element of benefit. When we speak of performance we are looking at the time factors in responding to requests for service. In modeling a system, performance includes the time expended from when the request is received until the service is completed (Brudney and Duncombe 1992, O'Toole and Marshall 1987). The modeling of the system includes inputs that are developed, from historic data. Distribution of the inputs to reflect frequency of requests must be determined and used in the model. This will reflect the frequency of service requests. Time required to respond to the request is also modeled, based on historic data. The same is true for the time required to complete the service request. Running the model reflects a simulated time period with the output reflecting the results from exercising the input based on historic data distribution (Pegden, Shannon, and Sadowski 1995).

O'Toole and Marshall look at three separate areas to measure the level of work output. In their output measures they first identify the workload measure. Workload measures are defined as those that address the amount of work that has been accomplished. The next measure they identified is that of efficiency. This area specifically relates to, "...the amount or cost of input per unit of output." The third area is that of effectiveness. Effectiveness is the measure of, "...the extent to which the goals or objectives of the service are being met" (1987, 14). Botner talks about municipalities being concerned with, the measurement and monitoring of performance (Botner 1991, 444). However, Botner did not identify performance measures.

It is apparent from the literature that performance is an element that is to be improved as a result of the implementing of a solution. Since response time is a performance element, it needs to be improved in solutions involving systems that must provide resources to resolve or to positively impact an incident. Therefore, an improvement in performance in modeling the virtual consolidated operations center concept will actually be a decrease in response time. In this case a decrease in response time is an improvement in performance.

Queuing Theory

Since an issue of performance is the ability to respond and a decrease in response time is a performance improvement, then there must be a method to determine the elements that impact response time. Queuing theory is a quantitative method to look at service to people having to wait in lines for service or materials having to be worked on. Essentially, queuing theory looks at the time spent waiting to be served and the time being served (Lapin 1994, 776-777). Through the use of queuing theory. it is possible to determine the optimum number of servers to have in support of an operation based on economic efficiencies (Buffa and Dyer 1981, 430-433, Lapin 1994, 776).

Lapin states that the usual objective of queuing theory is to model queues and determine how to provide efficient operations. The model looks at the characteristics of the queuing system being measured. The characteristics include the amount of time required to wait in a line and the mean length of the waiting line. Buffa and Dyer say that the situations that queuing theory models have inputs that may have to wait, a service to be performed, and an output. The input is the arrivals. The arrivals appear at some arrival time which is controlled by a probabilistic process. The time required to service the input follows a probability distribution. The output rate of the system will depend on the interplay between the random arrivals and the variable processing times (Buffa and Dyer, 430).

Lapin and Buffa explain the different setups that may occur when looking at queues. One is a single-service single–stage queue. In this type queue a customer is provided all their services prior to leaving (Lapin, 777). An example of this is the case of a cashier in a restaurant. Where you have several servers providing to a single line of customers, as in a post office with several open windows, you have the multiple-server single-stage queue (Buffa, 435).

For the purposes of this research and the specific look into the emergency medical services organization, queuing theory appears to have application. For this operation there are multiple individuals that may be waiting for service. A call is made for medical support to an incident site. An ambulance and crew is dispatched. The ambulance and crew are the single-service. Since the ambulance and crew provide specific service to the individual from the time they are dispatched, until they deliver the patient to the hospital, this would be a single-stage queue.

Lapin, as well as Buffa and Dyer, state that queuing theory is able to characterize the waiting line in terms of probability distribution for the number of customers in the system, mean number of customers in the system, mean customer time spent in the system, length of the line, mean waiting time, and the utilization factor of the server ((Lapin, 780-781, Buffa and Dyer, 439). Lapin discusses how to use the characteristics to determine the costs of a queuing situation and how to compare the results with other alternatives (Lapin, 786-787, 793-794).

Summary on Cost and Benefit Modeling

The literature supports the ability to model the cost and benefit of municipal organizations and operations. By using this modeling technique it is possible to demonstrate the costs and benefits of integrating technology and using the virtual consolidated operations center concept and decreasing response time. The decision-aiding theory to be used in this study will be discussed in the chapter on methodology. Additionally, it is shown that queuing theory may also be used to look at the virtual consolidated operations center concept. Queuing theory would allow the measuring of the characteristics of the concept and provide cost data to be compared. This comparison can help to identify costs and benefits of alternative solutions.

Summary of the Literature Search

The first section of this chapter discussed what was found in the search of the material on crisis management. It began by developing a definition of crisis management which was determined to be a disruption in the traditional structure of the area has either been rendered neutral or destroyed. The general discussion surrounding a definition also identified the level of disruption to the structure in terms of services that were no longer available or negatively impacted by the incident.

In the literature, there was a certain amount of discussion on the level of severity of an incident. The highest level is the crisis, followed by a disaster, and then by an emergency. There was identification that the level of severity at a lower-level organization was greater than that of a higher-level organization. In other words, what would be a crisis in a city might only be considered an emergency at the state level.

There was then a search of problems that had been identified in the area of crisis management. The literature indicated that the most significant problems were in the areas of communications and coordination. This was specifically between organizations within a governmental institution, such as, a city, a county, or a state. It was suggested in the literature that two of the five phases of the crisis management theory could be positively impacted through improvements of communications and coordination. There was recognition that technology could be a factor in improving coordination and communications. Further, there was indication that the ability to know the location and status of mobile resources could positively impact the allocating of those resources to an incident. Another element of technology that was discussed was that which would permit the sharing of information and data between functional organizations.

The literature review then covered the area of technology. The technologies that were researched were those that would permit the coordination and communications between resources and their parent organizations as well as between other functional organizations. Additionally, there was a look at technologies that would assist in providing the organizations with data to track their mobile resources with minimal human intervention. This human intervention minimization allows for speedier response to incidents.

Through the review of the literature there was identification of existing technologies that could permit data sharing between the functional organizations. This data sharing may be accomplished through the networking of computer resources.

Further, it was found that the current integration of GPS, GIS, and wireless communications allowed the mobile resource units to automatically transmit their location to their parent organization dispatchers. By having this positional data overlaid on a computerized map, the dispatcher is able to identify resources being closest to the incident site. This helps to decrease the time to determine which resources to dispatch in response to an incident.

The literature suggested that GPS was the better positional technology since it was more accurate and would have a longer system life. The GIS technology was identified by the literature, as being able to be modified to reflect information needed by any particular functional organization. Further, the GIS data could be shared among functional organizations. This would help assure that the organizations were sharing current and similar data.

The literature indicated successful utilization of human intervention minimization devices in mobile resources. Specifically, there has been successful integration of laptop computers, GIS, GPS, and wireless communications. This integration has proven that an organization dispatcher may be constantly provided updated locational information without disturbing the vehicle operator. The literature also suggested that the transmitting of messages and information could be made through the computer through the wireless communications network.

Following the search on technology, was the research on cost and benefit modeling. The literature identified the decision-aiding theories that could assist in modeling costs and benefits of a particular solution. The identified decision-aiding theories were cost-benefit theory, decision theory, and social choice theory. A review of cost modeling suggested a simplified algorithm that would adequately model costs. The benefit side of the cost-benefit model involves looking at the medical research on timeliness of response impact on victims. This approach appears to be appropriate since an emergency medical services organization is the functional organization that will be the primary focus of this study. The literature gave evidence of the decreasing of mortality rates resulting from reduced times in moving a victim to a medical treatment center.

The literature search also identified another means of modeling the costs and benefits through the use of queuing theory. It was stated that the performance characteristics of a queue may be quantified. Further, it was stated that the costs of various alternative solutions could be quantified and compared to determine possible benefits. Therefore, queuing theory appears to be a tool that could evaluate the concept of the virtual consolidated operations center.

Chapter III will be an analysis of the findings from the literature search. That chapter will determine which elements will be used in the synthesis of a solution to the problem being researched.

CHAPTER III

ANALYSIS

In this chapter there will be a focused discussion of the findings from a search of the literature. There will be a determination of the method used to model the costs and benefits of implementing the virtual consolidated operations center concept. There is also explanation for selecting the specific decision-aiding theory in modeling the cost and benefits of the concept. Additionally, there is identification of the various elements that make up the costs for the integrated technology and how that technology integrates into the virtual consolidated operations center concept.

Choice of Decision-Aiding Theory

In Chapter II there was a review of the three decision-aiding theories. The relevant theories identified were the cost-benefit theory, decision theory, and social cost theory. The cost-benefit theory looks at the advantages and disadvantages of a project in terms of costs and benefits. Additionally, the cost-benefit theory is used to compare alternative decisions. This method is reasonably objective in that dollar values placed on costs may be determined from acquisition costs, personnel costs, and operation and maintenance costs. The decision theory is used for making decisions in uncertain conditions. The probability of risk associated with a particular alternative is determined using subjective methods. This theory is also used to compare alternative solutions. In the social choice theory the decisions are made based on the synthesis of the preferences of all individuals affected by the decision. This involves conducting surveys to determine the preferences of those individuals who will be impacted by the decision.

After reviewing the three decision-aiding theories, a decision was made to use the cost-benefit theory. This determination was made as the cost-benefit theory best fits the research question under investigation. The benefits can be identified from previous research, and dollar values have been related to those benefits. The studies that were identified, reviewed, and discussed in Chapter II (one by Baxt (1983); another by Miller (1995), and a third by Grubb and Keith (1996)) showed the use of different techniques in evacuating injured or ill persons. These studies were able to successfully model the costs and benefits of those techniques. That those efforts were able to successfully use the cost-benefit theory as the decision-aiding theory caused a preference for using that theory in this study. However, a review of the other two theories did take place and the reasoning for their exclusion follows.

Decision theory was determined to be unsuitable for this study. Decision theory is used to find the best alternative among several possibilities. In this study there is a single concept being considered. There are multiple ways of implementing the concept but that is not the concern of this study. This study is to determine if a specific concept will provide benefits to local government in improving the communications and coordination for incident response. Admittedly, incident response is a micro-view of the problem areas identified in crisis management. Further, decision theory looks at the element of risk for various alternative solutions. Decision theory is a probabilistic approach where weighting of each alternative is established based on the level of risk for failure or probability of success with particular alternatives (Merkhofer 1987; Stiefel, 1990)). In the literature review, the studies on medical response show direct correlation between lower morbidity levels and mortality rates and reduced time of response in getting to and moving a victim. This means that there is not a concern with probabilities of risk of an alternative decision but rather the benefit of a particular solution. As a result, the use of decision theory for this study is not appropriate.

In looking at the social choice theory, there is the view that the decision made is based on the preferences of all impacted individuals. With regard to this study the individuals are neither the workers or managers of the functionally affected organizations, but rather the public that is serviced by those functional organizations. Since this concept requires a cost expenditure that comes from public funds, it would be necessary to determine how the public would react to such expenditure (Merkhofer 1987; Adams 1996). In order to make such a determination of the desires of the public it would be necessary to create and conduct a survey of a sample of the local citizenry. It is not the purpose of this study to determine the desires of the public, but rather to determine if the proposed concept provides benefit to the public. The desires of the public would certainly justify an additional research effort. As a result of this logic it was determined that the decision-aid theory of social choice theory is not the appropriate approach for this study.

In view of the above reasoning, it is concluded that the approach which is most appropriate for this study is the cost-benefit theory. The review of the literature in Chapter II indicates that research may evaluate alternative projects and comparing their costs and benefits to each other. In this study there is a single concept being looked at as to its costs and its corresponding benefits. Hence, there will be no comparison to other projects or solutions. This means that the modeling will be composed of the elements of cost compared to the elements of benefit followed by the analysis of the results for the costs and benefits of this single concept.

In order to fully determine what must be included in the cost-benefit model there must be further analysis of what was discovered during the literature search. The next section will discuss the findings from the literature search.

What Crisis Management Theory Tells Us

The literature search on crisis management has identified some important considerations. Wenger stated that lower-level events have less impact on government organizations than higher level events. Wenger further states that an incident in a city that is classified as a crisis is not as significant at the state or federal level. The state might classify the event as a disaster or an emergency (this is portrayed in Figure 1). The impact of this is the realization that the lower level organizations must meet and contend with these events. Further, lower-level organizations must be able to commit resources to handle these events very quickly, to preclude their escalating. Additionally, Wenger identified that technology has a significant impact on an organization's ability to respond to an incident, coordinate interagency efforts, and successfully overcome the situation. (Wenger 1978)

The studies by Mitroff and Pearson provide further important insights. Organizations that were prepared, had advanced technology, and good communications were better able to respond to crises. At the same time, both the Government Accounting Office and the National Academy of Public Administration stated that strong local emergency management organizations reduced the need for intervention by federal agencies. Mitroff and Pearson also concluded that the key to support in emergencies and disasters was a close relationship between the local county and municipal agencies. The studies strongly suggest that successful handling of emergencies is through timely response and application of proper resources to those events. The emphasis on the need to have significant technology and communications ability at the local government level is due to local government agencies being the first organizations to be notified about and respond to a disaster or emergency event. (Pearson and Mitroff 1993; Mitroff 1994)

Pearson and Mitroff identified the five phases of crisis management (1993). Of the five phases two are especially important relative to resolving a situation once it occurs. These two phases are containment and recovery. In containing the event there is an attempt to keep it from spreading to additional areas and impacting more people, equipment, and property. In the recovery phase the purpose is to bring back normalization of activities.

Chartrand's contributions discussed the use of technology to assist in locating incident sites, dispatching mobile resources, and exchanging information between emergency operations centers and between remote sites. This work also identified the need for the interagency sharing of data through a communications network. (Chartrand 1986)

Kreps made contributions in identifying the importance of the need for constant coordination and information sharing between the police, fire, and emergency medical services. It is imperative that these organizations maintain data links so there is an organized response to events. The better prepared and equipped a municipality is, the less significant will be the impact on that community. There was discussion on the impact of communications between organizations and how they assure an improved integration of efforts between those organizations. (Kreps 1978)

Drabek's study on the disaster in the Indianapolis Coliseum identified significant factors in the areas of mobilization, communications, coordination, and control. This work concluded that quick notification of organizations resulted in fewer difficulties in reaching the disaster site. It was found that problems occurred when organizations were not tied together in a common communications link. This study strongly supports the belief that there is a need for integration between local response units for successful event resolution. Drabek further identifies the need for continual data sharing between organizations. (Drabek 1994)

The common link found in these studies and reports is that crises will occur no matter how much planning and preparation take place. When organizations have communications links between them, they will be able to respond to an event in an expeditious manner. Additionally, a communications link will allow for improved and faster coordination of effort. It was also found that there was a consistent discussion on the use of technology to assist in making the component agencies more integrated and the sharing of data easier. Further, it is evident from the studies that with technology there is an ability to quickly identify resources and allocate them to a situation. This allows for a quicker reaction and better opportunity to contain and recover from a crisis or event. At the same time the improved communications and coordination that occur allow for better utilization of scarce resources which positively impacts the use of public moneys.

Technology

From the analysis on the findings from the search of the literature on crisis management it is evident that there is strong agreement on the importance of using of technology to improve the communications and coordination problems. There were a number of statements on how technology will improve the time to respond to events. Further, the discussion on using technology to help establish data sharing and emergency operations centers was very important in supporting the concept of the virtual consolidated operations center. The evidence of the successful integration of specific technology in day-to-day operations indicates that transferring of that technology to other areas can enjoy similar success.

The studies by Karimi (1991), Massasati (1991), Ben-Akiva (1992), and Radosevich (1993) showed the successful integration of GPS and GIS on laptop computers to identify the location of mobile resources. Hurn's writings on the GPS system explained the accuracy of that system and its use in navigation (1989, 1993). Karimi explained his success in prototyping an Automatic Route Guidance System and its use for dispatching mobile resources. The success Karimi had in bringing together the GPS, GIS, and laptop computers was important in demonstrating the capabilities and practicality of this type of systems integration. Karimi's use of the technology in dispatch operations was involved in the monitoring and managing of a vehicle fleet. In this situation there was successful transmission of vehicle locations to a central location. In this instance there was integration of a communications system with location technology.

The integration of GPS, GIS, and laptop computers into communications systems allows for the information on location of mobile resources to be monitored and managed. By taking this integrated technology and applying it across agency lines there is an ability to coordinate efforts and communicate resource needs and allocations on an interagency communications network. This capability answers the problems that were identified by the GAO and NAPA studies of emergency operations during disasters.

It is significant to consider that without the ability for a dispatcher to know where the mobile resources are currently located, time is needed to call each mobile unit to inquire as to its location. If there are multiple resources at a variety of locations throughout an area, it is conceivable that several calls would have to be made to individual units to determine which unit is closest to the incident site and is available for dispatch. With the integration of technology that constantly updates location information onto a computerized map, the dispatcher can quickly see from the map where the mobile units are located. This allows for fast dispatching of resources to incidents.

Cost

Brudney and Duncombe (1992), and McKinney (1995) discuss the modeling of cost for a municipality. Each of them supported the case that the cost model must include basic elements of labor and equipment. From a labor standpoint the cost included wages.

salaries, pensions, fringe benefits, recruiting, training, supervising, and cost of living. For equipment there is a combination of both acquisition and operational costs. These researchers also identified other costs which include materials, support services, supplies, and utilities. The formula that was identified in their studies was simple in form but included the significant elements. The cost formula will be adequate for the modeling of costs for this study. However, discussion on that application will be in the following chapter on synthesis.

In their studies there is discussion on present and future costs. Specifically, future costs address the operating costs and any increment expansion of existing hardware. Where there is consideration of consumable materials and supplies, inflation factors must be included. The inflation factor would also apply to labor costs, in that new hires coming on-board in future years would be hired at the inflated rates. (Brudney and Duncombe 1992; McKinney 1995) Frank and Gianakis discussed forecasting models (1993). For this exploratory and descriptive study forecasting will not be brought into the modeling of the costs since it is the intention of this study to look solely at the acquisition costs and one year's operational costs for the cost side of the model. The Frank and Gianakis study also found that there was no statistically significant relationship between forecast error and the level of aggregation of sources in a model (1993). This being true, aggregation can be used with confidence that this simplification will not skew the results to any great degree.

From the results of the literature search, the cost portion of the model will maintain a level of simplicity while addressing the important elements of cost. It is apparent that those important elements are labor cost, system acquisition cost, system setup cost, and operation and maintenance costs.

Benefits

In chapter two there is discussion on the definition of a benefit for the purposes of this exploratory and descriptive work. That chapter states that benefits would accrue through a reduction of costs and through decreases in response time to incidents.

Baxt and Moody identified trauma as the third leading cause of death for people between the ages of one and 35. From this data, there have been attempts at upgrading the trauma treatment received in hospitals and the basing of helicopters at hospitals to provide speedier movement of patients and medical treatment crews. Baxt's studies showed a relationship to the rapid evacuation of battlefield casualties and a decrease in mortality rate per 100 casualties (1983). This study showed data as indicated in the following table:

Table 2. Deaths per 100 battlefield casualties.

Period	Deaths per 100 casualties
World War II	4.5
Korean Conflict	2.5
Vietnam War	1

That study admitted that the reduction could not be totally attributed to the helicopter. It was stated that definitive treatment enroute to the hospital was one of the factors. This was due to trained medical crews being available to treat the casualties while the helicopter was enroute. In the same study there was a comparison of survivor rates between those patients transported by helicopter and those transported by land. The patients were all treated at the same hospital, so the staff skills were the same and there would not be an influence of having differing skill capabilities entering into the results. Furthermore, those that were moved by helicopter had two additional factors entering into the data: first, prior to movement of the patient there had to be a medical determination that the patient would benefit from the movement prior to dispatching the helicopter, and second, that the helicopter-moved patients were in rural areas surrounding the city. (Baxt and Moody 1983) It is evident that this caused an increase in time and the data results should show a skewing of the time. The following table shows the method of patient movement, the prediction of deaths, and the actual deaths for each of the movement types:

Table 3. The type of movement of patient and the predicted and actual deaths.

Movement Type	Predicted Deaths	Actual Deaths
Land	15	19
Helicopter	21	10

Baxt and Moody stated that the results indicated in the above table were due to a combination of timely movement and the composition of the emergency medical teams.

The study by Grubb and Keith involved memory impairment and rehabilitation of people that suffered cardiac arrest outside a hospital. The concern was with the prevalence and severity of the memory deficit of those patients that were resuscitated after a cardiac arrest. The findings were significant in that they showed evidence of severe memory impairment in 37 percent of the study group, which occurred outside of the hospital. There was also a significant correlation between the severity of the impairment and the duration of the cardiac arrest. The researchers concluded that improvement in response times of emergency services reduced the severity of the memory deficits and rehabilitation time. (Grubb and Keith 1996) This is important since memory-deficit level corresponds with morbidity levels and rates. This has an impact on the current exploratory and descriptive work since it supports the relationship of reduced response times and morbidity levels, which are a major benefit that will be considered in the benefit side of the cost-benefit model.

It has been previously stated that benefits were in reality, reduced costs or costly activities that were reduced. The literature search also found a study by Miller that identified the medical costs related to gunshot wounds. This study looked at the costs in Canada during 1991 and 1992. This study indicated that individual survivor medical care cost was $16,597 per individual and a lifetime medical care cost of $28,879. The study indicated that the average daily cost for a gunshot victim was $2,252 and was $1,664 for all other injuries. The average daily cost for a gunshot victim is 1.35 times that of the all other type of injury costs. (Miller 1995)

Queuing Theory and Cost-Benefit Analysis

In reviewing the information obtained in Chapter II on queuing theory, the following elements are revealed. A certain number of servers are available at any time. In the case of the emergency medical services organization, these are, specifically, looking at the ambulances and their crews. Each server is able to provide for a certain number of customers during a specific period of time. Additionally, a period of time is required to serve a single customer. The server (ambulance and crew) has a cost, which may be broken into a cost per time period. The customer has a value. That value is the money he/she is paid for an incremental period of time. With this data, the cost of the service, both from the server and customer standpoint can be determined. From those, a total cost for service may be computed (Lapin, 792-794).

The literature demonstrates how to compute the costs for a particular queue and its service. Modifying the queue, results in additional solutions. Through use of the demonstrated methods the costs are calculated for the new solution. The original and new solution may then be compared to each other and a determination made as to the solution providing the lower costs or better service characteristics. When the costs or times of service decrease, there is a proportionate benefit. When a benefit is determined then a comparison may be made between the costs and the comparative benefit (Lapin, 796).

Summary of Analysis

The literature search has identified that two problems are most in need of resolution for handling of crises, disasters, and emergencies. They are poor communications and poor/inefficient coordination between agencies within municipalities and counties. Additionally, there is evidence that the local governments are the organizations that are at the forefront in responding to these events, and for them to be able to quickly contain an event to prevent its expanding, the impacted agencies must be able to quickly dispatch mobile resources to the incident site. Their ability to share information and data with other agencies in their locale permits speedy response to, containment of, and recovery from the event. There is strong and consistent evidence that technology has a positive impact on the agencies' ability to respond to incidents. A significant amount of literature shows that there have been excellent results in the integration of GPS, GIS, laptop computers, and wireless communications technology to decrease response time in the dispatch of mobile resources to incidents. Further, the research has shown evidence of successful application of these integrated technologies in assisting in improving communication and coordination within user organizations. The apparent widespread use of these integrated technologies suggests a low level of risk in bringing their application to new situations and configurations.

Medical studies have provided information and data on the impact of speedy response to incidents and the decrease in both mortality rates and levels of morbidity. These studies give evidence of the benefit of speedy response to both the survival of the patient and the decrease in medical costs. Some of these studies have placed dollar values on the medical benefits resulting from reduced response time to incidents.

In analyzing the research, there was a determination that, of the three decision-aiding theories, the cost-benefit theory best applied to this current study. The cost-benefit theory looks at the advantages and disadvantages of a problem solution in terms of the cost to implement compared to the benefits derived from that implementation. This method attempts to be as objective as possible since dollar values are placed on both the costs and the benefits. Additionally, the cost-benefit theory was selected since previous research has identified the pertinent benefits and placed dollar values on those benefits.

Decision theory was not selected for use since it looks at finding the best alternative among several possibilities. This study is focused on a single concept to solve the problem. Therefore, this methodology would not be appropriate for use in this current study. At the same time, social choice theory would not fit this current research.

Social choice theory looks at the impacted social group's desires as to a solution. This study is looking at the impact on a whole community, and it would be impractical to survey the community to determine their desires. The impracticality is due to the necessity to first having to educate them on the problems and the possible solutions.

It is evident from the analysis that simple formulae are appropriate for use in cost-benefit analysis. Further, analysis shows that the cost-benefit theory has the greatest applicability to this particular study into the use of the virtual consolidated operations center concept as being useful and cost effective for use in a city government environment. From this analysis, it is decided to perform a cost-benefit analysis in determining the impact of implementation of this concept in the city of Colorado Springs.

It is apparent from the analysis of the findings in the literature search, that queuing theory methods may be used for cost and benefit comparison between solutions. This being true allows the use of a second methodology to help validate the results of the cost-benefit computations made using the previously identified and analyzed techniques. Therefore, queuing theory will be used as a backup method to determine the costs of various solutions. Where results are similar, this will be a indication that the results are probably valid.

The following chapter will be a bringing together of those elements determined to be pertinent to a solution to the crisis management problems of a need for improved communications and coordination inter- or intra-agency. It will develop a concept and then model the costs and benefits of that concept.

CHAPTER IV

SYNTHESIS

In Chapter III, there was an analysis of information found during the search of the literature. In that chapter, there was discussion on which decision-aiding theory would be most appropriate for this current study. The decision was made that the cost-benefit theory was most appropriate.

The analysis in Chapter III also looked at the literature concerning crisis management. The analysis concluded that the linking of communications between functional organizations was important for improving the coordination between these elements. It was determined that decreasing response time would allow for improvement in containment and recovery from an incident. Additionally, the analysis found that improved communications and coordination between the functional organizations would allow for better utilization of scarce resources.

The analysis in Chapter III identified successful integration of technology that would be useful for monitoring and controlling mobile resource units. It was determined that laptop computers and GPS receivers would permit the automatic transmitting of the current location of those mobile resources. Further analysis determined that the integrating of GIS and the locational data, from the mobile resource units, on the dispatcher's monitor would permit speedier decision making as to which resource to allocate to an incident. This dispatching could be accomplished with minimal human intervention. With this technology in place, it becomes a simple matter to tie them together through wide area networking methods and create a virtual consolidated operations center.

Using the results of the analysis presented in Chapter III, this chapter will model the costs and benefits of the integration of technology into a virtual consolidated operations center. Chapter IV will begin by identifying which technologies will be integrated with the naming of specific vendors and unit costs for the technology. Following the technology will be the cost model. The cost model will be followed by the benefit portion of the cost-benefit model. There will be an incorporation of data gathered from meetings with the emergency medical services organization supporting the city of Colorado Springs and El Paso County. This data will be used to reflect the benefits derived from implementing this new concept. The last area will be the analysis of the data with an interpretation of the findings.

Elements of Technology in the Virtual Consolidated Operations Center Concept

This section will identify the technology that will be used in the virtual consolidated operations center concept and the cost of that technology. In order to develop those costs there will be a focus on a specific functional organization operating in the city of Colorado Springs and El Paso County. (El Paso County is the county in which Colorado Springs resides.) This functional organization will be the emergency medical services, American Medical Response, Inc.. The technology that will be considered will be that currently used by that emergency medical services organization.

Currently the emergency medical services organization has a GPS receiver, two radio transmitters, and one receiver installed in each of its ambulances. There is one transmitter for voice communications and one for transmission of the GPS data. There is a separate transmitter and receiver in each of the ambulances for voice communications between an ambulance and the central dispatcher. GIS capability will be the same as that in current use by the emergency medical services organization. In this case, the emergency medical services organization dispatcher is using GIS at the dispatch operations center. This GIS system is currently being run on a personal computer based system. For this study, the laptop computers will be identical to those in use by the police department. Additionally, 450-megahertz wireless communications will be used as the wireless communications element for data transmission and 800-megahertz for voice. Costs for the communications systems will be based on those paid by the emergency medical services organization.

Cost Model

In Chapter II, there was review of cost modeling for municipalities. The algorithm identified by Brudney and Duncombe (1992), specifically had major element breakouts of labor, equipment and facilities, and other costs. The other costs included materials, support services, supplies, and utilities. There was additional breakout of labor into components of wages and salaries, pensions and fringe benefits, and the recruiting, training and supervising costs. There was further discussion on the bringing in a cost of living factor to the labor element. In this study the costs will look at present costs of labor and will not perform projections of the future labor element involving cost of living. The cost model will use a simple approach by using present rates in the algorithms.

The following list of assumptions applies to the cost model.

1. Current personnel will be using the new technology. That implies that no additional hires are necessary since there is only a change in equipment and not an increase in workload or additional mission requirements.

2. Each organization will use the II Morrow map information for their basic GIS for dispatching purposes. This is the system currently in use by the emergency medical services organization (Greenberg 1996, Silloway 1996).

3. Updates to the dispatching GIS will come from both the vendor and the utilities department. The utilities department GIS geographic data is in ArcInfo format and must be downloaded in the format compatible with II Morrow GIS or be manually entered into the II Morrow GIS. The utilities department updates include new streets being built within the city and county.

4. The vehicles and on board operators will not change from the current organization number. There are currently 15 vehicles and 2 on board operators per vehicle. Additionally, there are varying numbers of vehicles operating at different times of the day (Barberi 1997).

The cost model for this study is represented in the following formulae:

$$TC = TAC + yTAOC$$

Where:

TC represents total cost,

TAC represents total acquisition cost,

yTAOC represents total annual operating costs with y being the multiplier for the number of years that are to be used in the specific instantiation of the algorithm,

and,

$$TAC = HAC + SAC + DbSC + n(MRAC) + n(MREC)$$

$$TAOC = LC + HOMC + SOMC + DbMC + Fac + m(MROMC)$$

where:

DbMC represents database maintenance costs.

DbSC represents database setup costs,

Fac represents facility costs,

HAC represents hardware acquisition costs,

HOMC represents hardware operations and maintenance costs,

LC represents labor costs,

where:

LC_D represents labor costs for dispatchers, and

LC_O represents labor costs for equipment operators.

MRAC represents mobile resource acquisition costs,

MREC represents mobile resource add-on equipment costs,

MROMC represents mobile resource operation and maintenance costs per mile,

n represents the number of mobile units,

m represents the number of total miles

SAC represents software acquisition costs, and,

SOMC represents software operations and maintenance costs,

Cost Data

The data that is represented on the cost elements is based on current information provided by public safety or emergency medical organizations operating in El Paso

County of Colorado. As cost elements are introduced, they will be identified as to their source.

Personnel

The personnel costs are related to those individuals involved in the dispatching of mobile resources. The emergency medical services organization identified the personnel costs in the following table. The personnel costs they have identified are ranges for personnel. For the purposes of this study, the midrange will be used as the labor cost for the individual dispatcher and entered into the cost model.

Table 4. Salaries and benefit costs for emergency medical services organization dispatchers.

Item	Number	Range	Mid-Range	Total
Dispatcher/Analyst	1	$35,000 - 50,000	$42,500	$42,500
Dispatchers	9	$22,000 - 31,000	$26,500	$238.500
Total Salaries				$281,000
Benefits @ 15%				$42.150
Total Salaries & Benefits				**$323,150**

To determine the number of on board personnel working per hour, the following method was used. A review of the vehicles working each hour of the day, as identified in Table 5, was made. Summing those vehicles and dividing them by 24, yields the number of vehicles per hour. The average number of vehicles operating per hour rounded to 10. On board personnel were two per vehicle for an average of 20 people per hour. Table 4 Salaries and benefit costs for emergency medical services organization dispatchers., represents the salaries and benefit costs for the paramedics and emergency medical technicians (EMTs). This table is separate since their shifts are different due to the varying number of vehicles that are operating at different times during a day.

Table 5. Vehicles operating at each hour segment per day.

Period	Number of Vehicles
0000-0100	7
0100-0200	7
0200-0300	6
0300-0400	6
0400-0500	5
0500-0600	6
0700-0800	6
0800-0900	7
0900-1000	8
1000-1100	8
1100-1200	10
1200-1300	11
1300-1400	12
1400-1500	12
1500-1600	13
1600-1700	13
1700-1800	13
1800-1900	15
1900-2000	15
2000-2100	15
2100-2200	14
2200-2300	10
2300-2400 (0000)	10
Total Vehicles	229
Average Vehicles per hour	9.5

From the data provided by the emergency medical services organization, in Table 5, it is determined that over the period of a day there are 229 vehicle operating hours. By dividing the 229 by the 24 hours in a day, a figure of 9.5 average vehicles per hour is computed. This is rounded to a figure of ten vehicles per hour.

Table 6. Salaries for paramedics and emergency medical technicians.

Item	Number	Range	Mid-Range	Total
Paramedic	10	$11.00-18.60	$14.80	$1,292,928
Emergency Medical Technicians	10	$7.00-12.40	$9.70	$847,392
Total Salaries				$2,140,320
Benefits @ 15%				$321,048
Total Salaries & Benefits				**$2,461,368**

Table 6 shows the salaries and benefits for the personnel that man the mobile resources for the emergency medical services organization. The total column represent the annual salaries which are calculated by multiplying the $14.80 per hour by the average number of vehicles serving per hour, by 24 hours per day, seven days per week, for 52 weeks. This represents that there must be coverage by personnel, all day, every day, for 52 weeks.

Vehicles

The emergency medical services organization must purchase special purpose vehicles. These vehicles contain specialized equipment that allows the transport and life and medical support of the patients. The following table reflects the purchase price of the ambulances and the patient life and medical support equipment, but not the radios or GPS.

Table 7. Cost of ambulances and medical support equipment.

Item	Quantity	Unit Cost	Total
Ambulance	15	$63,000	$960,000
Medical Support Equipment	15	$57,000	$855,000
Total			**$1,815,000**

The cost of operating the vehicles was provided by the emergency medical services organization. The data was produced from their vehicle maintenance records and is reflected in Table 8. The sinking fund is to establish replacement cost of the vehicle. To maintain a simple model, the life of the vehicles will be based on seven years. The mileage will be the average miles per vehicle per incident, for the period covered in Table 13 (9.51 average miles per incident for 1937.77 average incidents per month). The mileage and incidents will be rounded up to the next whole number (ten miles and 1,938 incidents). Growth factors in population will not be applied nor will there be consideration for inflation. The sinking fund cost per mile is calculated by multiplying the average miles per incident (ten) by the average number of incidents per month (1,938). This number is divided by average number of vehicles per hour (ten). This calculates to 1,938 average miles per month and when multiplied by 12, for the number of months in the year, produces a result of 23,256 miles per year per vehicle. The total cost of the ambulance and its patient support equipment is $121,000 per vehicle. Taking the vehicle and support equipment cost and dividing it by the seven years of life, we get an annual sinking fund cost of $17,286. Taking that amount and dividing it by the number of annual miles per vehicle, produces a result of $0.74 per mile as the operating cost for the sinking fund.

Table 8. Operating cost per mile.

Item	Cost per Mile
Maintenance	$0.18
Fuel and Oil	$0.17
Sinking Fund	$0.74
Total	**$1.09**

The total operating cost of $1.09 per mile, identified in Table 8, is used as an input for the variable MROMC. When the total operating cost per mile per vehicle is multiplied by the average number of miles per vehicle per year (23,256) we have the actual MROMC ($25,349.04).

Facilities

It is necessary to have an area set aside for use by the dispatcher operations. That area can be either used exclusively by the dispatcher or shared with some other operation. However, space is needed for the dispatching operations. The space must allow for the dispatcher, the computer systems, display screens, and radio equipment. The space and cost figures are provided by the emergency medical services organization. Due to respect for proprietary information protection, ranges of the costs are included in this study and mid-ranges of those figures will be used.

The following information was provided by the emergency medical services organization and that data is located in the interview of the local director at Appendix B. The information provided in that interview was that the total square footage of space rented by the emergency medical services organization is 14,640 square feet. Of that space, 1,080 square feet is devoted to the dispatch operations. The total rental cost per month for the whole facility is between $8,500 and $11,000. The midrange of this is $9,750. The dispatch operations area is 7 percent of the total space. That would place a dispatch area monthly cost of $682.50 and an annual cost of $8,190, which is the data for the Fac variable.

Technology

The technology costs are provided by the users, or vendors, of the products currently in use, either in a functional department within the city of Colorado Springs, the El Paso county government, or local service agencies. An overview of the concept presented in this study is included in Figure 7. The problems that will be alleviated by implementation of this concept are identified in Figure 10. The technology to be used, the vendor of the technology, and where in the concept the technology will fit are identified in Figure 11 and Figure 12

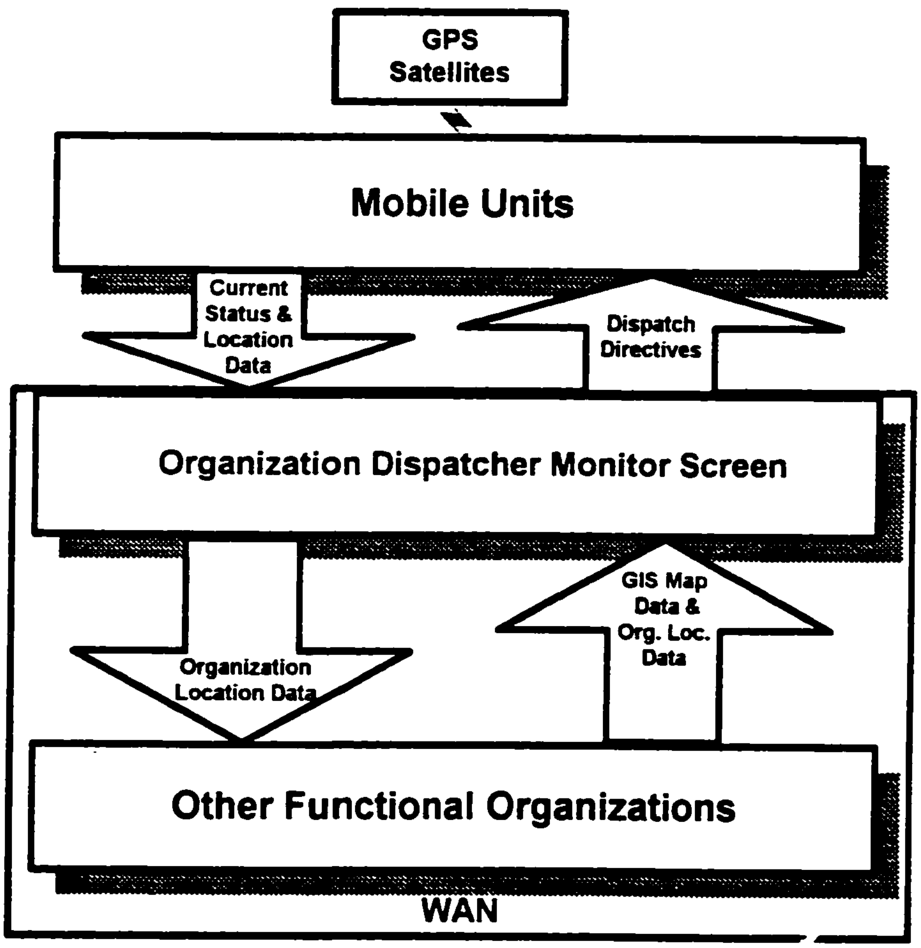

Figure 7. Overview of virtual consolidated operations center concept.

Figure 7 is a model of the concept. It delineates the three major portions of the concept: the mobile units, the organization dispatcher, and the other functional organizations. This figure shows the mobile units receiving GPS Satellite input and passing the current mobile units' location data and status information to their parent organizations. The location data and status are automatically transmitted to the parent organization. At the same time, the parent organization passes dispatch directives to available mobile units. Passing current location data back to the parent organization, and displaying it on the dispatcher's monitor screen enable the dispatcher to quickly see the location of each mobile unit under his/her control. Additionally, passing current status back to the dispatcher's monitor screen enables the dispatcher to determine which unit is currently available for dispatch. With these two elements available to the dispatcher there is a decrease in the amount of time it takes to determine which unit is able to quickly move to an incident. The old method is to issue a call to each unit that is supposed to be available and determine its current location, make a decision on which to dispatch, and issue a dispatch directive to that particular unit. These two methods are portrayed in the following figures.

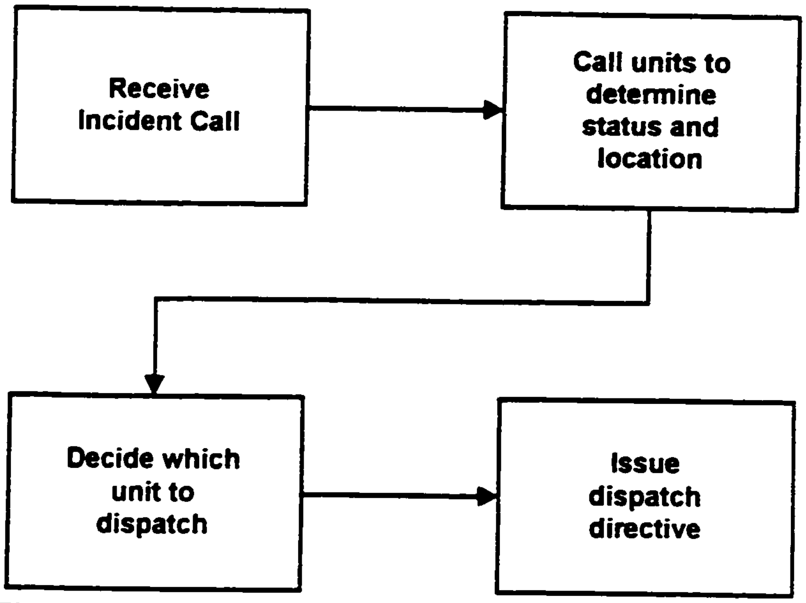

Figure 8. Old method of dispatching mobile units.

Notice that the second step in the process, "Call units to determine status and location," could require multiple calls to units. Each call represents time spent getting a response and collecting the information.

In Figure 9 notice that there is no process step that requires the calling of units to determine location and status. Instead, this data is automatically provided from the conversion of GPS data to locational information that is then provided to the parent organization dispatcher. This elimination of multiple calls allows the dispatcher to quickly ascertain which resource is available and can best respond to the incident.

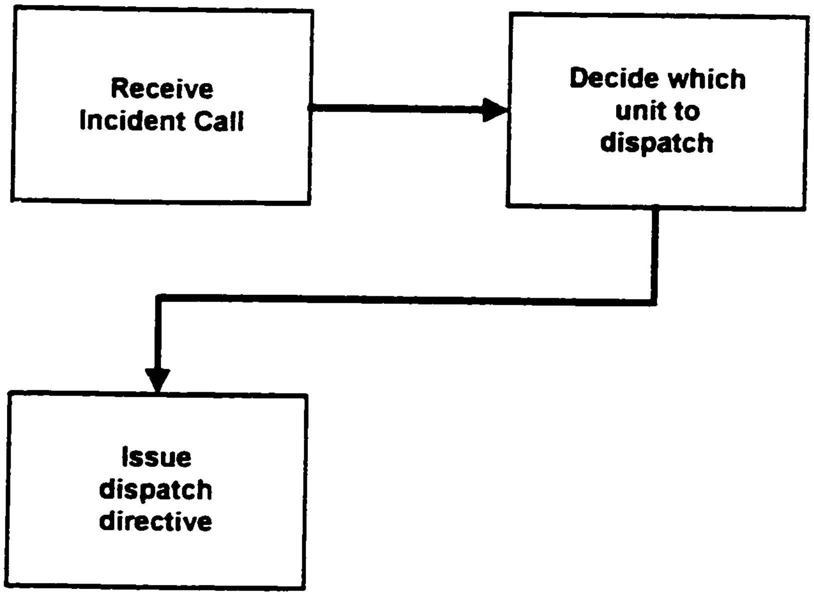

Figure 9. New method of dispatching mobile units.

The following figure, Figure 10, identifies where problems, uncovered in the search of the literature, are impacted and corrected through integration of technology. Specifically, the literature discussed the problems with communications and coordination. The figure points out specific areas where the technology will minimize or alleviate these problems. The figure shows that current status and location data is passed from mobile units to their parent organization dispatcher's monitor screen. This improves the communications problem in that area by automatically sending the data to the organization without human intervention. This will improve the speed in having the data available to the dispatcher. The passing of dispatch directives from the parent organization dispatcher to the mobile unit improves both communications and coordination problems. The communications impact is that the dispatcher is dealing with automatically transmitted unit location information and doesn't have to spend additional time calling units and can, therefore, quickly identify an available resource and make direct contact with that unit. The coordination between dispatchers and their mobile units is impacted since the dispatcher obtains information of other resource locations involving either the parent organization or other organizations. By having this data available, the mobile resource can be provided with information as to what other resources will be assisting at the incident site.

This same figure shows the sharing of data between the dispatchers of other organizations. This can be accomplished in an automatic or manual manner. However, it would make better sense to automatically submit data between the dispatcher stations. This impacts both communications between organizations and coordination of their efforts. Having knowledge of what resources are being provided by other organizations in response to an incident it allows the dispatcher from any organization to see if there is need for additional support.

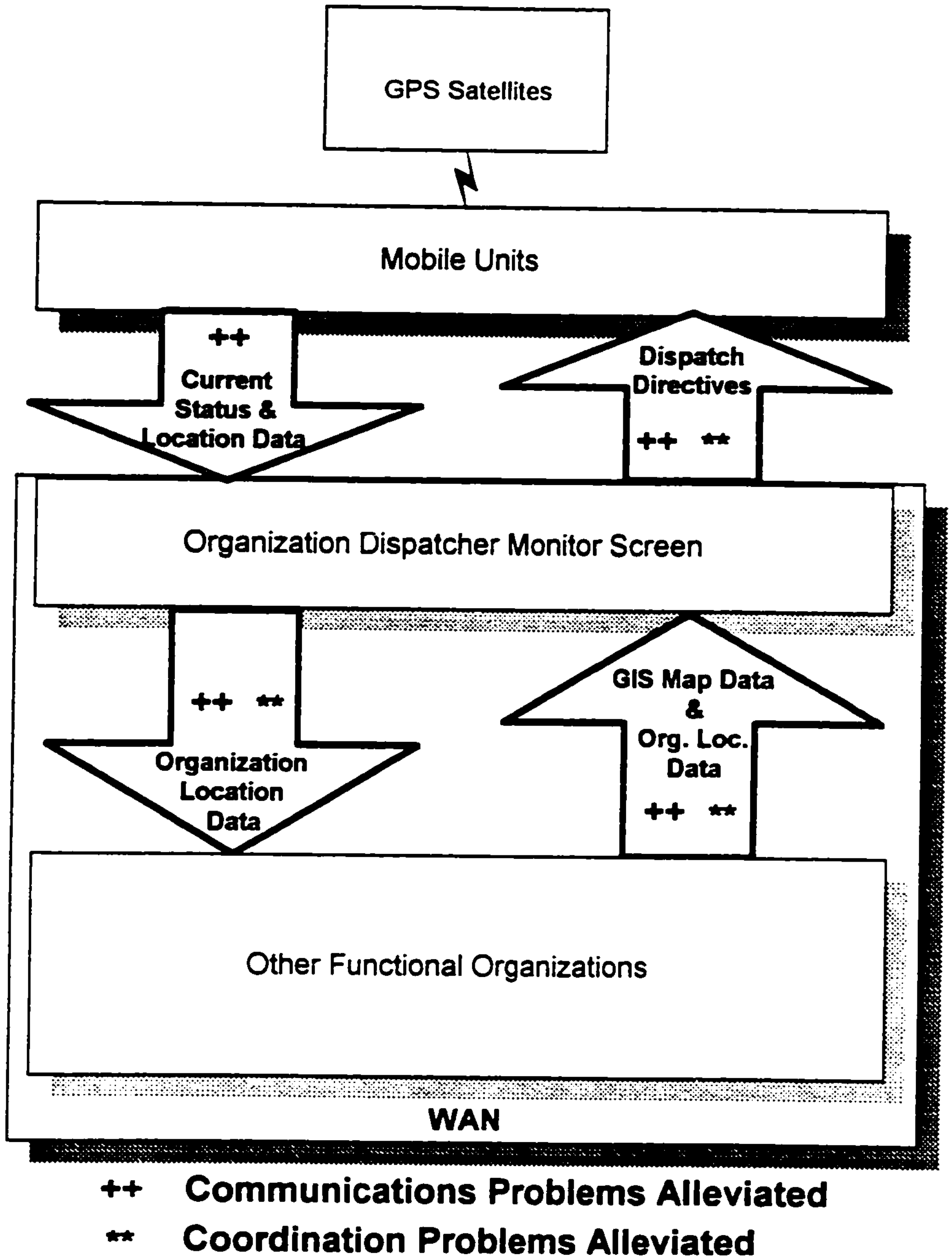

Figure 10. Problems alleviated by use of virtual consolidated operations center concept.

In Figure 11, the specific technologies for use in the mobile units and the vendors providing those technologies are identified. This identification allows for the compilation of cost data for the cost-benefit model.

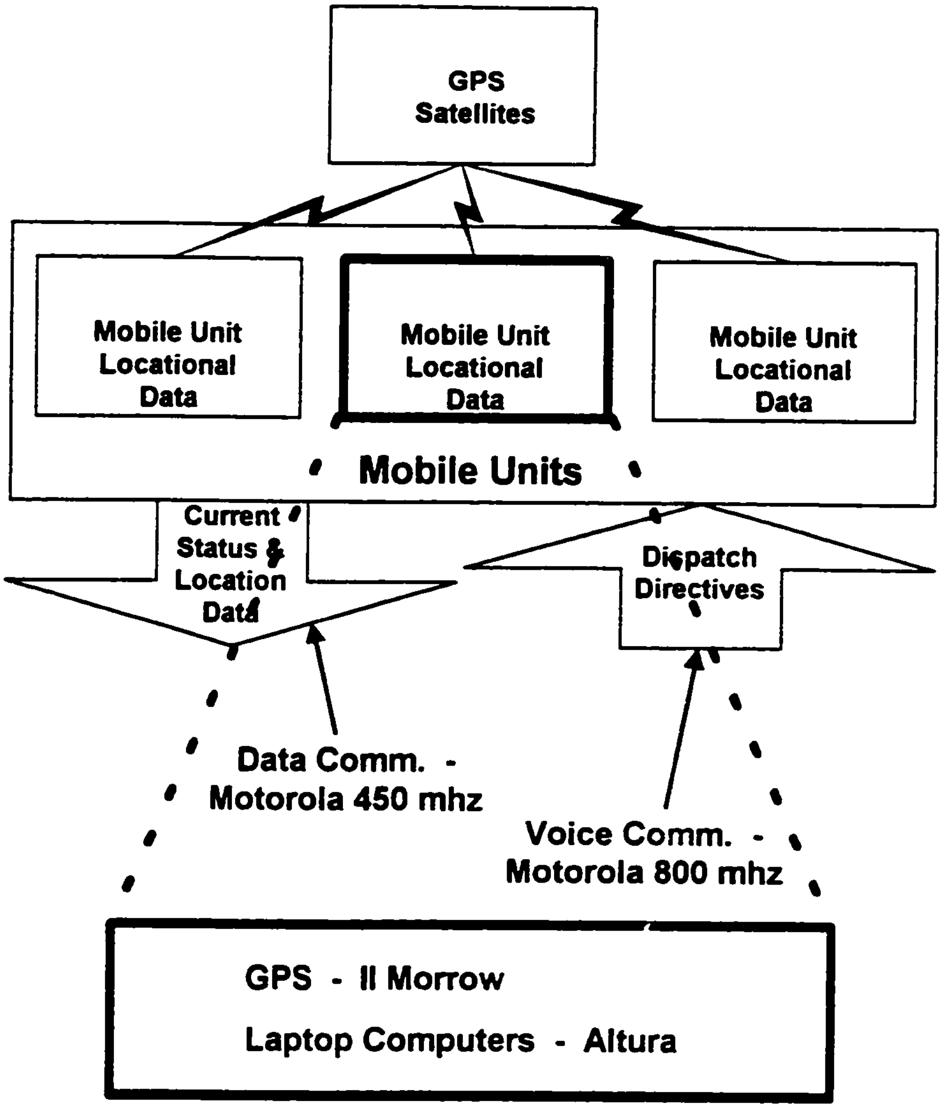

Figure 11. Identification of technology and possible vendor for mobile units.

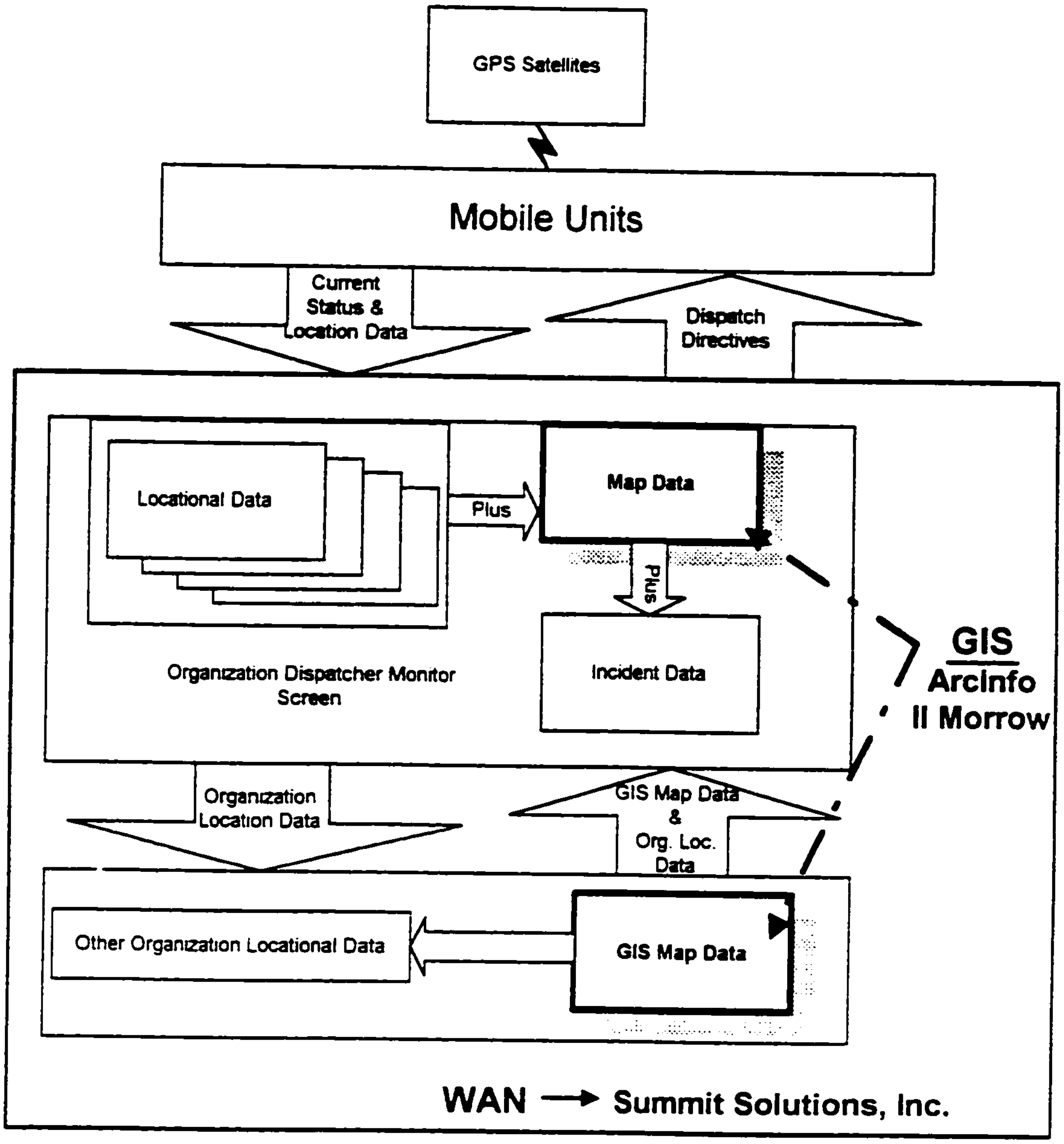

Figure 12. Identification of technology and possible vendors for organization dispatch stations.

Figure 12, above, identifies where GIS will be used and the vendors who will be used for cost data. Additionally, use of the WAN is identified and the vendor that will provide the installation of that technology. The vendor for the WAN indicated the charge they would assess the organization for equipment and materials, but did not indicate the hourly fee. In the following table, the technology and its per-unit cost is identified.

Table 9. Vendors supplying technology and the per unit cost.

Technology (vendor in parenthesis)	Per-Unit Price in Dollars
GPS Receiver - (II Morrow)	1,330.00
Laptop Computer - (Altura)	2,395.00
Radio Transmitter - (Motorola 450 and 800 MHz)	670.00
GIS - (II Morrow) – acquisition Annual maintenance (ArcInfo) – conversion	89,100.00 4,500.00
WAN – Minimum T1 communications lines to 911, emergency medical services, each of the 4 functional departments, and the county operations center. (Assume 1.5 miles for each connection and initial cost followed by monthly charge for each connection. Installation Monthly	 313.00 125.00
Router and DSU/CSU for each location: 911, emergency medical services organization, 4 functional departments, and the county operations center.	4000.00
Microwave backup to each location and connection.	1,000.00

Cost Computations

In this section the cost computations for integration of the technology into the emergency medical services will be presented. The focus will continue to be the emergency medical services organization.

Emergency Medical Services

In the emergency medical services organization the maintenance of the GIS database is the responsibility of the Dispatcher/Analyst. In the interview of the director of that organization, it was stated that the mid-range salary for this individual is $42,500 plus 15% of annual salary for benefits ($6,375). This represents total salary and benefits of $48,875 annually. The interview of the dispatcher/analyst (Stephen Silloway) provided information that 2 to 3 hours were spent per week for maintenance of the GPS and GIS system. Silloway further indicated that 0.5 hours of the 2 to 3 hours of system maintenance was devoted to updating the GIS database, with the remaining time spent on maintaining the equipment in the vehicles. Taking the annual compensation and dividing it by 26 weeks, a result of $1,879.81 is obtained. The director for this organization stated that the work hours for the personnel were 84 hours every two weeks. Taking the $1,879.81 and dividing it by the 84 hours gives an hourly rate of $22.38. Taking the $22.38 and multiplying it by the 3 hours per week for GIS system maintenance, the result of $67.14 per week is obtained. The annual cost is $67.14 times the 52 weeks for a total of $3,491.28. The 0.5 hours that are spent each week for updating the GIS database is 16.7% of the total 3 hours spent on system maintenance. Based on the $3491.28 spent annual on system maintenance, $583.04 is devoted to GIS database maintenance, which is the variable DbMC. The remainder, $2,908.24, is for the maintenance of the hardware (variable HOMC).

To determine the cost of the original setup for the database to support the GIS, contact was made with the Colorado Springs Utilities Department. That department has a GIS called Facilities Information Management System (FIMS). It has a variety of products that it sells to the public from its GIS. The fees that will be identified for the variable DbSC will be based on the structure from the department's document entitled, "Colorado Springs Utilities Public Access Strategy For Its Facilities Information Management Systems (FIMS)." It has identified a product that covers a 4,000 feet by 4,000 feet area. It is called a tile and provides planimetric features, annotation, and attribute packets. The cost for a tile is $195 for the first one and $98 for the remaining tiles if the requested number is greater than nine. The area that is served by the emergency medical services organization is El Paso County, with an area of 2,126.7 square miles. This computes to 3,615 tiles being necessary to represent El Paso County. The cost for this would be $354,367 for purchase of the digital map data from the utilities department. Trimble Corporation indicates that it has the capability of converting ArcInfo data into a format compatible with the II Morrow GIS system. Trimble indicates that the charge would be approximately $150,000. In order to allow for the risk of Trimble not bringing the conversion in on budget, an average between the two amounts will be used for the DbSC variable. The averaged amount would be $252,183.50.

The variable representing hardware acquisition cost, HAC, is composed of the combination of the equipment required in each mobile unit, times the number of mobile units, plus the cost of the base station equipment. Figure 11 identifies the technology necessary in each mobile unit. It is shown in that figure that each mobile unit will have a II Morrow GPS receiver, an Altura laptop computer, a Motorola 400 MHz transmitter, and a Motorola 800 MHz transceiver. Table 9 gives the cost for each of these elements. By looking at Table 11, it is evident that the emergency medical services organization has 15 ambulances that must be equipped with the technology. By adding the cost of equipment for a single mobile unit, it is found that the equipment cost for a unit is $5,065. This was calculated by adding the costs of a GPS receiver ($1330), a laptop computer ($2395), 450 MHz transmitter ($670), and the 800 MHz transceiver ($670), resulting in a total of $5,065. It is then necessary to provide the 450MHz transmitter and 800 MHz transceiver to the base station also, which costs $1,340. The total hardware acquisition cost for the emergency medical services organization results from multiplying the mobile unit hardware costs ($5,065) by the number of mobile units (15) and adding the base station cost ($1,340), giving a total hardware acquisition cost of $77,315, which is the variable HAC. Added to HAC is the equipment and material necessary for the connection to the WAN. The necessary items here are: the seven T1 lines ($313 each), a router and DGU/CSU ($4,000), and a microwave antenna ($1,000), for a total of $7,191 which is added to HAC. The cost of $125 per month per T1 line is necessary for the service charge by the local carrier, which is an annual rate of $10,500, added to the HOMC variable.

The dispatcher labor costs for the emergency medical services department is identified in Table 4. The dispatcher labor costs, including benefits, are $323,120 annually.

Table 10. Data input for variables in cost model.

Variable	Emergency Medical Services
DbMC	$583.04
DbSC	$252,183.50
Fac	$8,190.00
HAC	$84,506.00
HOMC	$13,408.24
LC	$2,784,518.00
MRAC	$64,000.00
MREC	$57,000.00
MROMC	$1.09
n	15
m	23,256
SAC	$89,100.00
SOMC	$4,500.00

Benefit Model

The benefit model is based on decreases in costs for services provided to injured individuals and reduction in mobile resource inventory. For this study, there are three major components of cost for services to injured individuals and one for reduction in resource inventory that are considered benefits. The first component is the reduction in mortality rates. The second component is the reduction in the level of morbidity. The third component is the cost for the medical care, loss of labor by an employer, and loss of income by the family. This third element, loss of income by the family is making a basic assumption that the injured individual is a financial provider to his/her family. In this study, there will be a look at the decrease in mortality rates of casualties between World War II and the Vietnam War. This will show a comparison between the movement of casualties in a land-locked vehicle and by helicopter. This will demonstrate the change in mortality rates based on transport time of the casualties. The last component is any reduction in inventory, equipment, and labor involved in the movement of patients.

Mortality Rate Benefit

This section will look at the mortality rates and the improvements that have been made in those rates since World War II. That data will be input in an algorithm that develops a benefit rate that may be attributed to the timely movement of a casualty to a medical facility.

The benefit algorithm for the mortality portion of the model is as follows:

$$\Delta MR = MRBH - MRAH$$

Where:

Δ MR represents the change in mortality rate,

MRAH represents the mortality rate after helicopter, and,

MRBH represents the mortality rate before helicopter

and,

$$DMR = \frac{\Delta MR}{MRBH}$$

where:

DMR represents the decrease in mortality rate,

and,

$$BMR = \frac{DMR_{MT}}{1/DMR_{woMT}}$$

where:

BMR represents the benefit mortality rate,

DMR_{MT} represents the decrease in mortality rate when medical treatment is available while enroute to the treatment facility, and

DMR_{WOMT} represents the decrease in mortality rate when medical treatment is not available while enroute to the treatment facility.

The decrease in mortality rate represents the improvement rate for that specific element. In the search of the literature, Baxt and Moody stated that the mortality rate during World War II was 4.5 per 100 casualties and in Vietnam it was 1 per 100 casualties. They also stated that this decrease was due to two factors: the first was the helicopter with its quick movement of the casualty to a hospital and the second was the definitive medical assistance available to the patient enroute to the hospital. This means that portions of the decrease are attributable to two separate reasons. There is no indication of what proportion should be attributed to each of the components. However, the data in Table 1 shows that the deaths per 100 battlefield casualties was 4.5 during World War II and 2.5 per 100 during the Korean Conflict. During the Korean Conflict, helicopters had litters mounted on the skids, and there was no medical assistance other than the pilot. This was calculated by subtracting the Korean Conflict mortality rate from the World War II mortality rate. The result is then divided by the World War II rate, giving the 44 percent improvement rate. This is the improvement rate that occurred due to the rapid movement of the patients from incident site to emergency medical treatment site. Therefore in the computation of the decrease of mortality rate the benefit will attribute 44 percent to the rapid movement of the casualty. The other factor is the medical assistance being brought forward to the victim's location. Therefore, there is a combination of influences on the mortality rate. This is the medical treatment portion. In order to consider that element it is necessary to look at the comparison between the Korean Conflict and the Vietnam War. Again, in the Korean Conflict there were 2 fatalities per 100 wounded. During the Vietnam War, there was 1 fatality per 100 wounded. In the Korean Conflict instance there were no medical personnel on the helicopter. However, in the Vietnam War there were medical personnel capable of providing initial trauma treatment. Therefore, a comparison of those two conflicts (Korea and Vietnam) would give us a means of estimating the impact of medical personnel on the decrease of fatalities. Once the computations for the time period with the use of helicopter and with and without medical personnel, it is possible to attribute what portion of the total decrease in fatalities may be attributed to the speedy transport of wounded personnel. This then allows for establishing a factor that would be used to determine what portion of those people who survive serious injury may attribute their survival to the speedy response and transport. These computations will be made in Chapter V.

Benefit Data

The data that follows is provided in complete form at Appendix A. The initial data is compiled from the El Paso County Emergency Medical Services Office. The data includes the number of requests for service and the time required to respond. The data covers the years of 1991, 1992, 1994, 1995, through September of 1996. The significance of this data is that the years of 1991 and 1992 saw two organizations providing service to the county. They were St. Francis Hospital and American Medical Response. At that time neither service had a GPS or GIS capability. The last years of 1994 - 1996 had service provided by only one organization, American Medical Response. During this period, GPS and GIS technologies were in use by the provider. Additionally, data is taken from the research by Baxt, discussed in Chapter II. It is important to understand that that data reflects the costs of providing medical service in a hospital and is the means of projecting possible savings based on speedier response by the emergency medical services.

Table 11. Resources available for population.

	1991	1992	1994	1995	1996
Population for El Paso County	403,731	420,705	454,220	465,885	473,982
Ambulance Providers	2	2	1	1	1
Ambulances Operating Daily	21	21	15	15	15
Population served per ambulance	19,225	20,034	32,444	33,278	33,856

Compiled data provided through interviews, Table 11 indicates the resources that were available during the years of 1991 through 1992 and 1994 through 1996. It is important to note that, when there were two organizations providing service, 21 ambulances were responding to incident requests; and when there was only one organization, 15 ambulances were operating daily. At the same time the population increased from 403,731 in 1991 to 473,982 in 1996. This means that the number of people supported by an ambulance went from 19,255 to 31,599. In 1996 the population supported by an ambulance was 1.64 times more than in 1991.

The El Paso County Emergency Medical Services Office provided the data covering response time during the periods of 1991 through 1992 and 1994 through 1996. The data from 1991 through 1992 covers all twelve months of each of those years. The data from the period of 1994 through 1996 includes the months of April – December, 1995, all twelve months of 1995, and January through September of 1996.

Table 12. Response times and distance for emergency medical - 1991 thru 1992

Year	Responses to Incidents	Average Response Time	Average Total Time	Average distance to Scene	Average Total Distance per Call
Apr-91	1044	5.14	29.55	2.72	8.22
May-91	1225	5.29	29.79	3	8.78
Jun-91	1216	5.26	28.6	2.98	8.67
Jul-91	1274	5.32	29.11	2.89	8.44
Aug-91	1259	5.18	29.24	2.9	8.6
Sep-91	1171	5.28	29.62	2.84	8.39
Oct-91	1102	5.39	30.07	2.81	8.4
Nov-91	1057	5.6	31.38	2.71	8.24
Dec-91	1144	5.53	30.78	2.96	8.49
Jan-92	1050	5.23	30.25	2.7	8.3
Feb-92	1001	5.23	30.07	2.86	8.61
Mar-92	1052	5.44	30.47	2.87	8.51
Apr-92	1091	5.18	29.77	2.8	8.52
May-92	1185	5.41	30.05	2.96	8.81
Jun-92	1222	5.68	30.54	3.17	9.66
Jul-92	1292	6	30.17	3.31	9.54
Aug-92	1233	6.28	31.02	3.48	9.38
Sep-92	1196	5.7	30.88	3.05	8.94
Oct-92	1186	5.76	30.24	3.17	8.6
Nov-92	1103	5.86	30.79	2.91	8.61
Dec-92	1207	5.79	30.66	2.86	8.3
Average	1,137.67	5.46	30.10	2.93	8.64
Minimum	923	4.96	28.6	2.63	8.19
Maximum	1292	6.28	31.38	3.48	9.66

Table 11 provides data concerning the population in the years of 1991 – 1992 and 1994 – 1996. The average population for the years of 1991 – 1992 was 412,218, and in 1994 – 1996 it was 464,696. This reflects a 12.5 percent increase in average population. The average responses in 1991 – 1992 was 1,138, while in 1994 – 1996 it was 1,938. This represents a 70.3 percent increase in responses in 1994 – 1996 against a population increase of 12.5 percent. At the same time there was a 67 percent decrease in the number of ambulances available for responding to requests. Additionally, the response time reflects a 9.5 percent increase in the 1994 – 1996 timeframe with two thirds the mobile resources and a 12.7 percent average population increase.

Table 13. Response time and distance for emergency medical - April 1994 thru September 1996

Year	Responses to Incidents	Average Response Time	Average Total Time	Average distance to Scene	Average Total Distance per Call
Apr-94	1302	5.65	31.43	3.23	8.96
May-94	1366	5.69	31.04	3.21	8.99
Jun-94	1342	5.9	31.08	3.5	9.49
Jul-94	1457	6.48	32.5	3.67	9.82
Aug-94	1548	6.22	31.51	3.66	10.25
Sep-94	1472	6.1	31.67	3.55	9.48
Oct-94	1414	5.88	31.65	3.35	9.25
Nov-94	1338	6.02	32.42	3.47	9.65
Dec-94	1370	6.48	33.02	3.47	9.65
Jan-95	2061	5.54	31.98	3.34	9.2
Feb-95	2017	5.92	33.53	3.31	9.53
Mar-95	2240	5.62	32.35	3.11	9.13
Apr-95	2069	5.78	33.48	3.34	9.85
May-95	2364	5.62	31.88	3.19	9.22
Jun-95	2415	5.78	31.96	3.13	9.12
Jul-95	2420	5.84	32.11	3.28	9.37
Aug-95	2663	5.92	31.93	3.24	8.99
Sep-95	2575	5.64	31.93	3.21	9.33
Oct-95	2565	5.72	31.89	3.27	9.45
Nov-95	2209	5.80	32.94	3.34	9.51
Dec-95	2214	5.64	32.02	3.27	9.45
Average	1,937.77	5.98	32.45	3.41	9.51
Minimum	1302	5.54	31.04	3.08	8.93
Maximum	2663	7.13	36.31	3.98	10.72

The differences between the two time periods are reflected in the following table.

Table 14. Amount of changes comparisons.

Item Being Compared	1991 – 1992 Non-GPS	1994 – 1996 GPS	Percent Change
Available ambulances	21	15	29% decrease
Average population	412,218	464,696	12.7 increase
Average responses	1138	1938	70% increase
Average response time in minutes	5.46	5.98	9.5% increase
Technology	Non-GPS	GPS	

In reviewing the data found in Table 14, there is a disproportionate increase in the time to respond to incidents than would be expected based on the increase in population and a decrease in mobile resources available to respond. The possible difference that would provide that level of impact is the use of GPS.

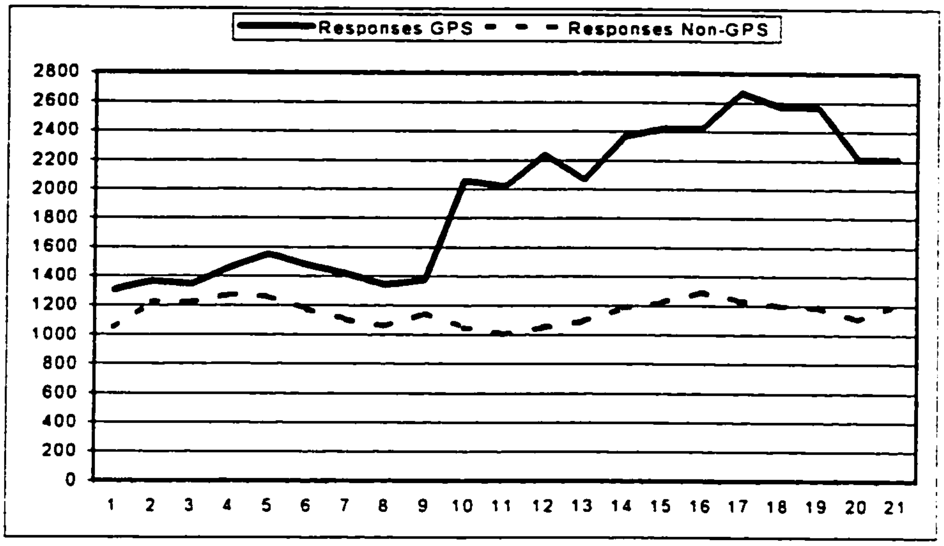

Figure 13. Graphical comparison of incident responses prior to GPS and after GPS.

Figure 13 graphically portrays the number of responses to incidents. The responses during the period of 1991-1992 are prior to the use of GPS and were supported by two separate organizations and 21 ambulances. The solid line reflects the responses from the 1994 – 1996 years, which were after the beginning of use of GPS. As identified in Table 14 there was an increase of 70 percent in responses to incidents.

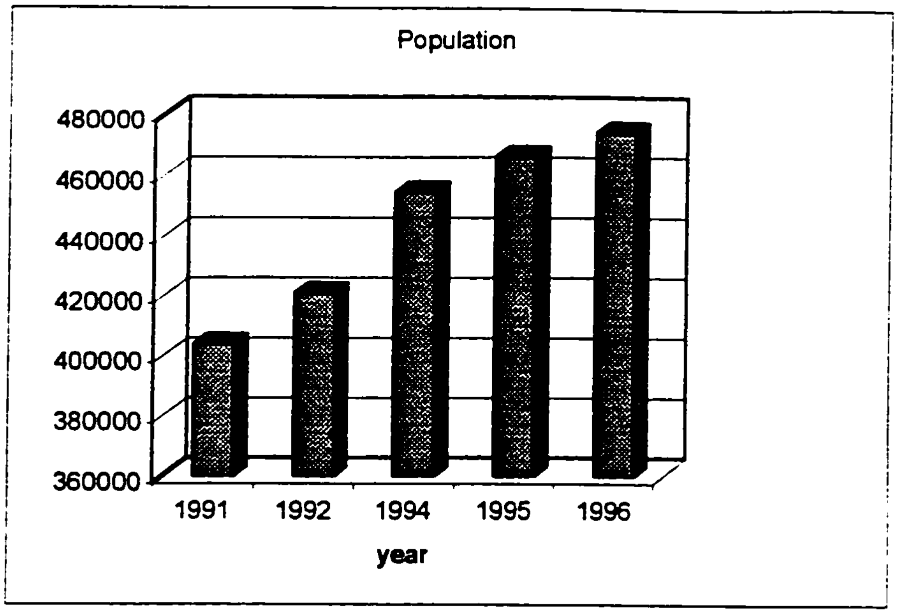

Figure 14. Graphic portrayal of population for the years examined in the research.

The population is represented in the bar graph in Figure 14. The population increase is 17.4 percent from 1991 to 1996.

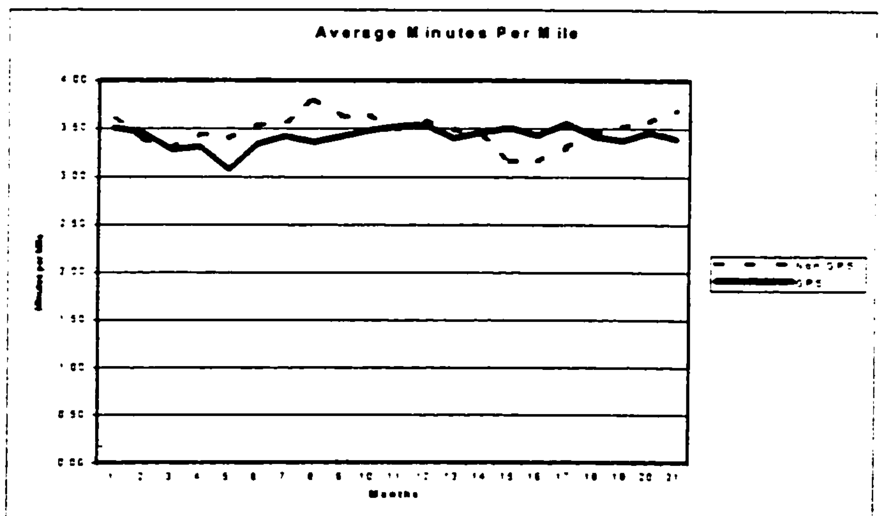

Figure 15. Comparison of Response Minutes per Mile, with and without GPS.

When looking at the graph in Figure 15 it appears that there is little difference between the data representing non-GPS and GPS Response Minutes per Mile. However, it must be noted that there is a significant difference in the resources available to respond to incidents during the two periods. The non-GPS period was accomplished with 21 ambulances, while the GPS period was done using 15 ambulances. Yin (1994, 106-109) indicates that one of most desirable strategies to use in the analysis of data in a case study is that of pattern –matching. In this study, it is evident from the patterns in that there is no change between the response from when 21 ambulances were in use and when 15 ambulances were used. The factor that changed during that period was the integration of technology. This suggests that the use of technology allows for a decrease in resources used to service a population without a comparable decrease in the service to that population. The question arises on how to compare the two separate sets of data, one when there was no use of GPS technology and the second after the use of GPS. This question would not be addressed if the ambulances used during each period were the same in number. However, in this case we have the introduction of new technology with a decrease in mobile resources. Additionally, consideration must be given for the fact that the difference between the two sets of data as shown in Table 14, is only 0.52 minutes. The next section discusses the use of queuing theory to look at the support of the community by the emergency medical services organization.

Queueing Theory

In this research there is a look at integrating technology to improve the communications and coordination of allocating mobile resources to incidents. This study focuses on the impact of that integration on an emergency medical services organization. In this case there is a set of ambulances available to move to an incident site and provide service by moving a patient to a medical facility. Here the patient is waiting for service and the ambulance provides the service. Responding quickly has previously been identified as being important in minimizing mortality rates and lowering morbidity levels.

Queueing theory specifically looks at waiting lines and service of those elements in the waiting lines. It allows the analysis of those waiting lines and the services by providing algorithms that determine the following:

1. Length of the waiting line,
2. Mean element waiting time,
3. Mean element time spent in the system,
4. Mean number of elements in the system, and
5. Server utilization factor.

The terms in the above list should be looked at in terms of patients and ambulances, in lieu of waiting, element, system and server.

By looking at the various aspects of the queuing involved in this organization and analyzing the data, costs may be developed that allow for the determination of benefits derived from a particular implementation of resources. In this research, queuing theory will be used to help determine the benefits derived from the integration of technology in the emergency medical services organization. (Lapin 1994, 776-807; Knowles 1989, 786-829; (Buffa and Dyer 1981, 430-469)

Queuing Theory Algorithms

The algorithms that will be used for this current study will assume a Poisson distribution of requests for service and an exponential distribution of the time between requests. In the work by Buffa and Dyer (1981, 430-434) there is a specific look at the emergency medical system in Los Angeles and the ambulance support. They state that, "Previous research shows that call rates follow a Poisson distribution." Based on their work, this study will use that distribution. Further, Lapin (1994, 94-97), states that the Poisson distribution provides probabilities for the number of events that may occur over a period of time and that exponential distribution provides for the probabilities for times between events. These events appear to be random in their pattern but the mean arrival rates between Poisson processes give them their comparative difference. The calls for service cannot be predicted since they are made only when the service is determined to be needed. Hence, the random number of call and time between calls call for the Poisson and related exponential distribution.

In the case of the emergency medical services organization, there is one individual answering calls for service. There are several ambulances available for responding to the requests. This means that there is a single waiting line with multiple servers. The following figure portrays that information.

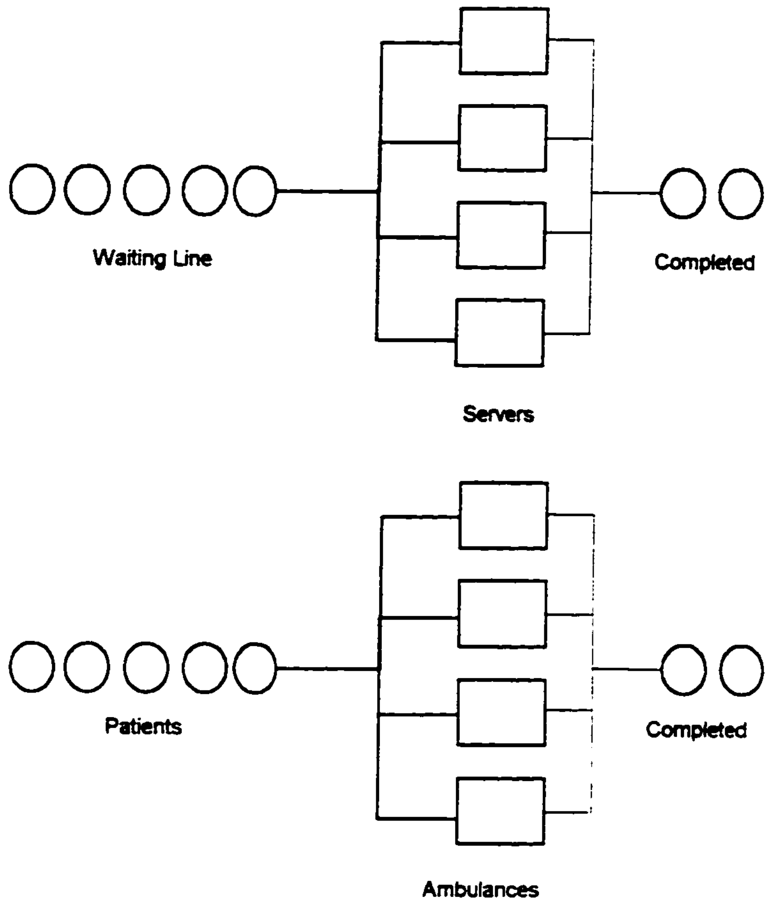

Figure 16. Portrayal of single line with multiple servers.

The algorithms that will be used to calculate the characteristics and performance of multiple server queues are as follows (Lapin 1994, 790-791):

To calculate the queuing system state probabilities,

$$P_0 = 1 \Big/ \left[\sum_{n=0}^{S-1} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^S}{S!} \left(\frac{1}{1-\lambda/S\mu} \right) \right]$$

$$P_n = \begin{cases} \dfrac{(\lambda/\mu)^n}{n!} P_0 \ldots\ldots\ldots\ldots\ldots\ldots \text{if } 0 \le n \le S \\ \dfrac{(\lambda/\mu)^n}{S!S^{n-S}} \tau_0 \ldots\ldots\ldots\ldots\ldots\ldots \text{if } n \ge S \end{cases}$$

To calculate the mean number of patients waiting (length of the line),

$$L_q = \frac{(\lambda/\mu)^S(\lambda/S\mu)}{S!(1-\lambda/S\mu)^2}P_0$$

To calculate the mean patient waiting time,

$$W_q = \frac{L_q}{\lambda}$$

To calculate the mean patient time spent in the system,

$$W = W_q + \frac{1}{\mu}$$

To calculate the mean number of patients in the system,

$$L = L_q + \frac{\lambda}{\mu}$$

To calculate the ambulance utilization factor,

$$\rho = \frac{\lambda}{S\mu}$$

The calculations for the above formulae are performed using QuickQuant Version 4.0. The reports from QuickQuant are provided in Appendix C. There were two separate runs of QuickQuant, one to represent the 15 ambulances in use with GPS and the other to represent the use of 21 ambulances prior to the integration of GPS. The data in Table 15 was provided by the emergency medical services organization and reflects the data for 1996. This data was used to determine the variable λ. It was calculated by taking the total requests for 1996 (23,468) and dividing by 365, giving the result of 64 average service requests per day. The 64 is divided by 24 to determine the average requests per hour, which is 2.7. λ is equal to 2.7. The variable μ is taken from the data in

Table 13, the average total time to service a request (32.45 min minutes) and divide by 60 to determine the average part of an hour (0.54 hours). The variable μ is 0.54. The number of servers (ambulances) is 15. That is the input for the computations for the period of 1994-1996 with GPS in use. For the period with non-GPS the figures are taken from Table 12. The variable λ is calculated by taking the average number of monthly requests for service, multiplying it by 12 to obtain the annual service requests and dividing that result by 365 to get the number of requests per day. This amount is then divided by 24 to determine the average number of requests per hour (1.56). The variable μ is obtained by dividing the average total time per service request (30.10) is divided by 60, giving 0.5.

Table 15. Average requests for service by hour in 1996.

Hours	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
0001-1000	111	97	121	97	127	163	148	864
0100-0200	99	86	92	80	101	176	140	774
0200-0300	83	80	83	80	79	163	131	699
0300-0400	63	69	52	58	62	102	87	493
0400-0500	44	62	53	45	36	77	72	389
0500-0600	60	37	52	48	44	42	55	338
0600-0700	70	69	84	61	69	63	52	468
0700-0800	116	91	112	115	107	78	87	706
0800-0900	123	121	149	126	121	124	88	852
0900-1000	144	126	148	140	145	136	92	931
1000-1100	138	143	156	169	160	145	106	1017
1100-1200	155	157	178	147	184	165	151	1137
1200-1300	182	166	189	175	197	188	148	1245
1300-1400	159	172	167	189	189	224	166	1266
1400-1500	150	156	198	180	188	190	146	1208
1500-1600	201	189	175	195	216	196	166	1338
1600-1700	193	202	184	195	211	215	167	1367
1700-1800	181	240	196	212	228	203	165	1425
1800-1900	199	198	190	203	205	193	164	1352
1900-2000	166	172	185	149	211	194	160	1237
2000-2100	178	165	151	185	227	160	158	1224
2100-2200-	182	152	166	185	186	198	134	1203
2200-2300	149	148	119	151	177	164	127	1035
2300-2400	126	121	119	117	179	133	105	900
Totals	**3272**	**3219**	**3319**	**3302**	**3649**	**3692**	**3015**	**23468**

Again, the results of the calculations for the queuing information are shown in Appendix C and will be discussed, with the results, in Chapter V. There will also be calculations of the cost and benefits models and discussion of those results. Further, there will be a comparison of the results of the cost and benefits models against the results of the queuing theory computations.

Summary

This chapter has identified which technologies will be integrated. It has named specific vendors of those technologies and provided those vendors' unit prices for acquisition of the technologies. Following the technology was the development of a cost model. The benefit portion of the cost-benefit model was presented. The data from the records of the emergency medical services organization was presented. The data represented periods from prior to and after the implementation of GPS and GIS technology by the emergency medical services organization. Comparisons of the data were presented and analyzed. Finally, there was an interpretation of the findings from the analysis.

The technologies to be integrated were determined to be GPS, GIS, laptop computers, wireless communications and standard hardwired networks. Each of these technologies is in common use and available as COTS (Commercial-Off-The-Shelf). The names of vendors have been provided so that it is possible to contact the vendor and make a purchase of the specific items. The prices were current during the first calendar quarter of 1997.

The cost model developed, was based on Brudney and Duncombe's (1992) algorithm. The simplicity of the model allows for quick and easy use by organizations in determining the costs for acquisition, operation, and maintenance of the system. The developed model allows for the calculation of the total annual operating cost over a number of years. The model also simplifies computation by using today's dollars as the comparison point. This implies a limitation on determining economic value due to not including the discounting of values for taking present value and calculating the future value of an item. The detail provided by using discounting methods can cause initial confusion when discussing cost-benefit with functional operating organization members.

The values that were input for the model variables were based on input from various sources. The personnel values were provided by the emergency medical services organization. The specific data covered the dispatcher personnel and the ambulance crew members. They also provided the number of ambulances that were in services at each hour of a day. The emergency medical services organization also provided the cost of the vehicles and the medical support equipment required in each ambulance. The data for the maintenance, fuel and oil were also provided by them. Additionally, the values for the facilities were provided by this same organization. However, the number of requests for service, distances traveled, and elapsed time for the missions was provided by the county health services organization. The costs of the technical equipment, GPS, GIS, wireless communications, and networking, came from a combination of vendors and the emergency medical services organization.

Graphic portrayals presented how the technology would be configured into a system architecture. There was a portrayal of where in the architecture solutions would occur for the communications and coordination problems identified in the literature. The graphics also identified the vendors for the specific technology pieces.

The tables in this chapter have identified the elements needed for input values to the model. Table 10 provided a single location where each of the input variable values could be found. Other tables provide data that is needed for comparing the results from the cost-benefit computations. This data was the population for the county, the number of service providers, number of ambulances operating daily, and the population served by each ambulance. Table 14 showed the comparison of the amount of change that occurred between the period prior to and after the use of technology.

The last section of the chapter, prior to this one, covered the queuing theory algorithms. It presents the equations and what information they provide. A tool was used to actually perform the queuing theory computations. The tool is QuickQuant Version 4.0.

The next chapter, Chapter V is where the actual computations take place. The results of the computations are presented, analyzed, and discussed.

CHAPTER V

RESULTS

Chapter IV identified the technology that would be integrated into the virtual consolidated operations center concept. The layout of the cost and benefit algorithms was presented and explained. The data to be used in the algorithms, was presented. The changes of data over the time period covered was presented and discussed. There was a look into queuing theory to assess the impact of technology in improving communication, coordination, and cost/benefit.

In this chapter there is actual computation using the algorithms for cost-benefit and queuing. Discussion of the comparisons of the costs for the technology and implied benefits from the quicker response that may be provided by the technology will be presented. This will be developed from the cost-benefit algorithms. Following that, will be a discussion on the results from the queuing theory formulae. Any disparities between the results will be presented and considered.

Computation of Cost-Benefits

In this section the cost algorithms will again be presented and the variables filled in with the actual data. When this is accomplished the calculations will be made. The cost calculations will be made first, followed by the benefit calculations.

Cost Algorithms and Calculations

The cost algorithms were explained in Chapter III. They are again presented, but without explanation. Total cost is:

TC = TAC + TAOC,

TAC = HAC + SAC +DbSC +n(MREC) + n(MRAC), and

TAOC = LC + HOMC + SOMC + DbMC + Fac + m(MROMC).

The values for the variables are identified in Table 10. They will be identified with each algorithm.

In calculating TAC the values for the variables are:

HAC = $84,506.00,

SAC = $89,100.00,

DbSC = $50,436.70 (*$252,183.50* is the total amount. *However, since there are 5 departments that will be using this same set of data it would be appropriate for each department to share in the total cost. In that case, the actual cost to an individual department will be $50,436.70*.),
n = 15,

MREC = $57,000.00, and

MRAC = $64,000.00.

Placing those values in the formula for calculating TAC:

TAC = 84,506 + 89,100 + 50,436.70 + 15(57,000) + 15(64,000);

TAC = 84,506 + 89,100 + 50,436.70 + 855,000 + 960,000;

TAC = $2,039,042.70

In calculating TAC (Total Acquisition Cost), it is seen that the emergency medical services organization would have an expenditure of just over two million dollars.

This would cover acquiring fifteen ambulances, their medical equipment, the radios, and all GPS and GIS components (including the database) for the mobile resources and dispatcher. It must be noted that this does not cover any extra vehicles that might be desirable for replacement of vehicles that are not available due to maintenance requirements.

The values for the variables in calculating TAOC, are:

LC = $2,784,518.00,

HOMC = $13,408.24,

SOMC = $4,500.00,

DbMC = $583.04,

Fac = $8,190.00,

m = 23,256, and

MROMC = $1.09

Placing those values in the formula for calculating TAOC:

TAOC = 2,784,518 + 13,408.24 + 4,500 + 583.04 + 8,190 + 23,256(1.09);

TAOC = 2,784,518 + 13,408.24 + 4,500 + 583.04 + 8,190 + 25,349.04;

TAOC = $2,836,548.32.

The results of calculating TAOC (Total Annual Operating Costs) is over two and three-quarter million dollars per year. That amount covers the cost of operations for the emergency medical services organization for the dispatch and ambulance operations. This amount does not include other personnel or facilities costs.

When calculating for TC (Total Costs), it must be remembered that the formula is TC = TAC + yTAOC. The variable y is the number of years that are being looked at by the model. In this study the y variable will have a value of 1.

TC = $2,039,042.70 + 1($2,836,548.32);

TC = $2,039,042.70 + $2,836,548.32;

TC = $4,875,591.02

The total cost for implementing the virtual consolidated operations center concept into the emergency medical services organization is $4,875,591.02. This reflects the acquisition of all equipment and setup of the GIS database. This figure also includes the operations cost for one year.

Benefit Algorithms and Calculations

This section will look at the benefits derived from use of the integrated technology. In Chapter IV there was an identification of four components where benefits were to be derived. Those components are reduction of mortality rates, reduction in morbidity level, reduction of medical costs (loss of labor by employer and income by the family), and reduction in inventory of mobile resources.

Benefit Algorithms

In Chapter IV the benefit algorithm for the mortality portion of the model identifies the formula for the change in mortality rate. That formula is as follows:

Δ MR = MRBH – MRAH.

At this time the values from Table 2 will be placed into the formula. The value of 4.5 will be used for MRBH and 2.5 for MRAH. MRBH represents the mortality rate before helicopters and MRAH represents the mortality rate after helicopters. The 4.5 is from the World War II mortality rate from 100 casualties. The value of 1.0 is the mortality rate from 100 casualties during the Vietnam War.

$$\Delta \text{MR} = 4.5 - 1.0,$$

$$\Delta \text{MR} = 3.5.$$

The results are then used in the formula to determine the decrease in mortality rate.

$$\text{DMR} = \frac{\Delta\text{MR}}{\text{MRBH}}$$

$$\text{DMR} = \frac{3.5}{4.5}$$

$$\text{DMR} = 0.78$$

The result of 0.78 for DMR (decrease in mortality rate) shows that between World War II and the Vietnam War there was a 78 percent decrease in the mortality rate for casualties. As previously found in the search of the literature, this decrease is attributable to the combination of the ability to quickly move the patient from the incident site to a treatment facility, and the ability to have medical treatment available within the helicopter.

The problem is to apportion the amount of the decrease that is attributable to the quick response and movement of the patient against that level attributable to having medical personnel on-board the helicopter and the movement of medical treatment facilities closer to the incident site. (Unfortunately, it has not been possible to calculate this for the current study since the hospitals do not have available data to show how patients arrived at the facility.)

The formula

$$BMR = \frac{DMR_{MT}}{1/DMR_{woMT}}$$

is used to determine the percentage that will be used to attribute a portion of benefits that are attributable to quick response and movement. The value for DMR_{MT} has already been calculated as 0.78. Now DMR_{woMT} must be calculated.

$$\Delta MR = 4.5 - 2.5,$$

$$\Delta MR = 2.0.$$

$$DMR = \frac{\Delta MR}{MRBH}$$

$$DMR = \frac{2.0}{4.5}$$

$$DMR = 0.44$$

$$BMR = \frac{0.78}{1/0.44}$$

$$BMR = \frac{0.78}{2.27}$$

$$BMR = 0.34$$

The result of BMR is 0.34 which means that 34 percent of benefits may be attributable to the movement of the individual and not to a combination of movement and medical personnel being available enroute with the patient. Therefore, in computations that are made pertaining to benefits, the results will be multiplied by the BMR to determine the amount of benefit that may be attributable to quick response and movement of the patient.

Benefit Calculations

In this section calculation will be made concerning the reduced costs resulting from having the decreased number of mobile resources and personnel attributable to GPS. There will also be computations on the number of individuals that were moved to treatment facilities that were considered to be in critical condition and those that died and the projected numbers that would have occurred if quick response were not available.

Benefit From Decreased Equipment and Personnel

In this section calculations will be made to determine the costs that were reduced since the implementation of GPS and GIS technology by the emergency medical services organization. The cost data was identified in Chapter IV and will be used for the calculation of costs that exist for the emergency medical services organization prior to the integration of GPS. In order to make the calculations, certain assumptions must be made; they are as follows:

1. The cost of vehicles and mobile medical support equipment are the same as those purchased today.
2. The number of dispatchers will be no different since the use of GPS does not increase the number of dispatchers.

3. The personnel that are on board each vehicle and their labor costs are the same as those in operation today. This means that there are two individuals on each vehicle: one is a paramedic and the other is an emergency medical technician.

The algorithms will be presented and the value for each variable will be identified and explained. In Chapter IV, the algorithms for total cost (TC), total acquisition cost (TAC), and total annual operating cost (TAOC) were identified as:

TC = TAC + yTAOC,

TAC = HAC + SAC + DbSC + n(MRAC) + n(MREC), and

TAOC = LC + HOMC + SOMC + DbMC + Fac + m(MROMC).

In order to determine the benefits derived from integrating GPS into the situation, the TC must be represented as both before and after GPS. To represent the before-GPS computations, the subscript "B" will be used and "A" for the after results. Each of the algorithms will have the appropriate subscript. In order to solve for $TC_{B\text{ or }A}$, $TAC_{B\text{ or }A}$ and $TAOC_{B\text{ or }A}$ must be resolved first.

TAC_B = HAC + SAC + DbSC + n(MRAC) + n(MREC). The following values will be used.

HAC = 0. There was no hardware purchased that was special prior to integrating GPS.

SAC - =. The reasoning is the same as that for HAC.

DbSC = 0. The reasoning is the same as that for HAC.

n = 21. There were 21 vehicles in operation during the period prior to the integration of GPS.

MRAC = \$64,000. The same value is used as when calculating current vehicle acquisition cost.

MREC = \$57,000. The same reasoning applies as in MRAC.

Now that the values have been identified the calculation is as follows:

$TAC_B = 0 + 0 + 0 + 21(64{,}000) + 21(57{,}000)$,

$TAC_B = 0 + 0 + 0 + 1{,}344{,}000 + 1{,}197{,}000$,

$TAC_B = \$2{,}541{,}000$.

The total acquisition costs for the 21 ambulances was \$2,541,000.

$TAOC_B = LC + HOMC + SOMC + DbMC + Fac + m(MROMC)$. Looking at the number of vehicles that provide support during any period of time, the El Paso County offices indicated that there were an average of 10 vehicles available per hour with the highest number providing support being 15. These same offices reported that during the period prior to having GPS integrated, 21 vehicles were the highest number providing support. With this data it is apparent that only two-thirds of the vehicles are being used on the average per hour. Since data is not available to determine the number of vehicles that were providing support during the period prior to the use of GPS, it will be assumed that the two-thirds is appropriate for that period as well. As a result two-thirds of the high number providing support during the period prior to GPS would be 14. With the average of 14 vehicles providing support per hour the computation for labor costs (LC) will use that figure for calculating the value for LC. The value of LC in Table 6 is \$2,461,368. This amount is only for those personnel that are on board the ambulances. Additionally, that figure represented the average of 10 vehicles per hour. If we use that figure and divide it by the number of vehicles per hour (10) we obtain the amount of $246,136.80 annual cost of personnel operating a vehicle. Taking that annual figure and multiplying it by the average vehicles operating per hour during the period prior to GPS, we have the value of $3,445,915.20. This will be the value used for the variable LC. The following values will be used.

LC = 3,445,915.20.

HOMC = 0. No special hardware is in use in the period prior to GPS.

SOMC = 0. No special software is in use in the period prior to GPS.

DbMC = 0. The same reasoning applies as used in SOMC.

Fac = 0. There is no difference in use of facilities prior to GPS being integrated.

m = 8,784. This is calculated by taking data from Table 12. The numbers are rounded up. The average responses to incidents (1138) is multiplied by the average total distance per call (9), giving 10,242 average miles per month. This figure is divided by the number of average vehicles per hour (14), giving 732 average miles per vehicle per month. This figure is then multiplied by 12 to give a result of 8,784 average miles per vehicle per year.

MROMC = 2.32. Since data is not available for maintenance and fuel and oil costs per mile, the same figures shown in Table 8 will be used. Additionally, a new sinking fund amount must be calculated. The annual sinking fund base figure costs that were used to calculate the amount in the above referenced table was $17,286 per year. Dividing that amount by the average annual miles of 8,784 gives a cost of $1.97 per mile. Add that to the 0.18 and 0.17 per mile for maintenance and fuel and oil the result is $2.32 per mile.

$TAOC_B = LC + HOMC + SOMC + DbMC + Fac + m(MROMC),$

$TAOC_B = 3{,}445{,}915.20 + 0 + 0 + 0 + 0 + 8784\ (2.32),$

$TAOC_B = 3{,}445{,}915.20 + 20{,}378.88,$

$TAOC_B = \$3{,}466{,}294.08.$

The total annual operating costs in the period prior to the integration of GPS is $3,466,294.08.

Since there will only be a look at one year of annual operating costs the value of "y" will be 1.

$TC_B = TAC_B + yTAOC_B,$

$TC_B = \$2{,}541{,}000 + 1(\$3{,}466{,}294.08),$

$TC_B = \$6{,}007{,}294.08,$

In reviewing the calculations of TC_B it was found that TAC_B = $2,541,000 and $TAOC_B$ = $3,466,294.08. The calculations gave a result for TC_B of $4,852,835.02 with TAC_A TAC = $2,026,786.70 and $TAOC_A$ = $2,826,048.32.

Table 16. Costs for before and after integration of GPS.

Component	Before GPS	After GPS	Difference	% Change
TAC (Total acquisition costs)	$2,541,000	$2,039,042	$501,958	20%
TAOC (Total annual operating costs)	$3,466,294	$2,836,548	$629,746	18%
TC (Total Costs)	$6,007,294	$4,875,590	$1,131,704	19%

It was stated in Chapter I, in the section entitled, "Design of the Case Study," that certain criteria would be used in evaluating comparisons between the costs before and after the integration of technology. The criteria stated, was, 10 percent or less change would be determined to be insignificant. A change of 11 to 20 percent would be determined to be moderate. Changes that were greater than 20 percent would be determined to be significant. When looking at Table 16, and remembering the evaluation criteria, it is apparent that there is a significant difference between the total costs between the before GPS operations and the after GPS operations. An analysis of where those costs difference exist, will be accomplished later in this chapter.

Comparison of Cost to Benefit for Decrease in Equipment and Personnel.

In Table 16 it is apparent that the difference between the costs from before GPS and after GPS is 19 percent which would be a moderate to significant difference. Since that difference is due to a reduced cost of acquisition and operations with the integration of GPS, this would indicate a cost benefit. However, determination of where this saving occurs must be made before a decision is made that integration of GPS will result in a cost benefit.

When looking at the elements that make up the acquisition, it is apparent that the cost of purchasing 6 additional ambulances with the appropriate medical support equipment has been greater than the purchase of the new technology, setup, and support costs. Further, review of the operating costs shows that the additional personnel required to operate an average of 14 vehicles per hour is an obvious increase. A more subtle increase is the increase of the per mile sinking fund cost. When considering the fixed annual sinking fund cost it becomes readily apparent that the greater the miles that are made by a vehicle the lower the sinking fund cost per mile.

A quick appraisal of the figures would probably cause an individual to make a decision to reduce the number of ambulances even more. By taking this action the result would be a lower amount of funds expended for acquisition as well as labor and operations. However, there needs to be consideration of the ability to serve the citizenry. In the next section there will be a look at the benefits from responding quickly to incidents and getting victims to proper treatment facilities. The use of queuing theory will identify differences in response times and assist in determining if there is a significant increase in the time it takes to respond to an incident request and arriving at the final destination with the patient.

Results From Use of Queuing Theory Algorithms

In this section the data provided by the El Paso County Health Services Office will be used as input to queuing theory algorithms to analyze the differences between the two collection periods (before GPS and after GPS). There will be specific attention given to any increase in time required to respond to a request and to move a patient from the incident site to the treatment facility.

Lapin's (1994) text includes licensed usage of a special 4.0 version of the QuickQuant decision science software package. As a result, QuickQuant was used to perform the computations for the queuing algorithms. Additionally, the multiple server function was used since in both time periods there was more than one ambulance being used in a single hour period.

Results from Queuing Theory Computations

The results, from the running of QuickQuant, are located in Appendix C. The following table will lay out the results so there is an easy comparison between the two runs.

Table 17. Queuing theory computation results between 21 vehicles without GPS and 15 Vehicles having GPS

Computed Element	(A) 21 Ambulances without GPS	(B) 15 Ambulances with GPS	Difference (B – A)
Mean Customer Arrival Rate	1.56	2.7	1.14
Mean Customer Service Rate	2.0	1.85	-0.15
Number of Servers	21	15	-6
Mean Number of Customers in System	0.78	1.45	0.67
Mean Customer Time Spent in System	0.5	0.54	0.04
Mean Length of Line	1.948255E-24	6.15967E-12	0.0006
Mean Customer Waiting Time	1.248882E-24	2.281359E-12	2.2814E-12
Server Utilization Factor	3.714285E-02	0.972973	0.9358

When reviewing the results in Table 16 the following information is observed:

1. There is an increased number of patients arriving per time period (an hour) with 15 ambulances than with 21 ambulances,

2. The amount of time that it takes to provide support to a patient has decreased with the 15 ambulances than with 21 ambulances,

3. There is an increased number of patients in the system at any point in time with 15 ambulances when compared to 21 ambulances, and

4. The average time spent, by a patient, in the system has increased with 15 ambulance than with 21 ambulances.

As the results are discussed there will be an evaluation of them based on the criteria identified in Chapter I, in the section entitled, "Design of the Case Study," where it was stated that changes in the range of 10 percent or less would be determined to be insignificant. Changes from 11 to 20 percent would be determined to be moderate. Changes that were over 20 percent would be determined to be significant. Using the criteria the calculated changes will be discussed. Some of these changes are to be expected but not necessarily in the amount of the changes that are computed. To begin with when looking at Table 11, the population for 1991 was 403,731 and in 1996, 473,982. This is a difference of 70,251, which is a 17 percent increase and is considered to be moderate. When looking at the mean patient arrival rate it shows a 1.56 rate before the use of GPS and 2.7 after GPS. This difference of 1.14 calculates to an increase of 73 percent. This rate of increase is not in line with the increase of population in the county and raises questions as to why there is such a difference between the two percentages. However, this difference will not be addressed in this study in that both numbers indicate an increase.

Comparing the mean rate of serving a customer the pre-GPS period (with 21 ambulances) the service was able to handle two per hour, while with 15 ambulances it was able to handle 1.85 per hour. This drop of 0.15 per hour represents a change of 8 percent (insignificant) while the change in the number of ambulances was 29 percent (significant). There is an expected drop in the capability to support the number of patients due to the decrease in the number of ambulances and the increase in population. However, there is only an 8 percent change in the number of patients that may be served in a time period as opposed to the 29 percent decrease in the number of ambulances available. This disparate difference in the percentage rates between these two factors may be related to a combination of the use of new technology (GPS) and a change in management techniques within the emergency medical services organization.

The mean number of patients in the system doubles under the use of GPS with 15 ambulances. This corresponds to the increase in patient arrival rate and the decrease number that are able to be serviced during a specific time period. Additionally, the population increase would also cause this number to increase. Furthermore, this increase shows a relatively close relationship to the patient arrival rate. The patient arrival rate increased by 73 percent while the mean number of patients in the systems increased by 87 percent.

When looking at the mean patient time spent in the system, it can be seen that with 21 ambulances prior to the use of GPS there was a rate of 0.5 hours, while with 15 ambulances and after the use of GPS, the rate was 0.54 hours. This represents an 8 percent (insignificant) increase in the time it takes from receiving a request and the patient arriving at the treatment facility. Again, this indicates that GPS has provided the ability to better allocate resources to an incident by knowing where the resources are at any point in time. Furthermore, the use of GIS and the analysis of where incidents appear to occur at particular time periods allows for the placement of resources close to expected problem areas, thereby decreasing the time it takes to get to a patient and to a treatment facility. Additionally, this is evidently accomplished with an apparently significant decrease in available resources.

The queuing theory computations have been discussed, and now there must be a look at those computations and the resulting cost differences between the 21 and 15 ambulance time periods. In looking at the costs and making comparisons, the salaries of the patients must be brought into the computations. The patient's time is of value and, therefore, must also be included. The problem is what is the average salary of a person and is that a good figure to use? Due to large salaries that may be made by a very small portion of the population, there can be a skewing of the data. The mean salary could reflect a higher amount than is real. As a result, the median salary will give a statistically more accurate number to work with (Mason and Lind 1996, 74-101). The 1991 median household income for Colorado Springs was $30,118.00 (Rocky Mountain Internet, Inc., URL address http://www.usa.net/cscvb/facts.html). The hourly income would compute to be $30,118 divided by 52 weeks is $579.19 per week, which is divided by 40 hours per week to give an hourly income of $14.48.

Using the data from the queuing theory computations, patient hourly income, hourly cost of the ambulance crews, and the cost per mile for the ambulances, the cost per patient service will be computed. The computations will be based on the 21 and 15 ambulances and compared.

Table 18. Cost Computation Variables from Queuing Theory.

Elements	21 Ambulances	15 Ambulances
Patient Income Per Hour	14.48	14.48
Patient Time in System	0.5	0.54
Crew Cost Per Hour	28.18	28.18
Ambulance Cost Per Mile	2.32	1.09
Average Miles Per Incident	8.64	9.51

The cost computations must be made and compared between 15 ambulances with GPS technology and 21 without the GPS technology. The first computations are for the cost per hour for the patient's time and the ambulance crew. It is necessary to add the patient per hour income ($14.48) and the crew cost per hour ($28.18). The result is $42.66. The cost per hour is then multiplied by the patient time in system to obtain the cost per incident. The figure for 21 vehicles is 0.50 and when multiplied by the $42.66 per hour gives $21.33. For the 15 vehicles the patient time in system is 0.54 and when multiplied by $42.66 gives $23.04. It was identified in Table 18 that the average miles per incident for the 21 ambulances was 8.64 and 9.51 for the 15 vehicles. By taking the cost per mile and multiplying by the average number of miles per incident, cost per incident for vehicles operations is determined. For the 21 ambulances 8.64 miles per incident is multiplied by $2.32, giving $20.05 vehicle cost per incident, while for 15 vehicles 9.51 is multiplied by $1.09, giving $10.37.

Table 19. Cost per incident.

Elements	21 Ambulances	15 Ambulances	Difference
Cost per hour	$21.33	$23.04	$1.71
Vehicle cost per mile	$20.05	$10.37	$9.68
Total	$41.38	$33.41	$7.97

In reviewing the results displayed in Table 19 it is apparent that with the use of the technology and 15 ambulances the cost is cheaper than without the technology and 21 ambulances. We have seen that under the use of queuing theory algorithms there is evidence that there is a 19 percent savings in cost per incident when using GPS and 15 ambulances ($7.97 divided by $41.38). At the same time with the increase in population between the time period when 21 ambulances without GPS were used when compared to the period with GPS and 15 ambulances there is an increase in the time it takes to provide service to the patient. The service is from the time of receipt of request for service until the patient arrives at the treatment facility. The time taken prior to GPS was 0.50 hours while with GPS it was 0.54 hours. The difference between these two times is 30 minutes prior to GPS and 32 minutes with the use of GPS. This is a 2-minute time difference and savings of $7.97 per incident. When you take this information and apply the savings to a 12-month period's responses (the responses to incidents column for the months of January 1995 through December 1995 in Table 13) the annual savings may be determined. Those computations are $7.97 multiplied by 27,812 incidents equals $221,661 of annual savings by using the new technology.

Comparison of Results from the Two Methodologies

In looking at the cost to benefit as far as decrease in cost is concerned, it was previously identified that there was a 19 percent decrease in costs, which is determined to be a moderate change. The costs for the 21 ambulances not having the technology of GPS was a total of $6,007,294 for acquisition and one year's annual operating cost. At the same time, the lower number of ambulances and the acquisition and operation of those ambulances with the GPS technology cost $4,875,591. This 19 percent difference can be considered to be significant. Therefore, it is easy to state that by integrating technology, it is possible to decrease the number of resources (ambulances and their crews) and be able to still provide service and reduce costs. However, that does not look at the actual service provided to the patients. Queuing theory provides that look.

Queuing theory looks at service and support of the patient. Table 17 lays out the results of performing the calculations of queuing theory. It was noted that there was a decrease in the number of patients that could be handled in an hour. It also demonstrated that the number of patients in the system at any hour would be approximately double when using 15 ambulances instead of 21. However, the time spent in the system was only 8 percent greater with 15 ambulances in lieu of 21. This would probably be considered a small decrease in service support to the patient.

Next, the results from the queuing theory computations when applied with cost figures shows a marked decrease in cost per incident. During the period of 21 ambulances supporting the community, the cost per incident computed to $41.38. For the period when 15 ambulances were supporting the community with the GPS technology, the cost was $33.41 per incident. The difference of $7.97 per incident is a decrease of 19 percent. This cost difference is significant and leans heavily towards favoring the integration of technology.

Summary of Conclusions

The calculations of cost to benefits, queuing theory, and the cost analysis based on the queuing theory results point to a particular answer as to the benefits of technology integration into municipal service organizations. The immediate response might well be to start looking to the integration of technology to save public moneys and still provide reasonable service to the citizenry. A note of caution must be given. In this study, there is an important question that has not been answered. This is not due to neglect but due to data not being available. There is no way of knowing what the management decisions were during the period prior to GPS being used. It is unknown as to how it was determined as to where ambulances should be located during different times of day, days of the week, weeks of the month, and months of the year. It is quite possible that data was maintained to show where calls came from and their frequency. However, there is no evidence to support or refute that notion. In view of the lack of support to either side of the issue, the results of this study must take the conservative approach. Taking the conservative approach would mean that even though the indications point strongly towards the decrease in costs and therefore a benefit to taxpayer it would be prudent to minimize the degree of change. Where the change was 19 percent cost savings in the time period when GPS and 15 ambulances were used, it might be more sound to estimate that the decrease was between 5 to 15 percent. At the same time it would be wise to use the factors that were determined from the queuing theory computations. These factors indicated that there was some degradation of response to patients, but it does not appear to be of such a level that there is a significant increase in mortality rates.

Overall, it is best stated that the integration of GPS has allowed the reduction of mobile resources that are in use at any specific time period against those that were in use prior to the use of GPS, GIS, and wireless data communications. Further, there is evidence that even though there was a decrease of 28 percent of vehicles in use, there is only an increase of 8 percent in the time from the request for support is received until the patient arrives at the treatment facility. This would give an indication that the use of GIS, GPS, and wireless data communications can decrease the cost of operations for centrally dispatched mobile resources. In line with this thinking, would be that if there had not been a decrease in the number of ambulances from 21 to 15 in the two periods for which data was available, that it is reasonable to expect that there would have been a decrease in response times. As pointed out in the queuing theory computation results, even though there was a decrease in 6 vehicles being available, the time increase was 0.04 hours, which is 2.4 minutes. That time difference is only 2.4 minutes in a half-hour. It shows that even though this reduction of vehicles was significant (28 percent) the increase in time was from 30 minutes from call for request to patient being at the treatment facility to 32 minutes (8 percent increase in time), which again meets the criteria for being insignificant.

The above results and analysis support the hypothesis of this study: that the use of state-of-the-art communications and technology integrated into a centralized dispatching facility will increase the benefits by specifically decreasing the response time of organizations having mobile resources. Additionally, the results demonstrate that there was a moderate reduction in costs with an insignificant increase in time for a patient to be in the system.

CHAPTER VI

IMPLEMENTATION

The subject of this chapter is implementation. To implement an idea there must be a process that takes place to make the idea known. Once the idea is known it may then be considered for use within an organization. When considering the implementation of an operational system that is developed from a concept, another process must be considered. That process identifies the steps that must occur to create the system. This means that the process is focused on acquisition of equipment and software, installation of those elements, and installation of a communications network. This chapter will be broken into two major sections. This first section will discuss the process of making the idea known, while the second section will discuss the process of making the concept operational.

Making the Concept Known

The first thing that must be done is to determine how to make this new concept known. To do that there will be a discussion on what has occurred in the implementation of strategy by organizations. The experience and observations of individuals who have had to implement a new organizational strategy should provide guidance and direction in this pursuit.

Findings Relating to Implementation of Ideas

Wheelwright and Hayes found that, in order to accomplish change in organizations, the managers had to be able to communicate their vision clearly. Additionally, there was a need to prepare the members of the organization for the changes that were to be made. Their article also states that if transition of an organization is to occur it requires at least one senior manager to be the key catalyst for the change. That means that this manager must have understanding, belief, and vision of what the transition can bring to the organization (Wheelwright and Hayes 1985, 110-111). It is implied that the key individual be able to adequately communicate that understanding, belief, and vision.

Porter makes several observations in one of his studies. He states that organizations that have an advantage by having had the publics' attention to their services or products for a period of time become satisfied with the image and market that they have. The organization has seen how it is successful and standardizes its methods and processes through documentation and training of employees. This standardization assures that the organization is able to continue with the same level of quality and production of services and products. However, this brings about stagnation and new organizations and ideas are not readily incorporated into the organizational culture. This results in a falling behind in the state-of-the-art and state-of-the-technology. Because it has been successful in the past, it tends to develop a bias for the stability that it has experienced as well as the predictability. The members of the organization tend to fear that if there is change, there is much that may be lost. Further, the organization will tend to filter out information that would cause change to the norm. The organization will isolate and expel individuals who question the current methods and processes. (Porter 1990, 138-139) This information suggests the importance of moving slowly and providing meaningful information to those in the management of the organization. Additionally, where there is a monopoly on providing the service and products, it may be beneficial to make certain that the users of those services and products are aware of what good the changes give to them. From this source there will be outside pressure and encouragement for the organization to incorporate change.

In another of Porter's studies, he says that the ability to develop synergism between organizations is helpful in that there can be a sharing of either common skills or different but needed skills. He discusses the possibilities of identifying the value that an element of the overall organization provides from a value-chain perspective. Further, he indicates that through the synergism there may be a reduction in costs due to a decrease in redundancy (1987, 244-246). This observation helps to identify an approach to present the concept to municipalities. The tying in of skill sharing could lend strength to any presentation since governmental agencies are always being asked to provide more with less.

It is apparent from the readings that there is a need to have a key manager within an organization to have belief in the concept to have any opportunity for it to be accepted. It was further identified that organizations that have been successful are comfortable with their success and the methods that they employed for attaining that success. A result is that they perpetuate the methods that brought them success and are resistant to make changes because they are unsure of where the change might take them. These organizations tend to not want people who will rock the boat since those people are trying to change the methods that were successful in the past. Additionally, it was stated that the sharing of common skills and specialized skills between organizations could reduce costs and decrease redundancies. Any attempt at implementing a new concept will require consideration of how these findings can be used

An Approach for Implementation of the Concept

The desire of this researcher is to have this concept adopted by city and county agencies that dispatch mobile resources. To have an opportunity for that to occur, it is necessary to have an implementation approach that will apply the findings from the above readings. From the readings it is apparent that the points that must be addressed in the implementation of a concept are:

1. Educate the public.
2. Educate the governmental agencies.
3. Make the concept a common approach as opposed to being new and unique.
4. Develop a process that makes operational implementation relatively simple.

There needs to be an identification of what is necessary to educate the two different groups above. What is necessary to educate the public will be somewhat different than what is necessary to educate the government agencies. Additionally, the method of delivery will be different.

Since the public is concerned with improved services for lower cost per incident, it is important for their education to be focused on the use of tax dollars by the service organization. For the agencies, there must be a focus on the simplicity and the success that may be obtained through use of the concept. Since the focus is different, it must be considered when developing the information to be presented. The data to be presented will be different and is indicated in the following table.

Table 20. Information to be aimed at different segments of community.

Information to Present	Public	Gov't Agencies
Technology Available	X	
Technology Usage	X	X
Past Usage by Similar Organizations	X	X
Equipment Costs	X	X
Per Incident Usage Cost	X	X
Ability to Improve Service	X	X
Organizational Changes		X
Procedures in Use of Equipment		X

The information to be provided to the two different groups needs to be presented through a channel or medium that will be consistent with the information being given. Additionally, it must be in a form easy to understand and believe. The next sub-section will look at how to get the information to the public, followed by a sub-section on getting the information to the government agencies.

Getting Concept Information to the Public

In Table 20, the information to be presented to the public is identified. There are several ways to get this information out through the use of multiple channels of communication. Duplication of presenting the information will help to assure the widest distribution. One of the problems in getting information to the public is that it is not easy to get a large group of people together at a single meeting. Therefore methods must be looked at that will allow for the information to get to the greatest number of people. The methods that can best allow for that are television, radio, newspaper, civic organizations, and public action groups.

Radio and Television

There are many communities that have public broadcasting stations, both television and radio. On these stations there are frequently talk shows. These shows become forums for providing information to the community. The information can be informative and stimulating for discussion. This format of a talk show with people calling in and asking questions and expressing their opinions can help to provide the answers to the questions that the public has. Additionally, this format can help the public to much better understand what the concept involves since they can have their questions answered as well as hearing the comments of other listeners. Furthermore, if an agreement can be reached with a local radio station, there can be a schedule of several shows that occur over the period of months. By establishing this type of schedule, the opportunity exists to reach a greater number of people. If the presentations are interesting as well as informative, the people who initially listen will mention the subject to their friends and neighbors, thus getting more people involved. If the information is presented clearly and fully the potential exists for the listeners to pass the information on to those who are not able to hear the shows due to other commitments. This is yet another reason to schedule a series of programs over several months and different stations.

With radio and television there must be consideration for what can best be presented through each. With radio all the information is presented verbally. The communications skills of the presenter are important since there might be only one chance to present the information, and clear, concise, carefully chosen words must be used. Since there is no way of presenting visual material over the radio, the words chosen must clearly paint the picture of the concept. Use of numeric data can be confusing and misinterpreted. The data that should be presented on radio would be discussions of the concept and what it can do. There can be a general mention of the cost and performance factors but these can be better presented visually.

With television there is the opportunity of not only speaking to the public, but also giving visual data, such as graphs, pictures, and video-tapes of the use of the concept and technology. With television it is important to have the opportunity to have prior discussion with the local host and give him/her a presentation packet of the material that is available for presentation. It is also possible to have the host use questions that are formulated to help present the ideas to the television audience. Usually television presentations are more formal than those of talk radio.

This media is excellent for presenting cost and performance data comparisons in a graphical form. There will be impact on the viewers when the data is presented. There is a good chance of the information be retained from a general aspect. Specifically, this would be that one alternative appeared to be more responsive than another or that it was cheaper to provide a service using a special method

Newspapers

Another format that can allow for repeated presentation of the concept to the public is through the newspapers. In a city like Colorado Springs there are several newspapers being published. One is the daily that provides the news from international items to local items. There are also neighborhood newspapers that are printed on a weekly or less frequent basis. The neighborhood newspapers generally cover items that are of use to the people living in a certain section of the community. The items found in these issues are more specifically centered around issues of concern a specific element of the population.

Through the use of newspapers there is the possibility of providing some graphic data or pictorial items to complement the information being provided in the article. It is possible to have a concept covered in a special section of the newspaper that only comes out on an occasional basis. Additionally, it is possible that the concept could be presented through a series of articles over a period of time. The newspaper is an excellent forum for presenting graphical data since the individual can read the article, observe the graphic, and then reread the portion of the article if there is some confusion in understanding the data. Additionally, by being able to view and review the information there is a greater possibility of retaining the information.

It is my opinion that it would be best to have an opening article that would get the attention of the public and create letters to the editor. Letters to the editor, in the Colorado Springs newspaper, usually concern issues of local government. An opening article that would discuss the technologies that are available to be brought into the local infrastructure and lower the tax expenditures would be of particular interest to the local citizenry. This method would be appropriate for both the daily newspaper or the neighborhood publication. That would open the series that would explain the concept and show where the technology has been successfully used. This would demonstrate that the risk of failure is low and the chance for local success high.

The information that could be best presented in this manner would be those elements that could be demonstrated through the use of graphics. Tables with comparisons of costs before and after the use of the concept could be displayed and make for an eye-catching presentation. Graphics that portray the connectivity of the technology could be readily explained within the articles and help to educate the public on both how this concept is presented to agencies and how it works. Building up the public's understanding of technical issues can help to develop trust in what is being proposed and the agencies that will decide whether to incorporate the concept or not.

Civic Organizations and Public Action Groups

It is important to make presentations to civic organizations and public action groups. Both of the types of organizations are composed of people wanting to support their community. They are looking for ways to improve what is available or identifying areas that are in need of improvement, within the community. Example of civic organizations are SERTOMA, Kiwanis, Civitan, Lions, and Rotary. Public action group examples are, SCAN (Springs Community Action Network), and the Sierra Club. These groups are always looking for speakers to do presentations. The presentations are normally 20 minutes in length. This means that the presentation will have to be packed with vital information. Additionally, this information will best be presented with graphics so that the full impact of the benefits may be understood. It is always possible to get follow-on presentations with the civic organizations.

For the public action groups it is important to have an understanding of what the focus of each group is. If it is a group that is concerned with not bringing technology into the local government infrastructure, then this is probably not a wise expenditure of time. With these groups the presentation should be in a context that is compatible with the charter of the group. This will help to assure an atmosphere that is hospitable to the presenter. Additionally, graphics of the information (cost comparisons, benefits) will be appropriate. Again, the contents of the presentation should be based on the information identified in Table 20.

Getting Concept Information to the Government Agencies

It is important that the information identified in Table 20 be presented to government agencies. There are several approaches that may be used in making presentations to government agencies, but the opportunity to speak to large groups will not likely occur. In most cases it is possible to speak to individual managers or small meetings of managers. In most cases the presentations will be on a one-on-one or one-on-two situation. This has both advantages and disadvantages. In small presentations it is possible to answer all the questions that an individual might have. However, it is also possible to not keep focused on the presentation and not enough information gets to the managers having the decision-making authority. So it must be remembered that when in the small groups it is imperative to keep on topic and have a good outline that allows for flexibility to move over areas that the participants already have a background in.

To make an impact in getting the information on the concept into the hands of people who can make the decisions, it is necessary to look at what levels of the organizations must be briefed. Obviously, access to the director or chief of a department to make a presentation provides the possibility of getting an early indication of the possibility of bringing in a new concept. These are usually the individuals who make the final decision on capital expenditures for that organization. They are aware of the other programs that are important to their organization and how an idea will work and benefit their organization. This being true, it is imperative that the presentation be concise but inclusive of the cost and benefit data, the service to users statistics, and how the concept will improve coordination with other organizations and agencies.

Desktop presentations or presentations using overhead projectors or laptop computers are appropriate for these small and relatively intimate groups. Graphics for displaying comparative information, connectivity, and typical deployment of technology will be most helpful in these presentations. Where there has been experience in the use of the technology by similar organizations or with organizations that dispatch mobile resources, comments from the managers and the operators could be helpful.

Another method of getting information to the government agencies is by submitting articles to the professional journals that are referenced by the specific agencies that would use the concept. Determination of the specific journals is accomplished by visiting the offices and observing the journals available in the outer reception areas.

Copies of the articles, once published, may be sent to managers at affected agencies with a personal handwritten note. The note should give a proposed date and time to meet and discuss the concept.

Additionally, many of the organizations support local professional association membership. It is possible to provide oneself as a speaker to those organizations and thereby meet the managers who would be affected by the concept. Further, demonstration of expertise in the concept can develop a network of people with the same interests and knowledge. These people can help to get appointments to make presentations to those decision makers who manage the organizations of interest. In Colorado Springs, the Chamber of Commerce is such an association, as are, the IEEE (The Institute of Electrical and Electronics Engineers, Inc.), the National Defense Transportation Association, and the Pikes Peak Area Council of Governments.

The above discussion identifies which people need to be approached and how to meet them. It also identifies the method of presentation that would be helpful in approaching these individuals. However, the important element is to have a presentation that is concise, can be delivered in twenty or fewer minutes, and contains backup information that will give more depth, clear graphics, and supporting evidence. The next section will discuss an approach to implementing the concept into an operational mode.

Making the Concept Operational

This section will focus on making the concept operational. It will look at the steps that are needed for implementing automated systems. These steps will be those that are recognized as helpful in assuring the success of making the system operational.

Findings from Related Readings

Powers, Chaney, and Crow state that the installation phase is accomplished after the development of a system. They state that this phase is critical for two reasons. The first, is that the development has been completed and the effort of that development is to be realized. Second, it is a transition time for the users. They state that the benefits that will be realized by the users will depend directly upon the learning that occurs during this period. Additionally, in order to maximize benefits, the users must have depth of understanding of the capabilities of the system. (Powers, Chaney, and Crow 1990,763-766)

Adams, Powers, and Owles, dedicate a whole chapter in their to user training, followed by a chapter on installation. They clearly state that training is a preparatory activity for installing a new system. It is further stated that the training is conducted in a series of steps that are oriented towards a specific group of users. It is recommended that the training be a combination of instructional lessons and hands-on practice. This book, too, emphasizes the importance of depth of understanding of the system. (Adams, Powers, and Owles 1985, 445-453)

Senn calls attention to training, system conversion, the installation of the system. His comments are the same as those previously discussed. In system conversion he speaks not only about converting the files but also converting the personnel from operating the old system to the new system. In the installation of the system, Senn goes into enough detail to provide an installation checklist. His checklist is all inclusive as applies to the installation of a system that includes both hardware and software. That is appropriate for the implementation of the concept which is the focus of this study. (Senn 1989, 744-746, 752-753)

Operational Implementation Checklist

This sub-section will take the information that has been discussed on installation of a system and determine what needs to be incorporated for the concept presented in this study. This will be accomplished by presenting a checklist in the form of a series of steps. The steps will be in the order or execution. This will be followed by an explanation of the steps. Following the explanation will be a proposed time schedule. There will be two separate models of the checklist. The first will be for setting up an individual organization without consideration of interconnectivity between organizations. The second will be for the add-on steps required to connect the organizations together.

Installation Checklist for Individual Organizations

In order to implement the integration of technology in a single organization, or a group of individual organizations the checklist in Table 21 should be used. The table identifies the individual events that must take place for successful implementation in an operational setting. The checklist primarily identifies what steps must be accomplished and a basic order for accomplishing the steps. A Gantt chart will be developed to show the relative timings of the events, possible time frames, and dependencies between the events.

In Table 21 the task and its duration is identified on each line. The bold lettered lines are summations for the lines that immediately follow. The first entry shows a line number of 0. It is the overall summary for the entire implementation. The area of training indicates a very long duration. That indicates the days it takes from the start of training until all training is complete. In reality the training, if in contiguous days, would be significantly less. The schedule gives a better portrayal of these times. Note that the table gives the duration for each activity since that data is not on the schedule.

Table 21. Installation checklist for individual organizations.

Item Number	Duration	Item
0	**121**	**Implementation for individual organization**
1	**45**	**Acquisition HW/SW**
1.1	10	Solicit bids from vendors for hardware and software
1.2	5	Submit PO's for H/SW
1.3	30	Receive hardware and software
2	**52**	**Fixed Facility**
2.1	20	Facility layout drawings complete
2.2	10	Install electrical at fixed facility
2.3	10	Install console furniture at fixed facility
2.4	1	Install electrical connections and power connections
2.5	2	Install cabling for modems and radios
2.6	5	Install computers at fixed facility
2.7	1	Test hardware at fixed facility
2.8	3	Install and test software at fixed facility
3	**26**	**Mobile Resources**
3.1	20	Install equipment in mobile resources
3.2	3	Test hardware in mobile resources
3.3	3	Install and test software in mobile resources
4	**30**	**Data Conversion**
4.1	20	Perform file conversion of GIS data
4.2	5	Test file conversion
4.3	5	Correct discrepancies
5	**106**	**Training**
5.1	3	Train personnel on operations & concept
5.2	5	Train personnel with new HW/SW
6	**15**	**New Operations**
6.1	10	Test radios between fixed facility and mobile resources
6.2	5	Correct discrepancies
6.3	0	Begin normal operations

The checklist identifies each of the tasks that must be performed and the expected duration for those tasks. Additionally, there is a summary of a group of tasks and this is represented in bold print. The schedule that follows is a typical Gantt Chart with the tasks to be accomplished listed vertically and the relative time periods on the horizontal axis. The schedule is presented so there may be an understanding of the relationships between tasks. The relationships indicate whether a task must be completed prior to work being accomplished on the next or whether they may be worked on concurrently.

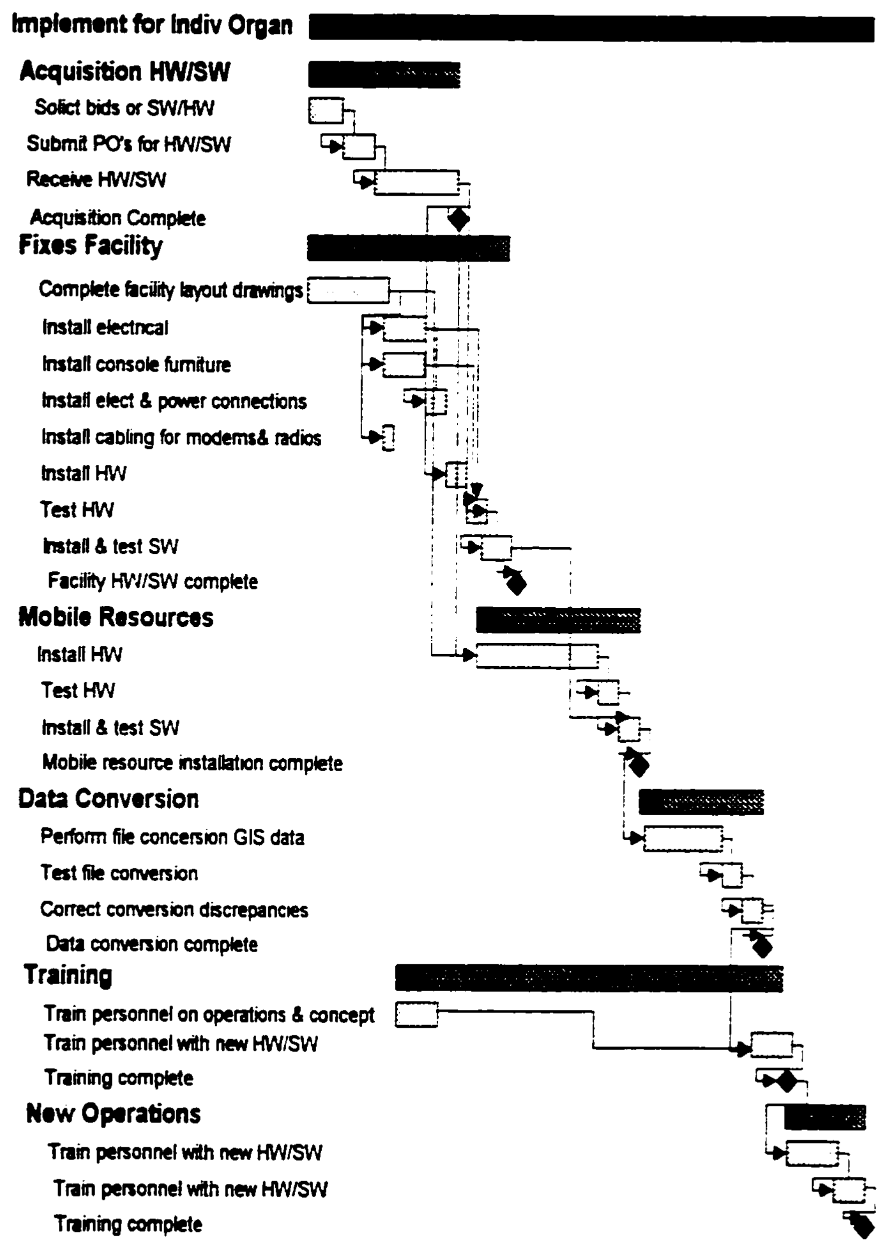

Figure 17. Schedule for implementation of concept for an individual organization.

The checklist and schedule reflect the implementation of the concept within an individual organization. The next sub-section will discuss the items on the checklist.

Explanation of the Checklist and Schedule.

This sub-section will cover each of the activities identified in the installation checklist at Table 21. The table is designed to cover what must be accomplished to implement the concept presented in this study. The activities were entered into Microsoft Project 4.1 and the data, as to duration of an activity and any dependencies it might have with other activities, identified. The application was then run to determine the overall project duration.

The items that appear in bold lettering are summary activities. The activities they summarize are indented below them. Notice item 0. It is the summary activity for the whole project. It shows a duration of 121 days. That means that when all the activities below it have their duration added together, the total will be 121. The first major area is the acquisition of hardware and software. This summary activity projects that it will take 45 days from the time a solicitation to vendors is submitted and the hardware and software is received. It is estimated that it will take ten days to solicit bids from vendors and receive their responses. The next activity is to submit the purchase orders to the vendors and should take no more than five days to complete. After the vendors receive the purchase orders they have to order out any special items they might need, consolidate the order, assemble the components, and test the equipment to assure it is working prior to their delivering it to the requestor. The actual receiving of the hardware and software would be an inventory check against the invoice to assure that all the components have arrived. Additionally, the receiving department will probably also look for any obvious damage resulting from the shipment. This activity is estimated to take no more than 30 days. That brings the total of the acquisition of hardware and software process to 45 days (10 + 5 + 30).

The next bold lettered activity is the fixed facility. It shows a total of 52 days duration for its accomplishment. The first activity is completing the drawings of the facility layout (20 days). This activity is to identify where electrical outlets, furniture, data cables, and equipment will be placed. The next activity is to install the electrical lines and outlets for the equipment that is purchased (10 days). The installation of the console furniture will be next. It must be in place before the hardware can be installed. This activity takes ten days. The next activity is attaching the electrical power to the console positions. This will also be true for any equipment racks that need electrical power. This activity takes no more than one day. It is necessary to make the runs of cable that will attach the modems, radio receivers, and computers. This activity takes no more than two days, and, once this is accomplished, the computers and peripheral equipment can be installed. The computers and their peripherals are installed and provided power and data connectivity. This is a no more than five-day activity. Once the equipment is attached to its power source and connected for data passing, it is tested. This process should take an additional day. Only one day is provided for this activity because a portion of the testing will occur while the equipment is being hooked to the power and data cabling. This one day is specifically to assure that nothing was missed during installation. The last activity for the fixed facility is to install and test the software that will be running on that equipment. This is estimated to take no longer than three days. Addition of the duration of each of the activities results in 54 days (20 + 10 + 10+ 1 + 2 + 5 + 1 + 3).

The next major group of activities is working with the mobile resources. The estimate is 26 days and is based on 15 vehicles having to have equipment installed in them. The first activity is installing the equipment into the vehicles. This is not as easy a process as office installation. The installation people are working in a tightly confined area and having to reach places that are difficult to get to. It is estimated to take 20 days for this to be accomplished (that comes out to about one-and-a-third days per vehicle). It is apparent that this could be pretty time-consuming if there is a large fleet of vehicles. That would be the case with a police department or sheriff's office. The testing of the equipment in the vehicles should take three days. That means that five vehicles could be tested per day. Again, the vehicles would have had their equipment partially tested while it was being installed. This activity is followed by the installation and testing of the software that will be needed in the vehicles, and should take three days for the 15 vehicles. The total of these activities is 26 days (20 + 3 + 3).

The next major area is that of data conversion. This is necessary only if the organization has been using another system that has a GIS database incorporated. The other instance would be if it is determined that they would use a standard database that is from the FIMS database (in Colorado Springs and El Paso Co·:nty). The time for the conversion is estimated to be 20 days. This is followed by a five day test to assure that the data converted correctly. If there were discrepancies a period of five days is allowed to make corrections. The total time for data conversion is 30 days.

The training of the personnel would occur in two phases. The first phase is orienting the people to work with this concept. That element of training is three days. The second phase gets the people to work in a hands-on environment with the new hardware and software and should take five days. However, the total time for the training activity is 106 days. The reasoning for this is that there are many things that take place between the two training periods.

The last major activity is the commencement of new operations. The first activity takes ten days and is continuous testing of radio communications between the fixed facility and the mobile resources. Some of the transmissions will actually go directly from the laptop computer in the vehicles to the dispatcher's console with positional data from the GPS receiver in the vehicle. Any problems that are found will be taken care of in a five-day effort to correct discrepancies. The total time is 15 days.

When looking at the time for all the activities, 121 days are allocated for the total implementation. The thing that must be looked at is the dependencies that exist between each of the activities. When looking at the schedule, lines are seen connecting activities. When a line goes from the end of one activity to the beginning of another activity, there is a relationship that shows that one activity cannot begin until another is complete. It is apparent some activities cannot begin until several other activities are complete. For example, the training activity of personnel training with the new hardware and software has a dependency on the preceding training activity and the completion of data conversion. If people are going to be trained on how to use the new hardware and software then those components must be complete, the data converted so it con work on the new equipment, and people must have had prior training on how the system operates.

In the acquisition of the hardware and software each activity is dependent on the preceding task being finished. Further, several activities are dependent on the hardware being received. It is also apparent from the schedule that many activities can take place in parallel. An example of this is the installation of the electrical components, installation of the console furniture, and installation of the cabling for the modems and radios.

To fully implement the concept of the virtual consolidated operations center to multiple agencies the same activities would have to take place within each organization. Additional activities would also take place in order to provide connectivity between all the organizations.

Implementation Across Organizations

In order to implement the virtual consolidated operations center concept the same activities previously identified in Table 21 will need to be accomplished plus an additional step. That step is the attachment of the dispatcher's console being connected to a router that will allow it to enter a Wide Area Network (WAN). Through this network data will be passed from the 911 operators and other dispatchers' deployment of assets. The step will require about five days for each organization and ten days of testing to iron out any problems and to assure connectivity of all organizations. All the other steps will be the same except for training. Training will require an additional day to give more information to the dispatchers on the WAN connectivity. In order to be certain that these people understand the way to operate in a wide area network environment it would be beneficial to add an additional two days to the second training course. This should take care of all training issues and operational questions that may occur from introducing people to a more sophisticated system.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

In this study there has been a presentation of problems that exist for governmental organizations in responding to crises, disasters, and emergencies. The problems have been identified as being communications and coordination of resources and between functional operations departments. These departments are police, fire, emergency medical services, transportation, and utilities. The resources are mobile and are difficult to constantly track so that the current location is known.

It is apparent from the search of the literature that technology is available that can be integrated to help improve the communications, coordination, and tracking of the mobile resources. At the same time there is evidence that these technologies are presently in use in the Colorado Springs area and the organization provides emergency medical services in the form of ambulances. This organization has integrated GPS, GIS, and wireless data communications to dispatch, monitor, and control their mobile resources.

The hypothesis of this study is that the use of state-of-the-art communications and technology, integrated into a virtually centralized dispatching facility, will increase the level of service by specifically decreasing the costs of operation without significant increase in the response time of organizations having mobile resources. The data is available to allow the comparing of the service response and operational costs prior to the integration of technology and after. This study shows that the level of service did not decrease while operational costs decreased. Additionally, the study showed that the number of resources currently supporting a larger population has decreased. From the evaluation criteria that was presented in Chapter I the decrease in costs from the integration of technology within the emergency medical services organization has been moderate while the decrease in service response is insignificant.

As previously stated, this study has produced indications that the integration of technology can provide emergency medical support to communities with decreased costs without degrading service. It is not clear that in all instances, similar studies in other communities would render the same results. However, there is enough evidence from this study that other studies should be conducted to determine the reliability of the findings.

The evidence is presented in this study to show that there has been success in integrating technology into an organization that dispatches mobile resources. The findings suggest that, even though there was a significant decrease in the number of ambulances supporting the city of Colorado Springs and the surrounding county, there was not a corresponding decrease in the level of service. Further, the evidence was compelling in pointing out the benefits that were derived in conjunction with the change to the integration of GIS, GPS, and wireless data communications. The cost savings were 19 percent and the decrease in service was the need for an additional two minutes in a thirty-minute period from request for service and arrival of the patient at the treatment center.

This study shows that the technologies of GPS, GIS, and wireless data communications have been successfully integrated. There is indication that this integration can have a positive impact on the ability of communities to respond to incidents faster and that the activities of mobile units may be coordinated to provide improved coverage of areas of responsibility. This improved response can be instrumental in containing and recovering from crises, disasters and emergencies.

The study also presents a concept of virtual consolidation of operations centers within municipalities. The concept uses the integrated technology in use by the emergency medical services organization plus networking between the functional operating departments. The networking allows the sharing of data and information between dispatchers. This allows for the ability to coordinate the allocation of resources to incidents. Additionally, there is the capability of providing incident data and information from the 911 operators to the dispatchers through a single input.

With the use of these technologies and the networking of the various departments within a city, the ability to allocate mobile resources to incidents and coordinate their movement will be enhanced. At the same time this study indicates that the ability to provide support and service to the populace can be accomplished at a lower cost without degradation of service.

This study has also given a plan for the implementation of the technologies into other organizations. The plan has identified the way in which the public and relevant organizations may be provided information on the concept and its costs and benefits. A schedule for installation of the technologies is provided and is a baseline for what must be done and the expected timeframes for each of the activities. The schedule is easily modified to reflect the increase or decrease in time, based on the number of units that must be modified.

It is realized that this study must be followed up with additional research. This study concentrated on the emergency medical services organization because they already were using the integrated technologies necessary for a virtual consolidated operations center. It is now important that other organizations be studied to determine the impacts on their costs and service response that this integrated technology will have if implemented.

The next section will present recommendations that will allow for a continuing effort of expansion to the concept and its implementation.

Recommendations

In this section recommendations are presented that will extend the knowledge obtained in this study. It is recommended that studies should be directed into the use of these same integrated technologies for the police, sheriff's office, utilities, and transportation departments. For each of the departments there will be a need to stress particular areas to be researched. Specific recommendations will be presented for each of the departments. If a researcher is interested in pursuing the implementation of this concept then this study will provide a basic format and structure that may helpful and diminish the amount of time for developing a study format.

The police department has needs that parallel those of the emergency medical services organization plus additional ones. The police, like the emergency medical services organization, responds to accidents and situations where there are medical emergencies. The incidents that fall into this category would be accidents, fires, and the results of violence. The areas that are different deal with criminal acts or domestic violence. Particular attention should be given to collecting data on the impact of response on levels of violence in domestic disturbances and in criminal acts. It was stated by personnel from both the police department and the sheriff's office that they there is a belief that the quicker the response to a call in those situations that the lower the level of violence is when they reach the incident scene. However, they stated that there was no data available that could support or refute those opinions. As a result, research into those areas could be useful not only for extension of this work, but to provide data supporting the law enforcement organizations' work in obtaining public support for expanded use of technologies.

Additional areas that may be useful in extending the knowledge of this study would be the results from the police department's use of technology. The police department for the city of Colorado Springs is currently using laptop computers and wireless data communications in its patrol cars. There are plans to possibly install GPS receivers in the patrol cars. Studies comparing the response times before the installation of GPS and after would be expected to find a decrease in response times with a increase in the area that patrol cars cover. Studies covering the county sheriff's office should bring in results similar to those for the police department. Unfortunately, the sheriff's office does not anticipate installing GPS receivers in its patrol units.

Another area of study should focus attention on the utilities department. Studies there could focus on each of the sub-departments, such as water, electric, gas, and waste water. The studies in this area should look at the cost of utilities that are lost in emergencies. An example of this would be a fire hydrant that has been broken open by an automobile. That water has value and the ability to quickly get to that site and bring that loss under control can reduce the loss and the cost to the city. Additionally, water has other value than just for drinking. It is used in cooking, medicine, food processing, hygiene, and manufacturing. Another consideration is that a broken water main can cause erosion in the area it moves through. A broken hydrant or pipe can cause the undermining of roadways. If not quickly brought under control the possibility exists that the road may cave in, causing serious vehicle accidents and costly road repairs. It would be possible that each of those uses and situations place a different value on the water resource and thus the cost and benefits could be significant based on its importance to the usage intent and the extent of damage.

When discussing wastewater there must be an understanding that in many cases this could be hazardous waste and immediate containment and recovery is imperative. Contamination of the soil, streams, rivers, and roadways may occur if a waste water conduit is broken or destroyed. Again, the value could be different based on which segment is effected and the speed with which the contamination spreads. This means that here, too, the cost and benefit could be significant depending on the impacted area. Further, if wastewat :r is allowed to run unrestricted there could be expansion of the broken part or damaged area.

The study of the impact on gas and electric service outages and the ability to quickly make the required repairs could be impacted by the integration of the studied technologies. Knowing that a gas leak can cause extensive damage to property and be life-threatening means that value of quickly getting to the problem site can reduce the impact and therefore the cost and benefit of speedy response.

When looking at the transportation department there is different set of considerations. Whereas the transportation department is not responding to violence or broken utilities, they have two important functions that must be remembered. The transportation department has the capability of providing resources to quickly move large numbers of citizens from an area that may be threatened by some event. Also, the transportation department usually has responsibility for the roadway surfaces.

If there has been a flooding or undermining of a roadway, the transportation department will have responsibility to clear the damage and make the necessary repairs. This means that there is a need to quickly disperse work crews to the site, set barriers, and make the necessary repairs. By quickly responding to an event there can be a rerouting of traffic around the trouble, thereby reducing injury to other individuals.

The transportation departments resources include large vehicles with the capability to move a large number of people in a single trip. If there is an serious incident it may be necessary to move people out of the area. In the case of severe weather, homes may have been destroyed and the people must be moved to shelters. In cases where there have been hazard spills there is sometimes a need to evacuate the nearby residents. The ability to quickly respond to this mass movement need has a cost and benefit to the residents and the municipality. A study in the relationship of response and impact to those residents can provide a useful means of measuring the use of integrated technology.

Thus, studies should look at the data that cover response and the cost elements of immediate response versus late response. Taking the results of this study and working through the same process in other cities as well as other organizations within Colorado Springs should help to establish the reliability of the findings. The results of this study and follow-on studies should be of assistance to communities in evaluating the allocation of public moneys to functional departments in updating their use of technology. Understanding and education of the impacts of technology on the support services of communities should improve the ability to obtain taxpayer support for public service organizations' investment in that technology. Additionally, the presentation of results, showing the impact of improved communications and coordination through the use of technology integrated through a virtual consolidated operations center should encourage the transition to this new concept.

APPENDIX A

BENEFIT DATA

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services
SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s)
From: 1/ 1/91 From: To: 1/31/91

Transports : 1017

Average Response Time: 5.37 Min. Average Distance to Scene: 2.91 Miles
Average Scene Time: 13.49 Min. Average Dist. To Destination: 5.91 Miles
Average Total Time: 30.27 Min. Average Total Distance/Call: 8.81 Miles

ZONE INFORMATION:

Zone 1:	55	(5.41%)	Zone 6:	23 (2.26%)	Zone 11:	24	(2.36%)
Zone 2:	299	(29.40%)	Zone 7:	1 (0.10%)	Zone 12:		(0.0%)
Zone 3:	83	(8.16%)	Zone 8:	23 (2.26%)	Zone 13:	10	(0.98%)
Zone 4:	309	(30.38%)	Zone 9:	18 (1.77%)	Zone 14:	10	(0.98%)
Zone 5:	51	(5.01%)	Zone 10:	31 (3.05%)	Zone 15:	80	(7.87%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	509	50.05%
Five Minutes	152	14.95%
Six Minutes	90	8.85%
Seven Minutes	87	8.55%
Eight Minutes	52	5.11%
Nine Minutes	32	3.15%
Ten Minutes	20	1.97%
Eleven Minutes	15	1.47%
Twelve Minutes	7	0.69%
> Twelve Minutes	53	5.21%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

87.51%

EL PASO COUNTY HEALTH DEPARTMENT

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s)
From: 2/ 1/91 To: 2/28/91

Transports : 923

Average Response Time: 4.96 Min. Average Distance to Scene: 2.63 Miles
Average Scene Time: 13.23 Min. Average Dist. To Destination: 5.57 Miles
Average Total Time: 29.53 Min. Average Total Distance/Call: 8.19 Miles

ZONE INFORMATION:

Zone 1:	50 (5.42%)	Zone 6:	15 (1.63%)	Zone 11:	28 (3.03%)
Zone 2:	297 (32.18%)	Zone 7:	4 (0.43%)	Zone 12:	1 (0.11%)
Zone 3:	70 (7~58%)	Zone 8:	25 (2.71%)	Zone 13:	7 (0.76%)
Zone 4:	275 (29.79%)	Zone 9:	25 (2.71%)	Zone 14:	3 (0.33%)
Zone 5:	41 (4.44%)	Zone 10:	30 (3.25%)	Zone 15:	52 (5.63%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	487	52.76%
Five Minutes	144	15.60%
Six Minutes	76	8.23%
Seven Minutes	72	7.80%
Eight Minutes	48	5.20%
Nine Minutes	28	3.03%
Ten Minutes	22	2.38%
Eleven Minutes	6	0.65%
Twelve Minutes	8	0.87%
> Twelve Minutes	32	3.47%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

89.60%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s) From: 1 To: 19
From: 3/ 1/91 To: 3/31/91

Transports: 1054

Average Response Time: 5.10 Min. Average Distance to Scene: 2.73 Miles
Average Scene Time: 12.80 Min. Average Dist. To Destination: 5.71 Miles
Average Total Time: 29.43 Min. Average Total Distance/Call: 8.43 Miles

ZONE INFORMATION:

Zone 1:	41 (3.89%)	Zone 6:	29 (2.75%)	Zone 11:	24 (2.28%)
Zone 2:	315 (29.89%)	Zone 7:	3 (0.28%)	Zone 12:	2 (0.19%)
Zone 3:	94 (8.92%)	Zone 8:	32 (3.04%)	Zone 13:	3 (0.28%)
Zone 4:	319 (30.27%)	Zone 9:	38 (3.61%)	Zone 14:	9 (0.85%)
Zone 5:	65 (6.17%)	Zone 10:	24 (2.28%)	Zone 15:	56 (5.31%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	551	52.28%
Five Minutes	148	14.04%
Six Minutes	112	10.63%
Seven Minutes	70	6.64%
Eight Minutes	49	4.65%
Nine Minutes	31	2.94%
Ten Minutes	18	1.71%
Eleven Minutes	17	1.61%
Twelve Minutes	16	1.52%
> Twelve Minutes	42	3.98%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

88.24%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s)
From: 4/ 1/91 To: 4/30/91 Zones From: 1 To: 19

Transports : 1044

Average Response Time: 5.14 Min. Average Distance to Scene: 2.72 Miles
Average Scene Time: 12.91 Min. Average Dist. To Destination: 5.49 Miles
Average Total Time: 29.55 Min. Average Total Distance/Call: 8.22 Miles

ZONE INFORMATION:

Zone 1:	48 (4.60%)	Zone 6:	19 (1.82%)	Zone 11:	32 (3.07%)
Zone 2:	322 (30.84%)	Zone 7:	3 (0.29%)	Zone 12:	3 (0.29%)
Zone 3:	86 (8.24%)	Zone 3:	28 (2.68%)	Zone 13:	5 (0.48%)
Zone 4:	329 (31.51%)	Zone 9:	17 (1.63%)	Zone 14:	5 (0.48%)
Zone 5:	47 (4.50%)	Zone 10:	27 (2.59%)	Zone 15:	73 (6.99%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	538	51.53%
Five Minutes	138	13.22%
Six Minutes	102	9.77%
Seven Minutes	86	8.24%
Eight Minutes	57	5.46%
Nine Minutes	35	3.35%
Ten Minutes	21	2.01%
Eleven Minutes	11	1.05%
Twelve Minutes	12	1.15%
> Twelve Minutes	44	4.21%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

88.22%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 5/ 1/91 To: 5/31/91
Zone(s) From: 1 To: 19

Transports : 1225

Average Response Time: 5.29 Min. Average Distance to Scene: 3.00 Miles
Average Scene Time: 12.84 Min. Average Dist. To Destination: 5.80 Miles
Average Total Time: 29.79 Min. Average Total Distance/Call: 8.78 Miles

ZONE INFORMATION:

Zone 1:	78 (6.37%)	Zone 6:	28 (2.29%)	Zone 11:	27 (2.20%)
Zone 2:	346 (28.24%)	Zone 7:	12 (0.98%)	Zone 12:	1 (0.08%)
Zone 3:	102 (8.33%)	Zone 8:	42 (3.43%)	Zone 13:	1 (0.08%)
Zone 4:	366 (29.88%)	Zone 9:	26 (2.12%)	Zone 14:	5 (0.41%)
Zone 5:	65 (5.31%)	Zone 10:	32 (2.61%)	Zone 15:	94 (7.67%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	612	49.96%
Five Minutes	164	13.39%
Six Minutes	124	10.12%
Seven Minutes	97	7.92%
Eight Minutes	67	5.47%
Nine Minutes	44	3~59%
Ten Minutes	32	2.61%
Eleven Minutes	16	1.31%
Twelve Minutes	18	1.47%
> Twelve Minutes	51	4.16%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.86%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s) From. 1 To 19
From: 6/ 1/91 To: 6/30/91

Transports : 1216

Average Response Time: 5.26 Min. Average Distance to Scene: 2.98 Miles
Average Scene Time: 12.31 Min. Average Dist. To Destination: 5.71 Miles
Average Total Time: 28.60 Min. Average Total Distance/Call: 8.67 Miles

ZONE INFORMATION:

Zone 1:	82 (6.74%)	Zone 6:	24 (1.97%)	Zone 11:	29 (2.38%)
Zone 2:	370 (30.43%)	Zone 7:	2 (0.16%)	Zone 12:	3 (0.25%)
Zone 3:	92 (7.57%)	Zone 8:	37 (3.04%)	Zone 13:	4 (0.33%)
Zone 4:	367 (30.18%)	Zone 9:	21 (1.73%)	Zone 14:	12 (0.99%)
Zone 5:	70 ~ 5.76%)	Zone 10:	42 (3.45%)	Zone 15:	61 (5.02%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	628	51.64%
Five Minutes	153	12.58%
Six Minutes	114	9.38%
Seven Minutes	91	7.48%
Eight Minutes	67	5.51%
Nine Minutes	40	3.29%
Ten Minutes	34	2.80%
Eleven Minutes	20	1.64%
Twelve Minutes	8	0.66%
> Twelve Minutes	61	5.02%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.60%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s) From: 1 To: 19
From: 7/ 1/91 To: 7/31/91

Transports : 1274

Average Response Time: 5.32 Min. Average Distance to Scene: 2.89 Miles
Average Scene Time: 12.58 Min. Average Dist. To Destination: 5.55 Miles
Average Total Time: 29.11 Min. Average Total Distance/Call: 8.44 Miles

ZONE INFORMATION:

Zone 1:	85 (6.67%)	Zone 6:	13 (1.02%)	Zone 11:	32 (2.51%)
Zone 2:	346 (27.16%)	Zone 7:	7 (0.55%)	Zone 12:	3 (0.24%)
Zone 3:	125 (9.81%)	Zone 8:	49 (3.85%)	Zone 13:	4 (0.31%)
Zone 4:	379 (29.75%)	Zone 9:	28 (2.20%)	Zone 14:	8 (0.63%)
Zone 5:	94 (7.38%)	Zone 10:	30 (2.35%)	Zone 15:	71 (5.57%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	644	50.55%
Five Minutes	152	11.93%
Six Minutes	147	11.54%
Seven Minutes	99	7.77%
Eight Minutes	55	4.32%
Nine Minutes	38	2.98%
Ten Minutes	34	2.67%
Eleven Minutes	22	1.73%
Twelve Minutes	20	1.57%
> Twelve Minutes	63	4.95%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.11%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES

Period Covered From: 8/ 1/91 To: 8/31/91
Zone(s) From: 1 To: 19

Transports : 1259

Average Response Time: 5.18 Min. Average Distance to Scene: 2.90 Miles
Average Scene Time: 12.39 Min. Average Dist. To Destination: 5.70 Miles
Average Total Time: 29.24 Min. Average Total Distance/Call: 8.60 Miles

ZONE INFORMATION:

Zone 1:	61 (4.85%)	Zone 6:	28 (2.22%)	Zone 11:	25 (1.99%)
Zone 2:	362 (28.75%)	Zone 7:	7 (0.56%)	Zone 12:	3 (0.24%)
Zone 3:	122 (9.69%)	Zone 8:	53 (4.21%)	Zone 13:	8 (0.64%)
Zone 4:	365 (28.99%)	Zone 9:	26 (2.07%)	Zone 14:	1 (0.08%)
Zone 5:	57 (4.53%)	Zone 10:	58 (4.61%)	Zone 15:	83 (6.59%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	661	52.50%
Five Minutes	157	12.47%
Six Minutes	117	9.29%
Seven Minutes	102	8.10%
Eight Minutes	55	4.37%
Nine Minutes	44	3.49%
Ten Minutes	30	2.38%
Eleven Minutes	26	2.07%
Twelve Minutes	11	0.87%
> Twelve Minutes	56	4.45%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.74%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered
Zone(s) From: 1 To: 19
From: 9/ 1/91 To: 9/30/91

Transports : 1171

Average Response Time: 5.28 Min. Average Distance to Scene: 2.84 Miles
Average Scene Time: 12.71 Min. Average Dist. To Destination: 5.56 Miles
Average Total Time: 29.62 Min. Average Total Distance/Call: 8.39 Miles

ZONE INFORMATION:

Zone 1:	73 (6.23%)	Zone 6:	28 (2.39%)	Zone 11:	36 (3.07%)
Zone 2:	329 (28.10%)	Zone 7:	2 (0.17%)	Zone 12:	2 (0.17%)
Zone 3:	99 (8.45%)	Zone 8:	37 (3.16%)	Zone 13:	6 (0.51%)
Zone 4:	364 (31.08%)	Zone 9:	23 (1.96%)	Zone 14:	4 (0.34%)
Zone 5:	53 (4~53%)	Zone 10:	40 (3.42%)	Zone 15:	75 (6.40%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	570	48.68%
Five Minutes	169	14.43%
Six Minutes	144	12.30%
Seven Minutes	80	6.83%
Eight Minutes	46	3.93%
Nine Minutes	39	3.33%
Ten Minutes	40	3.42%
Eleven Minutes	20	1.71%
Twelve Minutes	14	1.20%
> Twelve Minutes	49	4.18%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.17%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 10/ 1/91 To: 10/31/91
Zone(s) From: 1 To: 19

Transports : 1102

Average Response Time: 5.39 Min. Average Distance to Scene: 2.81 Miles
Average Scene Time: 12.92 Min. Average Dist. To Destination: 5.59 Miles
Average Total Time: 30.07 Min. Average Total Distance/Call: 8.40 Miles

ZONE INFORMATION:

Zone 1:	51 (4.63%)	Zone 6:	24 (2.18%)	Zone 11:	22 (2.00%)
Zone 2:	347 (31.49%)	Zone 7:	5 (0.45%)	Zone 12:	1 (0.09%)
Zone 3:	88 (7.99%)	Zone 8:	34 (3.09%)	Zone 13:	5 (0.45%)
Zone 4:	344 (31.22%)	Zone 9:	29 (2.63%)	Zone 14:	10 (0.91%)
Zone 5:	54 (4.90%)	Zone 10:	31 (2.81%)	Zone 15:	57 (5.17%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	545	49.46%
Five Minutes	151	13.70%
Six Minutes	119	10.80%
Seven Minutes	85	7.71%
Eight Minutes	51	4.63%
Nine Minutes	26	2.36%
Ten Minutes	28	2.54%
Eleven Minutes	23	2.09%
Twelve Minutes	16	1.45%
> Twelve Minutes	58	5.26%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.30%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 11/ 1/91 To: 11/30/91
Zone(s) From: 1 To: 19

Transports. 1057

Average Response Time: 5.60 Min. Average Distance to Scene: 2.71 Miles
Average Scene Time: 13.74 Min. Average Dist. To Destination: 5.53 Miles
Average Total Time: 31.38 Min. Average Total Distance/Call: 8.24 Miles

ZONE INFORMATION:

Zone 1:	49 (4.64%)	Zone 6:	24 (2.27%)	Zone 11:	21 (1.99%)
Zone 2:	341 (32.26%)	Zone 7:	3 (0.28%)	Zone 12:	2 (0.19%)
Zone 3:	87 (8.23%)	Zone 8:	36 (3.41%)	Zone 13:	2 (0.19%)
Zone 4:	302 (28.57%)	Zone 9:	20 (1.89%)	Zone 14:	2 (0.19%)
Zone 5:	72 (6.81%)	Zone 10:	24 (2.27%)	Zone 15:	72 (6.81%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	480	45.41%
Five Minutes	164	15.52%
Six Minutes	88	8.33%
Seven Minutes	75	7.10%
Eight Minutes	66	6.24%
Nine Minutes	60	5.68%
Ten Minutes	38	3.60%
Eleven Minutes	26	2.46%
Twelve Minutes	13	1.23%
>Twelve Minutes	47	4.45%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

82.59%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 12/ 1/91 To: 12/31/91
Zone(s) From: 1 To: 19

Transports: 1144

Average Response Time: 5.53 Min. Average Distance to Scene: 2.96 Miles
Average Scene Time: 13.44 Min. Average Dist. To Destination: 5.54 Miles
Average Total Time: 30.78 Min. Average Total Distance/Call: 8.49 Miles

ZONE INFORMATION:

Zone 1:	45 (3.93%)	Zone 6:	30 (2.62%)	Zone 11:	19 (1.66%)
Zone 2:	338 (29.55%)	Zone 7:	1 (0.09%)	Zone 12:	(%)
Zone 3:	80 (6.99%)	Zone 8:	44 (3.85%)	Zone 13:	10 (0.87%)
Zone 4:	376 (32.87%)	Zone 9:	29 (2.53%)	Zone 14:	3 (0.26%)
Zone 5:	64 (5.59%)	Zone 10:	39 (3.41%)	Zone 15:	66 (5.77%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	527	46.07%
Five Minutes	162	14.16%
Six Minutes	127	11.10%
Seven Minutes	98	8.57%
Eight Minutes	58	5.07%
Nine Minutes	57	4.98%
Ten Minutes	32	2.80%
Eleven Minutes	14	1.22%
Twelve Minutes	17	1.49%
> Twelve Minutes	52	4.55%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

84.97%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSI

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES

Period Covered From: 1/ 1/92 To: 1/31/92
Zone(s) From: 1 To: 19

Transports : 1050

Average Response Time: 5.23 Min. Average Distance to Scene: 2.70 Miles
Average Scene Time: 13.06 Min. Average Dist. To Destination: 5.61 Miles
Average Total Time: 30.25 Min. Average Total Distance/Call: 8.30 Miles

ZONE INFORMATION:

Zone 1:	42	(4.00%)	Zone 6:	18	(1.71%)	Zone 11:	24	(2.29%)
Zone 2:	323	(30.76%)	Zone 7:	4	(0.38%)	Zone 12:	1	(0.10%)
Zone 3:	80	(7.62%)	Zone 8:	36	(3.43%)	Zone 13:	5	(0.48%)
Zone 4:	312	(29.71%)	Zone 9:	26	(2.48%)	Zone 14:	6	(0.57%)
Zone 5:	65	(6.19%)	Zone 10:	31	(2.95%)	Zone 15:	77	(7.33%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	536	51.05%
Five Minutes	128	12.19%
Six Minutes	106	10.10%
Seven Minutes	89	8.48%
Eight Minutes	58	5.52%
Nine Minutes	36	3.43%
Ten Minutes	25	2.38%
Eleven Minutes	17	1.62%
Twelve Minutes	17	1.62%
> Twelve Minutes	38	3.62%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

87.33%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Zone(s) From: 1 To: 19
Period Covered From: 2/ 1/92 To: 2/29/92

Transports :1001

Average Response Time: 5.23 Min. Average Distance to Scene: 2.86 Miles
Average Scene Time: 12.95 Min. Average Dist. To Destination: 5.76 Miles
Average Total Time: 30.07 Min. Average Total Distance/Call: 8.61 Miles

ZONE INFORMATION:

Zone 1:	71	(7.09%)	Zone 6:	13	(1.30%)	Zone 11:	16	(1.60%)
Zone 2:	308	(30.77%)	Zone 7:	6	(0.60%)	Zone 12:		(%)
Zone 3:	89	(8.89%)	Zone 8:	30	(3.00%)	Zone 13:	3	(0.30%)
Zone 4:	273	(27.27%)	Zone 9:	21	(2.10%)	Zone 14:	5	(0.50%)
Zone 5:	45	(4.50%)	Zone 10:	34	(3.40%)	Zone 15:	87	(8.69%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	514	51.35%
Five Minutes	129	12.89%
Six Minutes	112	11.19%
Seven Minutes	74	7.39%
Eight Minutes	33	3.30%
Nine Minutes	31	3.10%
Ten Minutes	25	2.50%
Eleven Minutes	17	1.70%
Twelve Minutes	16	1.60%
> Twelve Minutes	50	5.00%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

86.11%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 3/ 1/92 To: 3/31/92
Zone(s) From: 1 To: 19

Transports: 1052

Average Response Time: 5.44 Min. Average Distance to Scene: 2.87 Miles
Average Scene Time: 13.14 Min. Average Dist. To Destination: 5.63 Miles
Average Total Time: 30.47 Min. Average Total Distance/Call: 8.51 Miles

ZONE INFORMATION:

Zone 1:	55	(5.23%)	Zone 6:	21	(2.00%)	Zone 11:	33	(3.14%)
Zone 2:	291	(27.66%)	Zone 7:	7	(0.67%)	Zone 12:	1	(0.10%)
Zone 3:	105	(9.98%)	Zone 8:	26	(2.47%)	Zone 13:	5	(0.48%)
Zone 4:	313	(29.75%)	Zone 9:	15	(1.43%)	Zone 14:	3	(0.29%)
Zone 5:	64	(6.08%)	Zone 10:	27	(2.57%)	Zone 15:	86	(8.17%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	518	49.24%
Five Minutes	133	12.64%
Six Minutes	99	9.41%
Seven Minutes	85	8.08%
Eight Minutes	65	6.18%
Nine Minutes	47	4.47%
Ten Minutes	22	2.09%
Eleven Minutes	17	1.62%
Twelve Minutes	17	1.62%
> Twelve Minutes	49	4.66%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

85.55%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 **Ambulance Service(s): ALL AMBULANCE SERVICES**

Period Covered
Zone(s) From: 1 To: 19
From: 4/ 1/92 To: 4/30/92

Transports : 1091

Average Response Time: 5.18 Min. Average Distance to Scene: 2.80 Miles
Average Scene Time: 12.72 Min. Average Dist. To Destination: 5.72 Miles
Average Total Time: 29.77 Min. Average Total Distance/Call: 8.52 Miles

ZONE INFORMATION:

Zone 1:	60	(5.50%)	Zone 6:	22	(2.02%)	Zone 11:	26	(2.38%)
Zone 2:	336	(30.80%)	Zone 7:	5	(0.46%)	Zone 12:		(%)
Zone 3:	86	(7.88%)	Zone 8:	27	(2.47%)	Zone 13:	4	(0.37%)
Zone 4:	322	(29.51%)	Zone 9:	28	(2.57%)	Zone 14:	6	(0.55%)
Zone 5:	52	(4.77%)	Zone 10:	30	(2.75%)	Zone 15:	87	(7.97%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	535	49.04%
Five Minutes	148	13.57%
Six Minutes	113	10.36%
Seven Minutes	101	9.26%
Eight Minutes	67	6.14%
Nine Minutes	47	4.31%
Ten Minutes	25	2.29%
Eleven Minutes	11	1.01%
Twelve Minutes	13	1.19%
> Twelve Minutes	31	2.84%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

88.36%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 **Ambulance Service(s): ALL AMBULANCE SERVICES**

Period Covered From: 5/ 1/92 To: 5/31/92
Zone(s) From: 1 To: 19

Transports : 1185

Average Response Time: 5.41 Min. Average Distance to Scene: 2.96 Miles
Average Scene Time: 12.70 Min. Average Dist. To Destination: 5.85 Miles
Average Total Time: 30.05 Min. Average Total Distance/Call: 8.81 Miles

ZONE INFORMATION:

Zone 1:	67	(5.65%)	Zone 6:	31	(2.62%)	Zone 11:	33	(2.78%)
Zone 2:	356	(30.04%)	Zone 7:	10	(0.84%)	Zone 12:		(%)
Zone 3:	95	(8.02%)	Zone 8:	27	(2.28%)	Zone 13:	4	(0.34%)
Zone 4:	336	(28.35%)	Zone 9:	31	(2.62%)	Zone 14:	4	(0.34%)
Zone 5:	65	(5.49%)	Zone 10:	32	(2.70%)	Zone 15:	94	(7.93%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	587	49.54%
Five Minutes	153	12.91%
Six Minutes	135	11. 39%
Seven Minutes	76	6.41%
Eight Minutes	59	4.98%
Nine Minutes	43	3.63%
Ten Minutes	33	2 78%
Eleven Minutes	23	1 94%
Twelve Minutes	9	0.76%
> Twelve Minutes	67	5.65%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

85.23%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From. 6/ 1/92 To 6/30/92
Zone(s) From. 1 To 19

Transports : 1222

Average Response Time: 5.68 Min. Average Distance to Scene: 3.17 Miles
Average Scene Time: 13.02 Min. Average Dist. To Destination: 6.50 Miles
Average Total Time: 30.54 Min. Average Total Distance/Call: 9.66 Miles

ZONE INFORMATION:

Zone 1:	80	(6.55%)	Zone 6:	30	(2.45%)	Zone 11:	37	(3.03%)
Zone 2:	364	(29.79%)	Zone 7:	2	(0.16%)	Zone 12:		(%)
Zone 3:	109	(8.92%)	Zone 8:	42	(3.44%)	Zone 13:	4	(0.33%)
Zone 4:	325	(26.60%)	Zone 9:	28	(2.29%)	Zone 14:	5	(0.41%)
Zone 5:	68	(5.56%)	Zone 10:	49	(4.01%)	Zone 15:	79	(6.46%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	563	46.07%
Five Minutes	170	13.91%
Six Minutes	125	10.23%
Seven Minutes	101	8.27%
Eight Minutes	76	6.22%
Nine Minutes	45	3.68%
Ten Minutes	25	2.05%
Eleven Minutes	21	1.72%
Twelve Minutes	11	0.90%
> Twelve Minutes	85	6.96%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

84.70%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 7/ 1/92 To: 7/31/92
Zone(s) From: 1 To: 19

Transports : 1292

Average Response Time: 6.00 Min. Average Distance to Scene: 3.31 Miles
Average Scene Time: 12.49 Min. Average Dist. To Destination: 6.24 Miles
Average Total Time: 30.17 Min. Average Total Distance/Call: 9.54 Miles

ZONE INFORMATION:

Zone 1:	81	(6.27%)	Zone 6:	26	(2.01%)	Zone 11:	37	(2.86%)
Zone 2:	377	(29.18%)	Zone 7:	9	(0.70%)	Zone 12:	6	(0.46%)
Zone 3:	107	(8.28%)	Zone 8:	38	(2.94%)	Zone 13:	9	(0.70%)
Zone 4:	368	(28.48%)	Zone 9:	30	(2.32%)	Zone 14:	4	(0.31%)
Zone 5:	78	(6.04%)	Zone 10:	42	(3.25%)	Zone 15:	80	(6.19%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	560	43.34%
Five Minutes	170	13.16%
Six Minutes	131	10.14X
Seven Minutes	124	9.60%
Eight Minutes	69	5.34%
Nine Minutes	62	4.80%
Ten Minutes	39	3.02%
Eleven Minutes	30	2.32%
Twelve Minutes	23	1.78%
> Twelve Minutes	84	6.50%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

81.58%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 8/ 1/92 To: 8/31/92
Zone(s) From: 1 To: 19

Transports : 1233

Average Response Time: 6.28 Min. Average Distance to Scene: 3.48 Miles
Average Scene Time: 12.50 Min. Average gist. To Destination: 5.91 Miles
Average Total Time: 31.02 Min. Average Total Distance/Call: 9.38 Miles

ZONE INFORMATION:

Zone 1:	91	(7.38%)	Zone 6:	27	(2.19%)	Zone 11:	28	(2.27%)
Zone 2:	370	(0.01%)	Zone 7:	14	(1.14%)	Zone 12:	2	(0.16%)
Zone 3:	99	(3.03%)	Zone 8:	56	(4.54%)	Zone 13:	8	(0.65%)
Zone 4:	334	(27.09%)	Zone 9:	34	(2.76%)	Zone 14:	3	(0.24%)
Zone 5:	74	(6.00%)	Zone 10:	36	(2.92%)	Zone 15:	57	(4.62%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	488	39.58%
Five Minutes	182	14.76%
Six Minutes	136	11.03%
Seven Minutes	102	8.27%
Eight Minutes	85	6.89%
Nine Minutes	66	5.35%
Ten Minutes	37	3.00%
Eleven Minutes	24	1.95%
Twelve Minutes	21	1.70%
> Twelve Minutes	92	7.46%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

80.54%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 9/ 1/92 To: 9/30/92
Zones) From: 1 To: 19

Transports : 1196

Average Response Time: 5.70 Min. Average Distance to Scene: 3.05 Miles
Average Scene Time: 13.05 Min. Average Dist. To Destination: 5.90 Miles
Average Total Time: 30.88 Min. Average Total Distance/Call: 8.94 Miles

ZONE INFORMATION:

Zone 1:	62	(5.18%)	Zone 6:	19	(1.59%)	Zone 11:	34	(2.84%)
Zone 2:	385	(32.19%)	Zone 7:	4	(0.33%)	Zone 12:	2	(0.17%)
Zone 3:	118	(9.871)	Zone 8:	45	(3.76%)	Zone 13:	5	(0.42%)
Zone 4:	297	(24.831)	Zone 9:	40	(3.34%)	Zone 14:	3	(0.25%)
Zone 5:	52	(4.35%)	Zone 10:	54	(4.52%)	Zone 15:	76	(6.35%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	532	44.48%
Five Minutes	164	13.71%
Six Minutes	135	11.29%
Seven Minutes	88	7.36%
Eight Minutes	79	6.61%
Nine Minutes	51	4.26%
Ten Minutes	38	3.18%
Eleven Minutes	31	2.59%
Twelve Minutes	18	1.51%
Twelve Minutes	60	5.02%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

83.44%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 10/ 1/92 To: 10/31/92
Zone(s) From: 1 To: 19

Transports: 1186

Average Response Time: 5.76 Min. Average Distance to Scene: 3.17 Miles
Average Scene Time: 12.89 Min. Average Dist. To Destination: 5.43 Miles
Average Total Time: 30.24 Min. Average Total Distance/Call: 8.60 Miles

ZONE INFORMATION:

Zone 1:	65	(5.48%)	Zone 6:	34	(2.87%)	Zone 11:	21	(1.77%)
Zone 2:	335	(28.25%)	Zone 7:	8	(0.67%)	Zone 12:		(%)
Zone 3:	102	(8.60%)	Zone 8:	47	(3.96%)	Zone 13:	7	(0.59%)
Zone 4:	370	(31.20%)	Zone 9:	18	(1.52%)	Zone 14:	2	(0.17%)
Zone 5:	63	(5.31%)	Zone 10:	47	(3.96%)	Zone 15:	67	(5.65%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	506	42.66%
Five Minutes	179	15.09%
Six Minutes	143	12.06%
Seven Minutes	110	9.27%
Eight Minutes	61	5.14%
Nine Minutes	60	5.06%
Ten Minutes	33	2.78%
Eleven Minutes	19	1.60%
Twelve Minutes	16	1.35%
> Twelve Minutes	59	4.97%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

84.23%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES

Period Covered From: 11/ 1/92 To: 11/30/92
Zone(s) From: 1 To: 19

Transports : 1103

Average Response Time: 5.86 Min.
Average Scene Time: 13.03 Min.
Average Total Time: 30.79 Min.

Average Distance to Scene: 2.91 Miles
Average Dist. To Destination: 5.70 Miles
Average Total Distance/Call: 8.61 Miles

ZONE INFORMATION:

Zone 1:	58	(5.26%)	Zone 6:	29	(2.63%)	Zone 11:	16	(1.45%)
Zone 2:	318	(28.83%)	Zone 7:	2	(0.18%)	Zone 12:	2	(0.18%)
Zone 3:	120	(10.88%)	Zone 8:	25	(2.27%)	Zone 13:	7	(0.63%)
Zone 4:	300	(27.20%)	Zone 9:	30	(2.72%)	Zone 14:	2	(0.18%)
Zone 5:	68	(6.17%)	Zone 10:	36	(3.26%)	Zone 15:	90	(8.16%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	467	42.34%
Five Minutes	157	14.23%
Six Minutes	134	12.15%
Seven Minutes	99	8.98%
Eight Minutes	73	6.62%
Nine Minutes	36	3.26%
Ten Minutes	33	2.99%
Eleven Minutes	20	1.81%
Twelve Minutes	22	1.99%
> Twelve Minutes	62	5.62%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

84.32%

EL PASO COUNTY HEALTH DEPARTMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 6/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 12/ 1/92 To: 12/31/92
Zone(s) From: 1 To: 19

Transports : 1207

Average Response Time: 5.79 Min. Average Distance to Scene: 2.86 Miles
Average Scene Time: 13.09 Min Average Dist. To Destination: 5.44 Miles
Average Total Time: 30.66 Min Average Total Distance/Call: 8.30 Miles

ZONE INFORMATION:

Zone 1:	76	(6.30%)	Zone 6:	17	(1.41%)	Zone 11:	38	(3.15%)
Zone 2:	328	(27.17%)	Zone 7:	3	(0.25%)	Zone 12:		(%)
Zone 3:	113	(9.36%)	Zone 8:	27	(2.24%)	Zone 13:	5	(0.41%)
Zone 4:	376	(31.15%)	Zone 9:	26	(2.15%)	Zone 14:	8	(0.66%)
Zone 5:	80	(6.63%)	Zone 10:	47	(3.89%)	Zone 15:	63	(5.22%)

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	503	41.67%
Five Minutes	177	14.66%
Six Minutes	137	11.35%
Seven Minutes	140	11.60%
Eight Minutes	71	5.88%
Nine Minutes	53	4 39%
Ten Minutes	27	2.24%
Eleven Minutes	23	1.91%
Twelve Minutes	23	1.91%
> Twelve Minutes	53	4~39%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

85.17%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered- From: 4/ 1/94 To: 4/30/94
Zone(s) - From: 1 To: 19

Transports : 1302

Average Response Time: 5.65 Min. Average Distance to Scene: 3.23 Miles
Average Scene Time: 12.74 Min. Average Dist. To Destination: 5.73 Miles
Average Total Time: 31.43 Min. Average Total Distance/Call: 8.96 Miles

ZONE INFORMATION:

Zone 1:	28	(2.15%)	Zone 7:	337	(25.88%)	Zone 13:	6	(0.46%)
Zone 2:	136	(10.45%)	Zone 8:	65	(4.99%)	Zone 14:	25	(1.92%)
Zone 3:	102	(7.83%)	Zone 9:	116	(8.91%)	Zone 15:	6	(0.46%)
Zone 4:	124	(9.52%)	Zone 10:	63	(4.84%)	Zone 16:	5	(0.38%)
Zone 5:	106	(8.14%)	Zone 11:	36	(2.76%)	Zone 17:	4	(0.31%)
Zone 6:	56	(4.30%)	Zone 12:	14	(1.08%)	Zone 18:	73	(5.61%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	613	47.08%
Five Minutes	167	12.83%
Six Minutes	131	10.06%
Seven Minutes	108	8.29%
Eight Minutes	75	5 76%
Nine Minutes	62	4 76%
Ten Minutes	33	2.53%
Eleven Minutes	27	2.07%
Twelve Minutes	15	1.15%
Twelve Minutes	71	5.45%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

84.02%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 5/ 1/94 To: 5/31/94
Zone(s) - From: 1 To: 19

Transports : 1366

Average Response Time: 5.69 Min. Average Distance to Scene: 3.21 Miles
Average Scene Time: 12.46 Min. Average Dist. To Destination: 5.79 Miles
Average Total Time: 31.04 Min. Average Total Distance/Call: 8.99 Miles

ZONE INFORMATION:

Zone 1:	35	(2.56%)	Zone 7:	345	(25.26%)	Zone 13:	6	(0.44%)
Zone 2:	128	(9.37%)	Zone 8:	75	(5.49%)	Zone 14:	37	(2.71%)
Zone 3:	112	(8.20%)	Zone 9:	123	(9.00%)	Zone 15:	6	(0.44%)
Zone 4:	129	(9.44%)	Zone 10:	54	(3.95%)	Zone 16:	10	(0.73%)
Zone 5:	91	(6.66%)	Zone 11:	19	(1.39%)	Zone 17:	13	(0.95%)
Zone 6:	76	(5.56%)	Zone 12:	19	(1.39%)	Zone 18:	88	(6.44%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	603	44.14%
Five Minutes	215	15.74%
Six Minutes	153	11.20%
Seven Minutes	120	8.78%
Eight Minutes	82	6.00%
Nine Minutes	50	3.66%
Ten Minutes	32	2.34%
Eleven Minutes	23	1.68%
Twelve Minutes	19	1.39%
Twelve Minutes	69	5.05%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

85.87%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 6/ 1/94 To: 6/30/94
Zone(s) - From: 1 To: 19

Transports : 1342

Average Response Time: 5.90 Min. Average Distance to Scene: 3.50 Miles
Average Scene Time: 12.27 Min. Average Dist. To Destination: 5.99 Miles
Average Total Time: 31.08 Min. Average Total Distance/Call: 9.49 Miles

ZONE INFORMATION:

Zone 1:	33	(2.46%)	Zone 7:	371	(27.65%)	Zone 13:	6	(0.45%)
Zone 2:	111	(8.27%)	Zone 8:	63	(4.69%)	Zone 14:	34	(2.53%)
Zone 3:	91	(6.78%)	Zone 9:	139	(10.36X)	Zone 15:	7	(0.52%)
Zone 4:	102	(7.60%)	Zone 10:	41	(3.06%)	Zone 16:	9	(0.67%)
Zone 5:	90	(6.71%)	Zone 11:	34	(2.53%)	Zone 17:	14	(1.04%)
Zone 6:	79	(5.89%)	Zone 12:	15	(1.12%)	Zone 18:	102	(7.60%)
						Zone 19:	1	(0.07%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	592	44.11%
Five Minutes	171	12.74%
Six Minutes	136	10.13%
Seven Minutes	122	9.09%
Eight Minutes	79	5.89%
Nine Minutes	56	4.17%
Ten Minutes	49	3.65%
Eleven Minutes	36	2.68%
Twelve Minutes	19	1.42%
>Twelve Minutes	82	6.11%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

81.97%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 7/ 1/94 To: 7/31/94
Zone(s) - From: 1 To: 19

Transports : 1457

Average Response Time: 6.48 Min. Average Distance to Scene: 3.67 Miles
Average Scene Time: 12.80 Min. Average Dist. To Destination: 6.15 Miles
Average Total Time: 32.50 Min. Average Total Distance/Call: 9.82 Miles

ZONE INFORMATION:

Zone 1:	26	(1.78%)	Zone 7:	365	(25.05%)	Zone 13:	7	(0.48%)
Zone 2:	120	(8.24%)	Zone 8:	72	(4.94%)	Zone 14:	58	(3.98%)
Zone 3:	111	(7.62%)	Zone 9:	126	(8.65%)	Zone 15:	8	(0.55%)
Zone 4:	126	(8.65%)	Zone 10:	66	(4.53%)	Zone 16:	5	(0.34%)
Zone 5:	99	(6.79%)	Zone 11:	58	(3.98%)	Zone 17:	20	(1.37%)
Zone 6:	84	(5.77%)	Zone 12:	24	(1.65%)	Zone 18:	82	(5.63%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	600	41.18%
Five Minutes	194	13.32%
Six Minutes	162	11.12%
Seven Minutes	120	8.24%
Eight Minutes	91	6.25%
Nine Minutes	61	4.19%
Ten Minutes	43	2.95%
Eleven Minutes	31	2.13%
Twelve Minutes	19	1.30%
>Twelve Minutes	136	9.33%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

80.10%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered- From: 8/ 1/94 To: 8/31/94
Zone(s) - From: 1 To: 19

Transports : 1548

Average Response Time: 6.22 Min. Average Distance to Scene. 3 66 Miles
Average Scene Time: 12.02 Min. Average Dist. To Destination: 6.59 Miles
Average Total Time: 31.51 Min. Average Total Distance/Call. 10.25 Miles

ZONE INFORMATION.

Zone 1:	26	(1.68%)	Zone 7:	401	(25.90%)	Zone 13:	4	(0.26%)
Zone 2:	153	(9.88%)	Zone 8:	86	(5.56%)	Zone 14:	62	(4.01%)
Zone 3:	112	(7.24%)	Zone 9:	128	(8.27%)	Zone 15:	11	(0.71%)
Zone 4:	109	(7.04%)	Zone 10:	51	(3.29%)	Zone 16:	13	(0.84%)
Zone 5:	119	(7.69%)	Zone 11:	39	(2.52%)	Zone 17:	12	(0.78%)
Zone 6:	88	(5.68%)	Zone 12:	27	(1.74%)	Zone 18:	107	(6.91%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	659	42.57%
Five Minutes	187	12.08%
Six Minutes	183	11.82%
Seven Minutes	133	8.59%
Eight Minutes	99	6.40%
Nine Minutes	67	4.33%
Ten Minutes	31	2.00%
Eleven Minutes	36	2.33%
Twelve Minutes	22	1.42%
>Twelve Minutes	131	8.46%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

81.46%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered- From: 9/ 1/94 To: 9/30/94
Zone(s) - From: 1 To: 19

Transports : 1472

Average Response Time: 6.10 Min. Average Distance to Scene: 3.55 Miles
Average Scene Time: 12.75 Min. Average Dist. To Destination: 5.94 Miles
Average Total Time: 31.67 Min. Average Total Distance/Call: 9.48 Miles

Zone 1:	34	(2.31%)	Zone 7:	389	(26.43%)	Zone 13:	5	(0.34%)
Zone 2:	120	(8.15%)	Zone 8:	71	(4.82%)	Zone 14:	43	(2.92%)
Zone 3:	104	(7.07%)	Zone 9:	133	(9.04%)	Zone 15:	9	(0.61%)
Zone 4:	138	(9.38%)	Zone 10:	39	(2.65%)	Zone 16:	9	(0.61%)
Zone 5:	106	(7.20%)	Zone 11:	28	(1.90%)	Zone 17:	11	(0.75%)
Zone 6:	102	(6.93%)	Zone 12:	22	(1.49%)	Zone 18:	109	(7.40%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	587	39.88%
Five Minutes	218	14.81%
Six Minutes	184	12.50%
Seven Minutes	130	8.83%
Eight Minutes	90	6.11%
Nine Minutes	71	4.82%
Ten Minutes	43	2.92%
Eleven Minutes	25	1.70%
Twelve Minutes	17	1.15%
>Twelve Minutes	107	7.27%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

82.13%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered From: 10/ 1/94 To: 10/31/94
Zone(s) - From: 1 To: 19

Transports : 1414

Average Response Time: 5.88 Min. Average Distance to Scene: 3.35 Miles
Average Scene Time: 12.82 Min. Average Dist. To Destination: 5.89 Miles
Average Total Time: 31.65 Min. Average Total Distance/Call: 9.25 Miles

Zone 1:	47	(3.32%)	Zone 7:	382	(27.02%)	Zone 13:	6	(0.42%)
Zone 2:	136	(9.62%)	Zone 8:	86	(6.08%)	Zone 14:	34	(2.40%)
Zone 3:	107	(7.57%)	Zone 9:	123	(8.70%)	Zone 15:	5	(0.35%)
Zone 4:	139	(9.83%)	Zone 10:	26	(1.84%)	Zone 16:	6	(0.42%)
Zone 5:	102	(7.21%)	Zone 11:	23	(1.63%)	Zone 17:	7	(0.50%)
Zone 6:	58	(4.10%)	Zone 12:	20	(1.41%)	Zone 18:	107	(7.57%)
						Zone 19:		(0%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	619	43.78%
Five Minutes	196	13.86%
Six Minutes	156	11.03%
Seven Minutes	113	7.99%
Eight Minutes	94	6.65%
Nine Minutes	54	3.82%
Ten Minutes	40	2.83%
Eleven Minutes	40	2.83%
Twelve Minutes	18	1.27%
>Twelve Minutes	84	5.94%

PERCENT OF RESPONSE TIMES ACCOMPLISHED WITHIN EIGHT MINUTES OR LESS

83.31%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered- From: 11/ 1/94 To: 11/30/94
Zone(s) - From: 1 To: 19

Transports : 1338

Average Response Time: 6.02 Min. Average Distance to Scene: 3.47 Miles
Average Scene Time: 12.81 Min. Average Dist. To Destination: 6.18 Miles
Average Total Time: 32.42 Min. Average Total Distance/Call: 9.65 Miles

Zone 1:	42	(3.14%)	Zone 7:	339	(25.34%)	Zone 13:	9	(0.67%)
Zone 2:	102	(7.62%)	Zone 8:	77	(5.75%)	Zone 14:	24	(1.79%)
Zone 3:	91	(6.80%)	Zone 9:	118	(8.82%)	Zone 15:	9	(0.67%)
Zone 4:	121	(9.04%)	Zone 10:	45	(3.36%)	Zone 16:	12	(0.90%)
Zone 5:	111	(8.30%)	Zone 11:	21	(1.57%)	Zone 17:	15	(1.12%)
Zone 6:	85	(6.35%)	Zone 12:	22 (1.64%)		Zone 18:	95	(7.10%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	562	42.00%
Five Minutes	185	13.83%
Six Minutes	150	11.21%
Seven Minutes	148	11.06%
Eight Minutes	73	5.46%
Nine Minutes	43	3.21%
Ten Minutes	34	2.54%
Eleven Minutes	31	2.32%
Twelve Minutes	26	1.94%
>Twelve Minutes	86	6.43%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

83.56%

EL PASO COUNTY DEPARTMENT OF HEALTH AND ENVIRONMENT
Emergency Medical Services

SYSTEM RESPONSE ANALYSIS

Date: 12/ 5/96 Ambulance Service(s): ALL AMBULANCE SERVICES
Period Covered- From: 12/ 1/94 To: 12/31/94
Zone(s) ~ From: 1 To: 19

Transports : 1370

Average Response Time: 6.48 Min. Average Distance to Scene: 3.47 Miles
Average Scene Time: 12.84 Min. Average Dist. To Destination: 6.18 Miles
Average Total Time: 33.02 Min. Average Total Distance/Call: 9.65 Miles

Zone 1:	42	(3.07X)	Zone 7:	369	(26.93X)	Zone 13:	5	(0.36X)
Zone 2:	105	(7.66%)	Zone 8:	53	(3.87X)	Zone 14:	20	(1.46%)
Zone 3:	90	(6.57X)	Zone 9:	125	(9.12X)	Zone 15:	8	(0.58X)
Zone 4:	144	(10.51X)	Zone 10:	47	(3.43X)	Zone 16:	12	(0.88X)
Zone 5:	126	(9.20X)	Zone 11:	26	(1.90X)	Zone 17:	16	(1.17X)
Zone 6:	70	(5.11%)	Zone 12:	27	(1.97X)	Zone 18:	85	(6.20%)
						Zone 19:		(%)

RESPONSE TIME SUMMARY

Response Time	Number of Calls	Percent of Total Calls
Four Minutes or Less	567	41.39%
Five Minutes	187	13.65X
Six Minutes	141	10.29X
Seven Minutes	119	8.69X
Eight Minutes	78	5.69X
Nine Minutes	54	3.94%
Ten Minutes	42	3.07X
Eleven Minutes	27	1.97X
Twelve Minutes	26	1.90%
>Twelve Minutes	129	9.42%

PERCENT OF RESPONSE TIMES ACCOMPLISHED
WITHIN EIGHT MINUTES
OR LESS

79.71X

APPENDIX B

INTERVIEWS

SUBJECT: Interviews with local director of American Medical Response, Inc. (Lynne Greenberg)

Date and time of first interview: 19 December 1996, 1045 - 1145 hours.

Questions and answers follow:

1. Question: Could you please identify the position you hold with American Medical Response (AMR) and your name?
   Answer: I am the director of the Colorado Springs Operations and my name is Lynne Greenberg.

2. Question: How long have you been in this position?
   Answer: I came back to AMR in December 1996.

3. Question: You previously worked for AMR?
   Answer: Yes. I was the assistant director of operations.

4. Question: You previously worked for the emergency medical services office for El Paso County?
   Answer: Yes. I was the Health Services Officer.

5. Question: In that capacity you provided me with incident response data for the years of 1991-1992 and 1994 - 1996.
   Answer: Yes. The years of 1991 - 1992 was prior to AMR having a GPS capability while the years of 1994 - 1996 were the years in which GPS was being used.

6. Question: Is it true that in the years of 1991 - 1992 there were two separate organizations providing emergency medical response for the local area:
   Answer: Yes. St. Francis Hospital and American Medical Response were competing against each other for patients.

7. Question: How many ambulance were in use on a daily basis?
   Answer: Between the two organizations there were 21 ambulances vying for patients.

8. Question: You make it sound like they were racing each other to pickup a patient. Is that what was going on?
   Answer: Yes. It was a race to get to the scene and pickup the patient so we could assure that we would have them ride with us.

9. Question: How many ambulances do you have on a shift?
   Answer: We have 15 ambulances on during the peak hours.

10. Question: How accurate was your data on the location of your vehicles prior to the use of GPS?
Answer: Prior to GPS we were using LORAN. With LORAN we were sometimes off by as much as 30 miles. Now if two of our vehicles are side by side going down the street we are able to tell when one moves to the other side of the other one.

11. Question: How often do you update your GIS database?
Answer: We receive monthly updates from the city that identifies new streets and their coordinates which then are input to our map database.

12. Question: Would it be possible to meet with your dispatcher and discuss the GIS and GPS system with him?
Answer: Yes. His name is Stephen Silloway and he is very knowledgeable about the system and has worked with it for some time.

13. Thank you for allowing me to tape this conversation.
Question: Would you mind me transcribing this and having you review, sign and allow me to include it as part of the study.?
Answer: I would be willing to do that and have no problem with you including it with your study.

Date and time of second interview: 20 January 1997, 0830 - 0930 hours.

Questions and answers follow:

14. In the data you provided me when you were the Health Services Officer for El Paso County, there are some categories identified on the reports, which I need an accurate definition.
Question: What is Average Response Time?
Answer: That is the time the call is rung down to the EMS until the unit arrives on the scene.

15. Question: What is Average Scene Time?
Answer: That is the time the unit arrives on the scene until it departs for the hospital or other destination.

16. Question: What is Average Total Time?
Answer: That is the response time plus scene time plus the time it takes to arrive at the destination

17. Question: What is performance measure the county uses?
Answer: The county uses the standard of a response time of 8 or less minutes in the 90th percentile.

18. Question: Is that response time for all calls?
Answer: No. That is just for the urban areas. That data is reflected as Zones 1 through 10.

19. Question: What is the performance measure for your emergency medical service?
Answer: Since this is a for profit organization we use a performance measure of Unit Hour Utilization, which is the number of hours a unit is used per day.

20. Question: I know that your pay rates are proprietary. However, I need data with which to make cost and benefit calculations. I need information on annual salaries and benefits for your dispatch personnel and their hours of work.

Answer: I will give you a range of salaries and the percentage that is added to that for benefits. The chief dispatcher is also the data analyst and is paid at the rate of $35,000 to $50,000 per year. There are 9 other dispatchers and they are paid from $22,000 to $31,000 per year. The benefits are an add on of 15% of salary. The work schedules are setup on a two week basis. In week 1 an individual will work 4 - 12 hour shifts and in week 2 3 - 12 hour shifts.

21. Question: What is the initial training and orientation an individual receives when they are hired?
Answer: There training starts with 40 hours of general orientation on policies and basic procedures. There is then 33 hours of field training, followed by, two months of training at 44 hours per week. After that, if they have passed our standards, they are permitted to work as a primary team member.

22. Question: What is the pay for the operators of the vehicles?
Answer: Each vehicle has two people on board. The first is a state certified paramedic who is paid from $11.00 to $18.60 per hour. The second is a state certified emergency medical technician who is paid from $7.00 to $12.40 per hour.

23. Question: What are the fuel, oil, and maintenance costs for the vehicles?
Answer: Our maintenance records indicate that fuel and oil costs us $0.17 per mile, and maintenance costs are $0.18 per mile.

SUBJECT: Interview with a dispatcher of American Medical Response, Inc. (Stephen Silloway)

Date and time of first interview: 19 December 1996, 1045 - 1145 hours.

Questions and answers follow:

1. Question: What is your name?
   Answer: I am a dispatcher for American Medical Response in Colorado Springs.

2. Question: You have been working with the GPS and GIS system?
   Answer: Yes. I have worked with the current systems for the whole time it has been installed.

3. Question: On your GIS map displays how much detail can you get?
   Answer: I can zoom in until I get to a particular street but I don't have data showing addresses. However, I can determine what hundred block a street is..

4. Question: Whose is the vendor for your GPS and GIS systems?
   Answer: They are both provided by II Morrow corporation.

5. Question: Are there any moving maps within the ambulances?.
   Answer: No. Not at this time. However, I understand that there is some discussion on bringing that capability to our operations.

6. Question: Would it help your response to an incident if the ambulance had that capability?
   Answer: Yes. That would help the crew to be able to see where they were currently located and see their destination

7. Question: What are you using for communications between the ambulances and your site? I am particularly concerned with how the GPS data is transmitted back to this location and posting it to the GIS.
   Answer: We currently have a combination of 450megahertz and 800 megahertz radios and repeaters. The GPS data is sent by 450 megahertz but we are looking to possibly move it to the 800 MHz.

8. Question: Would you mind me transcribing this interview and having you review, sign and allow me to include it as part of the study.?
   Answer: I would be willing to do that and have no problem with you including it with your study.

Date and time of second interview: 20 January 1997, 0830 - 0930 hours.

9. Question: I need cost data for your GPS and GIS system. Can you tell me how much the basic elements cost?
   Answer: Yes. Each GPS unit that is installed in a vehicles costs $1330 for the GPS unit, which includes installation, plus $670 for the radio transmitter. The base station transmitter also costs $670.

10. Question: How much time is spent each week on system maintenance?
Answer: Two to three hours per week.

11. Question: How often do you receive map updates?
Answer: Every 3 to 6 months we receive an update to the map. However that update will not include all the streets. The time in the previous question also includes updates to the system that reflects additions to streets that were not included with the periodic update to the database by the vendor.

Date and time of third interview: 20 January 1997, 0830 - 0930 hours.

12. Question: You previously stated that two to three hours are spent each week on dispatch system maintenance. Could you please identify the average amount of time that is spent on updating the GIS and what the remaining time is spent on?
Answer: Of the two to three hours per week (see question 10 above), there is an average of 0.5 hours spent updating the GIS. The remaining time is spent on maintaining the equipment within the vehicles.

13. Question: Is AMR looking at replacing the II Morrow GPS and GIS system in the future?
Answer: Yes. There is a plan to install the VisiCad System that is produced by TriTech Corporation VisiCadd American TriTech – San Diego, CA

SUBJECT: Interview with a accounts manager of American Medical Response, Inc. (Michael Barbieri)

Date and time of first interview: 12 February 1997, 1000 - 1015 hours.

1. Question: The facility in which you are located is rented by AMR. What is the rental cost of the of the facility?
   Answer: You must understand that this is proprietary information and provides our company a competitive advantage, as a result, I will only give you a range of what that rental cost is. The rental cost is between $8,500 and $11,000 per month.

2. Question: What is the square footage of the total facility and what is the square footage of the space used by the dispatch operations?
   Answer: The total square footage of our facility is 14,640 square feet. There are two areas devoted to the dispatch operations. The first area is where the dispatchers, the dispatching computers, and GIS displays are located. This portion takes up 540 square feet. The second area is where the technical equipment is located and parts are stored. This portion also takes 540 square feet. That means that we allow 1,040 square feet of space for the dispatcher operations.

3. Question: What was the initial cost of the software used by the dispatcher?
   Answer: The software used by the dispatcher is both GIS and computer assisted dispatching. It cost $89,100 for purchase and has an annual maintenance cost of $4,500. The maintenance includes updates to the GIS database and modifications and enhancements to the software.

Date and time of second interview: 26 February 1997, 0900 - 1000 hours.

4. Question: What is the cost per ambulance?
   Answer: We purchase the ambulances for $63,000 each. However, the cost for the medical equipment, both non-consumable and consumable is $57,000.

APPENDIX C

QUICKQUANT REPORTS OF COMPUTATIONS

QuickQuant Report

BASIC QUEUING SYSTEM EVALUATION--MULTIPLE SERVERS

PROBLEM: Diss21 Date: 04-06-1997

Without GPS and 21 Ambulances

Parameter Values:

Mean Customer Arrival Rate: lambda = 1.56

Mean Customer Service Rate: mu = 2

Number of Servers: S = 21

Queuing Results:

Mean Number of Customers in System: L = 0.78

Mean Customer Time Spent in System: W = 0.5

Mean Number of Customers Waiting

(Length of Line): L_q = 1.948255E-24

Mean Customer Waiting Time: W_q = 1.248882E-24

Server Utilization Factor: rho = 3.714285E-02

Number in System n	Probability P_n	Cumulative Probability
0	0.4584	0.4584
1	0.3576	0.8160
2	0.1394	0.9554
3	0.0363	0.9917
4	0.0071	0.9987
5	0.0011	0.9998
6	0.0001	1.000

QuickQuant Report

BASIC QUEUING SYSTEM EVALUATION--MULTIPLE SERVERS

PROBLEM: Diss15 Date: 04-06-1997

With GPS and 15 Ambulances

Parameter Values:

Mean Customer Arrival Rate: lambda = 2.7

Mean Customer Service Rate: mu = 1.85

Number of Servers: S = 15

Queuing Results:

Mean Number of Customers in System: L =1.459459

Mean Customer Time Spent in System: W =0.5405405

Mean Number of Customers Waiting

(Length of Line): L_q = 6.15967E-12

Mean Customer Waiting Time: W_q = 2.281359E-12

Server Utilization Factor: rho = 0.972973

Number in System n	Probability P_n	Cumulative Probability
0	0.2324	0.2324
1	0.3391	0.5715
2	0.2475	0.8190
3	0.1204	0.9393
4	0.0439	0.9833
5	0.0128	0.9961
6	0.0031	0.9992
7	0.0007	0.9999
8	0.0001	1.0000
9	0.0363	0.9682
10	0.0181	0.9863
11	0.0082	0.9945
12	0.0034	0.9980
13	0.0013	0.9993
14	0.0005	0.9998
15	0.0002	0.9999
16	0.0001	1.0000

APPENDIX D

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