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Final Report

SYSTEMS ENGINEERING STUDY OF EMERGENCY COMMUNICATIONS SYSTEMS for the CITY OF CHARLOTTESVILLE, UNIVERSITY OF VIRGINIA and ALBEMARLE COUNTY

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Central Piedmont Urban Observatory

CENTRAL PIEDMONT URBAN OBSERVATORY

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ABSTRACT

This research addresses social and economic costs and benefits associated with possible emergency communications system innovations in the Charlottesville/Albemarle area.

The central goal of the research is to provide officials of Charlottesville and Albemarle County with a decision and policy analysis structure for planning by means of which decisions can be reached concerning feasibility of implementation of a "911 emergency telephone number system. Results of the research are presented in such a fashion as to allow decision making officials in Charlottesville and Albemarle County to relate quantitative and qualitative factors concerning the 911 system in order to determine decisions and likely consequences of these decisions.

It is anticipated that the major value of the work lies in the provision of a consistent and generalized method for studying and evaluating urban problems. Although applied specifically to a system, it is readily adaptable to the investigation and evaluation of a wide variety of urban service delivery systems.

FOREWORD

This report presents the results of a 7-month study conducted by the School of Engineering and Applied Science of the University of Virginia to provide officials of Charlottesville, the University and Albemarle County with a decision and policy analysis structure for planning, by means of which decisions concerning the feasibility and desirability of implementing an emergency communication system can be made.

This study was performed under the direction of Professor A. P. Sage, Quarles Professor and Associate Dean, with Professor O. A. Gianniny, Jr. as a senior faculty investigator and Mr. G. G. Yorke and Mr. T.D. Ricks serving as research assistants.

The authors wish to acknowledge the cooperation and assistance provided by members of the Project Review Committee - Mr. John Dek. Bowen, Chief of Police; Mr. Julian H. Taliaferro, Jr., Fire Chief; Mr. George W. Bailey, Albemarle County Sheriff; Mr. W. Wade Bromwell, Director, University Police Department; Dr. George Moore, Director, Department of Health; Mr. Fred L. Huckstep, Jefferson Country Firemen's Association; Mr. Josh Pritchett, Captain, Charlottesville/Albemarle Rescue Squad; Ms. Linda Nesbit, Coordinator, Emergency Services and Mr. R. Southall, CENTEL, Telephone System Communications Consultant. Without the strong dedication, effort and participation of these people in the various phases of our study, it would have doubtlessly been less realistic in its application to the Charlottesville/Albemarle area than it is at present. We very much appreciate the dedicated assistance of our Project Review Committee.

We would also like to express our special appreciation Ms. Marcia Marshaw, former Director of the Central Piedmont Urban Observatory and Ms. Linda Peacock, present Director for their invaluable contributions to this research effort.

Despite the generous assistance of so many, there are doubtlessly flaws in this effort and for these the authors assume full responsibility. This research activity, has to a large extent, been a learning process for all but especially for members of the research team.

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EXECUTIVE SUMMARY

Statement of the Problem

Many of our cities and urban areas are plagued with inadequacies in the accessibility, availability and quality of urban services. These inadequacies did not develop overnight. Rather, they were the result of a multiplicity of factors - population increases, industrial expansion, natural growth, etc., coupled with a lack of planning foresight and constant neglect. Further there are always reservations expressed by many concerning changes in the status quo.

Delivery of emergency services in the Charlottesville/Albemarle area is one element identified in preliminary University studies as needing comprehensive planning. Basic needs for emergency service delivery can be stated as follows: "The citizens of Charlottesville and Albemarle County should be able to summon help rapidly in emergency situations with a minimum of confusion." The studies suggest that geographic, demographic and socioeconomic characteristics have changed more rapidly than the service capabilities, so planning for efficient allocation and use of resources is needed now to avoid crisis situations in the future. On the other hand, many officials believe that the present emergency service system is adequate and meets the needs of the community.

This particular research has investigated alternative approaches available in the area for emergency service delivery, one of which is the

"911" communication system. An attempt has been made to expose all aspects of implementing some sort of emergency communication system, including important value-laden questions.

Purpose of the Project

The purpose of this project was to develop a comprehensive plan for evaluating, designing and implementing an emergency response communication system. Specifically, our upper level objectives were:

1. To inventory the response times, costs, and other factors of existing emergency services delivery systems in the City, University, and County.
2. To determine whether there are problems with the existing system and, if so, what are their magnitudes.
3. To analyze thoroughly, the social, economic and other costs and benefits associated with all pertinent factors involved in various implementation configurations associated with the "911" emergency telephone system.
4. To provide responsible officials in Charlottesville and Albemarle County with data regarding the need for a 911 system and an action plan which will analyze and outline all phases of implementation.
5. To thoroughly involve, or allow for involvement, responsible officials in Charlottesville and Albemarle County in development of the plan.

6. To present the research results in such a fashion as to allow responsible officials in Charlottesville and Albemarle County to relate quantitative and qualitative factors concerning the "911" system to their own value systems in order to consider alternative decisions and likely consequences of these decisions.

Scope of Work

From its inception, this project has involved close association and interaction between the researchers and officials in Charlottesville and Albemarle County, especially in the areas of fire protection, health care delivery, police services, and rescue operations. Questions relating to access points, special equipment dedicated to "911" service, answering stations, responding agencies, jurisdictional considerations, and institutional and financial arrangements have been addressed with assistance from the Central Telephone Company of Virginia. This study has also utilized the experiences of other communities which have implemented such systems in the past. The study has considered, to the extent possible, criteria established by Federal and State agencies in order that funds from these agencies may be secured for implementation.

To this end a project review committee was requested and appointed in accordance with policies of the Central Piedmont Urban Observatory to interact with the research team throughout the study. This project review committee consisted of:

John Dek. Bowen, Chief of Police, City of Charlottesville

Julian H. Taliaferro, Jr., Fire Chief, City of Charlottesville

George W. Bailey, Sheriff, County of Albemarle

W. Wade Bromwell, Director, University of Virginia Police Department

Dr. George Moore, Director, Charlottesville/Albemarle Department of Health

Fred L. Huckstep, Jefferson Country Firemen's Association

Josh Pritchett, Captain, Charlottesville/Albemarle Rescue Squad

Linda Nesbit, Coordinator, Emergency Services, City of Charlottesville

Rodney Southall, Communications Consultant, Central Telephone Company of Virginia

The Major Work Elements Undertaken by the Project Team were

1. To develop a narrative and graphic description of the Charlottesville/Albemarle area.
2. To investigate "911" systems in other communities.
3. To describe existing emergency communications in Charlottesville, the University, and Albemarle County.
4. To inventory potential agencies receiving emergency calls in Charlottesville, the University, and Albemarle County with respect to call volume and time distribution of emergency telephone calls.
5. To ascertain information requirements - volume - time distribution in Charlottesville, the University, and Albemarle County.
6. To determine latent and potential demand for emergency communication services in Charlottesville, the University, and Albemarle County.

7. To coordinate these findings with responsible officials in Charlottesville, the University, and Albemarle County and to obtain a full cross-section of views regarding possible "911" implementation scenarios.

8. To develop a comprehensive description of the organizational structure which will manage emergency communications resources and capability for the area.

9. To explore communication center location considerations.

10. To plan for integrating and coordinating the services of the responding agencies with an eye on equity, efficiency and cost.

11. To develop system plans, schedules, estimated expenditures, justifications and, to the extent possible, sources of funds and financial arrangements for various implementation scenarios.

12. To describe methods to be used in evaluating, monitoring and updating the system. To determine the cost effectiveness for various implementation scenarios.

13. To assist agencies in Charlottesville, University, and Albemarle County in use of systems methodology in order to determine worth scores, scoring functions, decisions, and policy with respect to various implementation strategies associated with the "911" system.

14. To present the final results of the effort in such a fashion as to establish appreciation and credibility for the results obtained by responsible officials so the methodology can be used to reach further decisions concerning implementation of the system.

It appears that successful application of technology to societal problem areas such as a "911 system" to summon emergency help must be based on studies of problems and possible ameliorations at three levels: technological systems, societal institutions and values. Anything less risks the chance of our having either "technological solutions looking for problems," or a mere treatment of symptoms. Thus, we used systems engineering methodology to examine the 911 system and its alternatives, including the present system, with respect to impacts on institutions and values. We strongly believed that determination of true cost-benefit ratios for systems of the 911 type would go far beyond an examination of a technological fix and the resulting hardware for system implementation. Such an approach merely directed at symptoms might well result in an expensive but ineffective remedy.

By attacking the "911" system problem at the level of institutions, we attempted to determine the impact upon institutions of the existing system and of likely alternatives. This effort could assist in a configuration determination such that agencies delivering emergency service could make maximum use of technology inherent in the "911" system.

By also approaching this problem at the level of values, we were able to identify basic issues associated with the system in terms of conflicting values. To utilize these value elements in determining likely results from implementing various alternative "911" systems is a highly desirable goal and one to which our efforts were directed.

Our project utilized a variety of techniques from systems engineering for problem analysis and resolution of technology and public policy issues while maintaining a level of analytical sophistication which is readily comprehensible.

We subdivided the emergency communication systems study into seven steps:

1. Problem definition (determination of needs, constraints, alterables and societal sectors).
2. Value system design (determination of objectives and objectives measures).
3. Systems synthesis (structuring of candidate systems, determination of possible policies, controls and measures of control and effectiveness).
4. Systems analysis and modeling (analysis of the system determined by elements of the problem definition, value system design, and systems synthesis steps in order to estimate changes in cost-benefit as a function of various alternative policy implementations and changes in control variables).
5. Optimization (ranking of alternatives in accordance with various effectiveness measures)
6. Decision making and worth assessment.
7. Planning for action

Iteration of this methodology has led to the recommendations contained herein. The major output from this methodology is a set of procedures that community officials can use in order to rapidly evaluate the effects and values of proposed policies and decisions.

The best efforts of the project team were directed to these ends. Our study, which is summarized here, does not represent a detailed engineering design resulting from a technological fix, but rather, represents an attempt to provide local emergency service delivery agencies and decision makers with the results of a substantive planning effort which will hopefully enable formulation of emergency communication plans and programs for community betterment. Six alternative system configurations have been formulated, analyzed, contrasted and compared. For each of these six alternatives, personnel requirements, telephone equipment and major capital cost elements have been determined. For the recommended alternative, our perceptions of efficacious methods of management, financing, and implementation are described.

Economic and social cost and benefits have been estimated as accurately as possible. In any large system such as this it is never possible to estimate with precision all costs and benefits. Nevertheless, we conjecture that our conclusions and recommendations are insensitive to the particular cost and benefit figures assumed for parametric variations in the range of 30 to 60 percent. Our specific conclusions, findings, and recommendations are as follows:

1. Desirability of Enhanced Emergency Communications

Analysis of communications systems for emergency service delivery in the Charlottesville/Albemarle area, and agency and user characteristics relative to the use of these systems, indicates the need for an improved emergency communication system. Each of fourteen agencies

providing emergency service has its own telephone number, increasing difficulty of access for children, elderly, transient or other callers operating under stress of an emergency. (Details substantiating this recommendation may be found in Chapter II of the final report).

2. Feasibility of a "911" Emergency Communication System

The sincere and cooperative attitude expressed by emergency service delivery agency officials towards consolidation of emergency communications and facilities, especially those dealing with public safety, indicates that a version of the "911" emergency communication system is feasible for the Charlottesville/Albemarle area from an institutional as well as a value viewpoint. Problems of telephone boundary mismatch, due to different area codes and different telephone companies in the area, can be ameliorated by methods which we outline in Chapter III, which recommends partial resolution to the boundary mismatch problem requiring intergovernmental cooperation. Further resolution would require expensive modifications to telephone exchanges, extending far beyond CENTEL's present plans for modernization.

3. The Recommended System

We have conducted a needs assessment as well as a value assessment associated with the impact of emergency communication systems upon relevant agencies in the Charlottesville/Albemarle area. On the basis of the problem definition and value system elements determined from this interaction, which are described in detail in Chapter III, we have postulated 6 candidate systems which potentially satisfy needs and achieve community objectives relative to emergency communi-

cation services. We have considered various measures of effectiveness in response to needs satisfaction. These include capital investment and operating expenses, security and privacy considerations, autonomy of agencies, accessibility, system dependability, vulnerability to harassment, and overall service delivery mission effectiveness. Paramount among these needs considerations are savings in time, added convenience, and savings in cost. Included among the alternatives considered is the presently existing emergency communication system.

The emergency service delivery agencies of Charlottesville/Albemarle County, represented on our project review board, have been most helpful in reviewing and iterating the needs, constraints, alterables and objectives as each of these program planning elements relates to the specific alternatives considered. From this set of potentially acceptable alternatives, one must be chosen as the candidate system which best satisfies the needs perceived in the problem definition step and is most consistent with the value structure of agencies responsible for emergency service delivery. Working with the project review team, we have structured the attributes of the candidate systems considered such that the multiple attributes of the various candidate emergency communication systems have become evident to all as well as amenable to treatment utilizing the method of worth assessment used to select the recommended system configuration. This methodology has allowed agencies to express group preferences among alternatives described by success attributes of emergency communication delivery. Each

agency official has expressed a scoring function of the attributes for each candidate system configured. The scoring function has been determined by each agency representative based upon economic and societal cost and benefit data provided as well as individual perceptions of total responsiveness of the candidate systems. The project team has analyzed responses from the individual agency representatives as well as a single preference structure for the entire project review team based upon simple averaging.

Alternative 5 described in Chapter IV, appears to be that which offers the greatest overall benefit-to-cost effectiveness of the various concepts considered. This particular configuration consists of a consolidated dispatch center for emergency communications which directly dispatches personnel for all police agencies and transfers calls to individual dispatch centers for all fire agencies and the rescue squad. Any person dialing 911 will thus be connected to a partially independent and autonomous emergency service agency which is capable of directly dispatching the majority of emergency calls received and which can transfer, after a brief interrogation period, an incoming call to those agencies which feel the strong need for maintaining close control in monitoring of the very specialized and capable dispatchers. All services currently delivered by fire and rescue, which includes some social service delivery calls, will thus be transferred in this fashion. Close interagency cooperation with the 911 communication center will be required for efficacious call handling procedures and policies.

It is our view, based upon interpretation of responses from emergency service delivery representatives, that any emergency communication system which does not include some form of direct dispatch from the communication center will not succeed in coordinating resources, improving delivery of emergency services, or reducing telecommunications costs to the community as well as a system which contains this direct dispatch feature.

4. Performance Requirements and Cost of Implementing Recommended Alternatives

In determining operating personnel requirements and telephone capacity requirements for each alternative, we have assumed that no more than 10% of all busy-hour calls received will be serviced with delays greater than 10 seconds. Call transfers must also be handled quickly or almost as fast as dialing a 7-digit number directly. A queueing analysis presented in Chapter V, has been used to show that this response time is such as to yield extremely low system losses. Personnel requirements to allow this service are less than four dispatch operators during the peak call period and less than two for off peak hours. We have also used a telephone capacity criterion to ensure that no more than one call in a hundred will receive a busy signal during the peak calling hour. Six incoming telephone lines are required to satisfy this criterion.

Our analysis leads to the conclusion that twelve full-time 911 dispatch operators will be required to meet performance requirements. Chapter VI presents detailed cost/benefit comparisons for system Alternative 5 as well as for other alternatives. These very preliminary cost figures

have been presented primarily to serve as an approximate bench mark concerning relative magnitudes of financial commitments.

The monthly cost associated with personnel and telephone equipment in any new centralized emergency communication system should be borne in an equitable way by the three jurisdictions - City, County, and University - involved in usage of the system. There exists the possibility that some or all costs associated with new dispatch equipment might be obtained by external funding, perhaps by the Law Enforcement Assistance Administration. Location costs are somewhat difficult to estimate and Chapter VI addresses major location renovation considerations.

5. Suggested Management Strategy

Emergency service delivery agency representatives, through the worth assessment methodology exercise of Chapter VII, have expressed their acceptance and preference for alternative configurations system No.5. However, all representatives have indicated, by their response to the worth assessment procedure, serious concerns relative to organization and management of any emergency communication system alternative to the present system. A variety of organizational and management structures have been presented and discussed with these representatives on our project review team. The recommended management and organizational structure is presented in Chapter VIII of this report. It was recommended that the 911 emergency communication center be organized as an autonomous agency, independent of police, fire and rescue and that it be governed by a board of directors

representing the various agencies associated with emergency service delivery in the Charlottesville/Albemarle area. It is felt that this management plan, considerably detailed in Chapter VIII, would allow continuation of the very beneficial efforts made by City, County and University towards joint ventures for an enhanced quality of life for residents of the area and visitors to the area.

6. Implementation Plan

The implementation plan suggested in our study suggests that System Alternative 5 could be implemented approximately two years after a decision is made to implement it and the CENTEL Company is requested to initiate changes. It should be noted that establishment of an emergency communication center, as envisioned with System Alternative 5, would serve as a center for coordinating resources and planning in the event of some local or national disaster in addition to serving the required function of meeting the considerable needs for emergency communications in this area. By virtue of the centralized location of the system configuration proposed, space and communication availability and equipment, planning for the new system should also encompass planning for its use in the event of those local or national disasters and catastrophies whose effects might be ameliorated by the proposed 911 emergency communication system configuration, possibly aggregated with other 911 emergency communication systems throughout the region and the nation.

Implementation plans should also include a public information campaign especially to identify the unique characteristics of this

system - public access to the center and agency responses. Understanding and confidence will be needed to retain community acceptance of the system.

7. Overall Recommendation

It is the recommendation of the project team that decision-making officials in Charlottesville, the University, and Albemarle County go on record as favoring implementation of a 911 emergency communication system. We recommend that proper technical guidance from telephone officials and telecommunications consultants be obtained to develop plans for project and operational details and that this effort be coordinated with existing emergency service delivery agencies who have strongly evidenced great community loyalty and support throughout this study. We recommend that System Alternative No. 5 (Direct Dispatch for all police emergency services and call transfer for all fire and rescue squad operations) be subjected to detailed technical scrutiny to determine more precise development and operational costs such that implementation can proceed at an early date. Our best efforts indicate that this system cannot help but be a big improvement over the present uncoordinated,fragmented and unsystematic emergency service system. We strongly believe that the dedicated emergency service delivery agencies of Charlottesville/Albemarle will continue to provide cooperative selfless community-minded support for progressive participative development and enhancement of the ability to deliver emergency services in this area. Thus, we urge prompt action to continue the planning efforts documented here into program development and an operating 911 system.

I. INTRODUCTION

In this chapter, we present a brief discussion of telecommunication innovations and their relationship to the delivery of urban services while emphasizing the social implications of these innovations. This discussion tends to amplify the need for a comprehensive methodology or framework for addressing urban problems. A methodology is presented which has applicability to many of the large-scale problems extant. A brief discription of the background of this study together with its objectives and the organization of this report is presented.

A. Telecommunication Innovations

Over the last decade or two, innovations in telecommunications have seen startling. Traditionally, telecommunications has been concerned mainly with only one of the human senses - that of hearing [1]. Advances in technology, however, have made possible a wide variety of visual communication services. Foremost among these advances are large information handling capacity transmission media of very large bandwith such as waveguides and optical fibers exploiting pulse-code modulation (PCM) digital techniques, computer controlled switching systems utilizing digital time-division switches, large-scale integrated (LSI) circuits, high capacity and fast access memory devices and new types of solid-state visual display and image sensing devices [1].

B. Innovations Related to Urban Services

In June 1971, the Committee on Telecommunications of the National Academy of Engineering produced a report, "Communication and Technology for Urban Improvement" containing some twenty ideas on the use of telecommunications information technologies to improve living conditions in U. S.

cities [2]. These ideas related the role of telecommunications in citizen-government interaction, education, health, pollution, transportation, crime prevention, and emergency services.

C. Social Implications of Telecommunications

The application of these new telecommunication technologies to the urban environment is fraught with social, economic and political considerations. Until recently, very little attention has been paid to the social implications of implementing new telecommunication technologies [3]. In part, this has been the result of the engineer's concern with hardware and the decision-maker's emphasis on cost-effectiveness. For example, two-way instructional television has been advocated to improve the quality and distribution of educational services. In order to fully assess the utility of this new technology, the following social questions should be addressed:

a. What will be the impact on existing forms of education and training?

b. How will the existing school system be organized to facilitate instructional television?

c. How does the method of presentation affect a student's ability to comprehend?

d. How much instruction should a student be exposed to before saturation occurs?

e. How does this method of instruction provide motivation?

This list is not exhaustive but it does present the flavor of social inquiry. Such inquiry is absolutely necessary if urban systems are to be functional and effective. Indeed, it is the absence of such inquiry that leads to bottlenecks in the planning of emergency and other urban services. To the best of our knowledge, in almost all communities where jurisdictional boundary problems exist, the planning and/or implementation

of a 911 communications system was carried out solely on a directive from the State legislature (e.g., California, Massachusetts, Florida). Here, in the State of Virginia, no such mandate exists. Implementation of technological fixes under mandate has often produced technological solutions looking for problems. It would appear that the successful application of technology, such as an emergency communication system to societal problem areas, must consider three levels of problem-existence and amelioration: systems, institutions, and values. We therefore propose to examine, using systems engineering methodology, emergency communication system alternatives with respect to the impact on institutions and values. We strongly believe that determination of true cost/benefit ratios from implementation of a system such as this will consist of much more than an examination of a technological fix and the resulting hardware for system implementation.

D. The Systems Engineering Concept

Systems engineering may be thought of as a process which facilitates decision-making by providing a rational method for reflecting the needs and values of a society, organizing information relative to the impacts of all reasonable courses of action and implementing and monitoring a given alternative solution to measure its performance, chart its impact and possibly modify system implementation to ameliorate negative effects [4]. As such, this process must contain, at minimum, the following ingredients [18]:

1. A way to deal successfully with problems involving many considerations and interrelations.

2. A way to deal successfully with areas in which there are far-reaching and controversial value judgements.

3. A way to deal successfully with problems, the solutions to which require knowledge from several disciplines.

4. A way to deal successfully with problems in which future events are difficult to predict;

5. A way to deal successfully with problems in which structural and institutional elements are given full consideration.

The systems engineering methodology presented here has been developed to possess these minimum ingredients.

E. Systems Engineering Methodology

There is no unique systems engineering methodology. Problems in large-scale systems, particularly in the societal sector, dealing with economic, resource, technological, and behavioral factors are very complex and difficult to quantify. Thus, it is doubtless unrealistic to expect development of a unique standard methodology. Nevertheless, the methodology presented here does appear to meet the conceptual requirements of a comprehensive, systemic and rigorous approach to the solution of large-scale problems.

Systems engineering has three major dimensions: a time dimension which includes the gross sequences or phases that are characteristic of systems work and extends from the initial conception of an idea through system retirement or phaseout, a logic dimension which deals with the steps that are carried out at each of the systems engineering phases and a knowledge dimension which refers to specialized knowledge from various professions and disciplines. These are the dimensions of the Hall [5] morphological box of systems engineering.

The thrust of our work will be specifically concerned with the activity plane of systems engineering consisting of the time and logic

dimensions or the phases and steps of systems engineering. The activity matrix for systems engineering is illustrated in Figure 1 and our exposition of systems engineering methodology will evolve by further development of the many important ideas represented by this activity matrix.

By methodology we mean an open set of procedures which provides the means for solving problems. The "tools" of systems engineering are the elements of a methodology necessary for accomplishing the steps and phases of the Hall activity matrix. We select as the tools of systems engineering-words, mathematics, and graphics. When we combine a set of tools, a set of proposed activities, and a set of relations among the tools and the activities, we have a methodology.

The objective of program planning is to ascertain the desirability of allocating resources to specific projects aimed at solution of a given problem. Project planning is characterized by a series of activities directed at a specific project or projects identified in the preceding phase and has as its major objective, the selection of alternative systems for development in the next phase. System development is concerned with detailed plans and designs for the selected alternatives. The production phase refers to the actual implementation or construction of the alternative systems developed in the preceding phase. The distribution phase refers to the existence of the systems to perform prescribed functions while the operations phase refers to the actual utilization of the systems. Finally the retirement phase refers to that period when the systems must be phased out due to obsolence.

Reference to Figure 1 suggests that each of the systems engineering phases is defined, to a greater or lesser degree, by the seven problem solving steps. These steps are:

Phases of the Coarse Structure (Time ↓) / Steps of the Fine Structure (Logic →)	Problem Definition	Value System Design	System Synthesis	Systems Analysis	Rank (Optimize) Alternatives	Decision Making	Planning for Action
Program Planning							
Project Planning							
System Development							
Production							
Distribution							
Operations							
Retirement							

Figure 1 Hall's Activity Matrix for Systems Engineering

1. Problem Definition: Problem definition is essentially a study of needs, constraints and alterables and collection and analysis of data in an effort to fully describe and formulate the problem.

2. Value System Design: Value system design is the establishment of objectives aimed at ameliorating or addressing the problem identified in Step 1 and the establishment of performance measures to evaluate these objectives. Objectives are established with an eye on needs identified, constraints reorganized (uncontrollable elements), impacts on various sectors involved and alterables (controlable elements).

3. Systems Synthesis: Thus far we have described the systems engineer's approach to discovering 'what' is the problem and 'what' should be done about that problem. We now devote our attention to 'how' this problem can be resolved. System synthesis is an activity which involves describing as completely as possible the various ways, systems, policies, etc. that can be implemented in order to achieve the stated objectives and thus satisfy the original needs. Consequently, we design hypothetical alternative solution systems.

4. Systems Analysis: Systems analysis follows logically from systems synthesis and involves an evaluation of each hypothetical solution in terms of cost, required inputs, expected outputs, etc. Here typical systems engineering tools and techniques, such as queueing theory, demand analyses, statistics, etc. are employed.

5. System Optimization: System optimization is carried out as an integral part of the iteration between systems synthesis and systems analysis. Here we attempt to rank each hypothetical system in the light of efficiency and effectiveness.

6. Decision-Making: Decision-making is a rather complex task. However, a variety of decision-making aids, value and worth assessment and cost-benefit analysis, together with results of systems analysis and value system design, serve to guide the decision-making process.

7. Planning for Action: Having decided on a particular course of action, a set of guidelines consistent with needs and objectives are detailed for implementation and operation.

The highly structured, logical nature of this methodology together with its claim to generality of application, in our opinion, can reduce client acceptance problems which must be addressed very diligently from the start. For example, the emphasis on separating needs from constraints and the insistence on postponing formal consideration of alternative solutions until the problem has been adequately defined ensures that all practical aspects of the problem can be accounted for, thereby avoiding most typical pitfalls resulting from more directly intuitive problem-solving approaches.

F. Background of the Study

In 1973, the Division of Biomedical Engineering, University of Virginia, began a major effort to improve the quality of medical care delivery in Planning District Ten which includes Charlottesville and Albemarle County. Major funding for this effort was provided by the Robert Wood Johnson Foundation, an independent philanthrophy interested in improving health care in the United States. The establishment of a universal emergency number in order to improve general accessibility was discussed with both city and county officials who expressed a desire for pertinent information with regard to its desirability. The University of Virginia School of Engineering and Applied Science was selected, under direction of the Central Piedmont Urban Observatory, to conduct a study of emergency communication system planning for the Charlottesville/ Albemarle County area with the Robert Wood Johnson Foundation providing the necessary funding. This is the final report of this study.

G. Objectives of Study

The purpose of this project is to develop a comprehensive plan for evaluating, designing and implementing an emergency response communications system. Specifically, the upper level objectives are:

1. To inventory the response times, costs and other factors related to existing emergency service delivery systems in the City, University and County.

2. To determine whether there are problems with the existing system and, if so, what are their magnitudes.

3. To analyze thoroughly, the social, economic and other costs and benefits associated with all pertinent factors involved in the 911 emergency telephone system.

4. To provide responsible officials in Charlottesville, the University, and Albemarle County with data regarding the need for a 911 system, if such a need exists, and an action plan which will analyze and outline all phases of implementation.

5. To involve thoroughly, or allow for involvement of responsible officials in Charlottesville, the University, and Albemarle County in the development of the plans.

6. To present the research results in such a fashion as to allow responsible officials in Charlottesville, the University, and Albemarle County to relate quantitative and qualitative factors concerning the 911 system to their own value system in order to determine decisions and likely consequences of their decisions.

H. Organization of Report

This report is organized to facilitate easy comprehension by public officials. The organization of chapters reflects the steps outlined in the systems engineering approach to problem solving.

Chapter II addresses program planning and describes the existing communication facilities in the Charlottesville/Albemarle area, the present citizen access system and agency response to emergency requests. Chapter III concerns various scenarios needed for problem definition and

value system design and emphasizes planning linkages necessary for a 911 communications system. Chapter IV is aimed at system synthesis and presents six conceptual alternative systems. Chapter V addresses system development and presents a technical analysis of hardware and personnel requirements. Chapter VI attempts to summarize cost and benefits associated with the alternatives presented, sources of funding and location considerations. Chapter VII addresses the complex task of decision making while Chapter VIII outlines specific action plans related to implementation. Finally, an Appendix is presented to familiarize decision-makers with the detailed operations of centralized communications systems existing in neighboring communities.

II. PROGRAM PLANNING

Program planning involves a conscious effort to project ideas of what ought to be into a framework amenable to tests of reality [18]. The problem is emergency communications in Charlottesville/Albemarle County, Virginia. The City of Charlottesville and Albemarle County encompasses a land area of some 750 square miles with an excess of 80,000 residents and represents a unique opportunity for the co-ordination and delivery of public services by virtue of the fact that the city is located in the heart of the County and is independent of the County. While Albemarle County has a rural agricultural character, the City of Charlottesville is rapidly approaching total urbanization. These divergent land use patterns tend to amplify the need for co-ordinative and supportive public services since many of the urban amenities required by County residents are to be found only in the City.

One important dimension of co-ordination for City and County concerns the degree and ease of accessibility of emergency services. We first describe the communication facilities of all responding agencies in the Charlottesville/Albemarle area. We then describe the existing citizen emergency access system. From these two descriptions, we are then able to describe more explicitly, agency response to emergency requests. These descriptions coupled with relevant analysis lead directly into an identification of needs.

A. Agency Description and Existing Communications

Visits to the various public service agencies indicate that the existing radio communications appear to be quite adequate (Table I) to satisfy many needs. In cases where further radio capability is required,

Table I

Service Agencies Characteristics

Agency	Type	Location	Area of Coverage	Emergency Telephone Numbers	Total No. of Telephone Lines at Dispatcher	Answering Locations	Radios and Frequencies	Dispatching Personnel	Methods for Alerting Personnel
Volunteer Fire Companies: Earlysville East Rivanna North Garden Stoney Point	volunteer		all of Albemarle County - mutual aid agreements	295-1125 -1126 -1127 rotary same as Charlottesville Fire Dept.	nine	Charlottesville Fire Department answers all calls on Ridge Street.	mobiles walkies 46.46 tone pagers	Charlottesville Fire Dept. dispatchers perform the dispatching for these volunteers.	telephone; tone pagers
Crozet Fire Department	volunteer	Main Street	Crozet area and west Albemarle County	823-4000 Charlottesville	two	4 - homes 3 - businesses 1 - fire house	tone pagers mobiles walkies 46.46 39.50 CB	Firemen are dispatched either by direct calls or through Charlottesville Fire.	Ch'ville Fire radio dispatch by tone pagers. Each phone has switch to turn on siren at the fire house.
Scottsville Fire Dept.	volunteer	Main Street	Scottsville area south Albemarle west Fluvanna north Buckingham	286-3611	two	1 - adjacent service station 4 - homes	mobiles 39.50 46.46 CB	no radio dispatch	telephone calling tree; siren
Scottsville Rescue Squad	volunteer	Main Street	Scottsville area south Albemarle west Fluvanna north Buckingham	286-2111	two	1 - squad 3 - homes	control console mobiles walkies 39.5 tone pagers	no radio dispatch until new system installed; volunteers dispatch.	telephone; new tone pagers
Charlottesville Police Dept.	paid	606 East Market Street	City of Charlottesville	295-4151 -4152 -4153 -4154 rotary	ten	police station - 606 East Market Street	control console mobiles portables walkie-talkies	Frequencies 39.44, 39.50, 46.46, 155.715/155.110 155.835/155.995	Dispatching Personnel 5 fulltime 1 special
Charlottesville Fire Dept.	paid and volunteer	203 Ridge Street	Charlottesville and surrounding county	295-1125 -1126 -1127 rotary street call boxes	nine	fire station - 203 Ridge Street	control console mobiles portables walkie-talkies tone pagers	46.46 39.50 tone pagers	4 fulltime - 56 hours/week performed by firemen who rotate.
Albemarle Sheriff	paid	County Court House	County of Albemarle	295-2112 -2113 -2114 rotary	three	Sheriff's Office - County Court House	control console mobiles CB base	39.50 39.86 CB	4 fulltime 1 parttime
University of Virginia Police	paid	412 Brandon Avenue	University of Virginia	street call boxes 924-7166 -7167 -7168 -7169 rotary	six	police station - 412 Brandon Avenue	control console portables	460.025/465.025 39.50 46.46 (monitor 155.835 only)	5 fulltime
Charlottesville/ Albemarle Rescue Squad	volunteer	828 McIntire Road	City of Charlottesville and County of Albemarle	295-1191 -1192 rotary	three	weekdays 8am-5pm - Little High Street; weekdays 5pm-8am & weekends - squad house	control console mobiles portables walkie-talkies tone pagers	155.835/155.955 463.025/468.025 39.50	1 daytime dispatcher on weekdays; at other times, various squad personnel.

this capability has already been recognized, and enhanced capacity plans made. We examine existing communications from a capability standpoint rather than a characterization of actual pieces of equipment which are documented elsewhere (Emergency Services Communications Plan [6]). The estimation and acquisition of communication equipment is a continuing function of the Emergency Medical System (EMS) group which is funded by the Robert Wood Johnson Foundation and administered by the University of Virginia, Biomedical Engineering Department. Although this group is directly concerned with Emergency Medical communications, its evaluations and recommendations span the entire realm of emergency services [6]. Usually two different modes of communications between public agencies are required to provide backup, reliability and security. The other mode generally employed is the telephone. There are many opportunities for combined use of radio and telephone in emergency service delivery.

1. The Charlottesville Police Department

The Charlottesville Police Department located at the corner of 6th and Market Streets has the most sophisticated communications center in the City or County. A wide range of frequencies allowing two-way communications with virtually every public service agency in the City and County is presently being utilized. Thus, radio communications between the Charlottesville Police and the County Sheriffs in Albemarle, Greene, Fluvanna, Louisa, Orange, Buckingham and Nelson together with the University Police, the City Fire Department, the County Volunteer Fire Departments, the Charlottesville/Albemarle Rescue Squad and the Scottsville Rescue Squad exist. Radio capability also exists for communications between the

Charlottesville Police and the University of Virginia Hospital's Emergency Room, the Airport Control Tower, the City Public Works and Traffic Engineering Departments.

(a) Frequencies

The frequencies utilized by the Charlottesville Police Department are 39.5 MHz - common to all law enforcement agencies; 39.44 MHz - unique to Charlottesville Police; 46.46 MHz - Fire and Airport Control Tower; 155.830/155.955 MHz - Rescue Squads and Hospital; and 155.715/155.110 MHz - Public Works and Traffic Engineering.

(b) Communication Aids

(i) The Charlottesville Police Department operates a teletype computer terminal which provides a link to both National Criminal Information Center (NCIC) and Virginia Criminal Information Network (VCIN). This enables rapid communication of pertinent information to officers in the field.

(ii) The Charlottesville Police Department has direct telephone capability with the National Weather Service for obtaining information related to storms, hurricanes, etc.

(iii) A dual set of magnetic tape recorders are used to assist dispatch personnel in administering the delivery of police services.

(iv) Emergency back-up power is provided by means of a generator.

(v) The status of personnel in the field is monitored and updated manually by use of a map indicator.

2. The Albemarle County Sheriff's Department

Albemarle County Sheriff's Department, located at the County Courthouse on Court Square in the City of Charlottesville, has considerably less radio and telephone capability as compared to the Charlottesville Police Department. However, the existing level of co-ordination between

law enforcement jurisdictions in the City and County is such that the Sheriff's Department can and does continually utilize the Charlottesville Police Department's emergency communication resources.

(a) Frequencies

The frequencies utilized by the County Sheriff's Department are 39.5 MHz - common to all law enforcement agencies, and 39.86 MHz - unique to the Sheriff's Department for inter-agency communications.

(b) Communication Aids

(i) The County Sherrif does not have direct access to VCIN or NCIC and must request such information through the Charlottesville Police Department, the University Police Department or the State Police.

(ii) There are no magnetic tape recorders to assist dispatched personnel in administering the delivery of police services.

(iii) The Sheriff's Department continuously monitors a Citizen's Band radio (Channel 9) for highway emergencies.

(iv) Emergency power for radio remote control does not exist. However, emergency power exists for dispatch operations.

(v) There is no sophiscated method for monitoring and updating the status of deputies in the field. Presently, this is accomplished by means of written logs.

3. The University Police Department

The University Police Department, located on Brandon Avenue, maintains radio communications with most City and County public agencies through use of the common frequency 39.5 MHz. A new UHF system is employed to meet the special needs of the University Police in patroling the interior of buildings where low frequencies do not transmit and receive as well. The existence of several emergency call boxes on the University grounds

near dormitories, parking lots and distant roads serve to facilitate easy access to the University Police.

(a) Frequencies

The frequencies utilized by the University Police are 39.5 MHz - common to all law enforcement agencies; 460.020/465.025 MHz - unique to the University Police for inter-agency communications; 46.46 MHz - monitoring City and County fire communications, and 155.830/155.995 MHz - monitoring local rescue squad's communications.

(b) Communication Aids

(i) The University Police have direct access to VICN and NCIC.

(ii) Emergency power is provided by means of a generator.

(iii) Dual magnetic tape recorders are employed to assist in the administering of police services.

(iv) Monitoring and updating the status of officers in the field is accomplished by written logs.

4. The Charlottesville Fire Department and Volunteer Fire Companies

The Charlottesville Fire Department, located on Ridge Street with another station located on the 250 By-Pass, approximately 2 miles away, handles its own dispatching as well as that of several county volunteer fire companies including East Rivanna, Stony Point, Earlysville and North Garden. Separate volunteer fire companies at Scottsville and Crozet have their own telephone answering system and are usually not dispatched through the Charlottesville Fire Department. However, Crozet can be dispatched by the Charlottesville Fire Department by means of tone pagers. Scottsville will have this capability in the near future. During an incident, the Crozet and Scottsville Fire fighting personnel are usually in direct radio contact with the Charlottesville Fire dispatchers.

Fire service for far western Albemarle County, which is in the C & P telephone district, is a long distance call from areas such as Greenwood to Crozet which is four to five miles away. Scottsville maintains a fire department which serves the southern part of Albemarle County as far north as Keene and as far west as Esmont. In addition, the Scottsville Fire Company serves areas of Buckingham and Fluvanna Counties, which are adjacent to the town.

(a) Frequencies

The frequencies utilized by the Charlottesville Fire Department are 46.46 MHz - common fire frequency (this frequency is also used for communication to the Airport Control Tower) and 39.5 MHz - common to all law enforcement agencies. The Charlottesville Fire Department will be adding a second fire frequency so that fire units on the scene of a fire can be switched to an operating frequency leaving the primary frequency for general use within six months.

(b) Communication Aids

(i) Emergency power is provided to the Charlottesville Fire Department by means of a generator.

(ii) Through co-ordination with the Charlottesville Police Department, the Charlottesville Fire Department has message recording capability.

(iii) The Volunteer Fire Companies communication aids are considerably less sophisticated than those associated with police services.

5. The Charlottesville/Albemarle Rescue Squad and Scottsville Rescue Squad

The Charlottesville/Albemarle Rescue Squad housed on McIntire Road at the 250 By-Pass serves all of the County with the exception of the

Scottsville area. There are no outlying stations directly affiliated with the Charlottesville/Albemarle Rescue Squad though consideration has been given to an East Rivanna satellite station. The Charlottesville/Albemarle Rescue Squad has a wide range of radio communication in order to perform their unique functions. Through the common low-band frequency - 39.5 MHz - they are able to communicate with all local law enforcement agencies and the Fire Department. Special frequencies enable them to communicate with the University of Virginia's Hospital and the Scottsville Rescue Squad. The sophistication of their equipment allows them to transmit EKG's and the like from their mobile units. Tone-coded systems are utilized to alert personnel and radio communications capability with Martha Jefferson Hospital is presently being acquired.

The Scottsville Rescue Squad which serves the immediate Scottsville area and surrounding areas of south Albemarle, west Fluvanna and north Buckingham presently lacks the necessary radio communications capability of the Charlottesville/Albemarle Rescue Squad. However, acquisition of a new radio system, together with tone pagers and patching capability to permit two-way communications between the Scottsville Rescue Squad and the County Sheriff's Office and the University of Virginia Hospital's Emergency Room is presently underway.

(a) Frequencies

The frequencies utilized by the Charlottesville/Albemarle Rescue Squad are 39.5 MHz - common to all law enforcement agencies; 155.835/155.955 MHz - inter-agency and squad-to-hospital communications; and 463.025/468.025 MHz - telemetry. The Scottsville Rescue Squad presently utilizes the 39.5 MHz frequency.

(b) Communication Aids

(i) The Charlottesville/Albemarle Rescue Squad has emergency back-up power.

(ii) The Charlottesville/Albemarle Rescue Squad has message-recording capability.

(iii) Both rescue squads continuously monitor a citizen's band radio for emergency requests.

B. Existing Citizen Access Systems - Description

Citizen access system refers to the facilities available to the citizen for requesting and reporting emergency situations. The Charlottesville/Albemarle area is characterized by three political jurisdictions - City, County and University. It is not unusual for a resident to be conducting business or using facilities in the City, County or University on a regular basis. Consequently, each resident of the entire area must become familiar with a variety of emergency services and numbers in the City, County and University.

There are at least 14 basic emergency telephone numbers which residents may need to use. These separate and distinct numbers are for the Charlottesville Police, the Charlottesville Fire Department, the Charlottesville/Albemarle Rescue Squad, the County Sheriff, the gas company, the power company, other volunteer fire and rescue squads, drug and child abuse centers, social services, hospital emergency rooms and the like.

In addition to this need to ascertain the correct political jurisdiction and telephone numbers, a caller may sometimes have to use a toll phone necessitating the further need for appropriate coins. Further, residents in the Greenwood part of the County must initiate a long distance call to request emergency services. Moreover, in some instances, residents are

required to dial separate and distinct numbers for the same emergency service before and after 5 p.m. (e.g. Welfare and medical emergencies).

This state of affairs would naturally imply some confusion in obtaining emergency assistance, especially to the elderly, handicapped, children and visitors. In the City of Charlottesville, some 24 percent of the population are between 10-14 years of age with some 10 percent over 65 years [7]. It is reasonable to suspect that a similar age distribution exists in the County. In an emergency situation, the degree of confusion, anxiety and frustration places severe stress on such persons not only in obtaining the appropriate numbers but more importantly in dialing them.

The University of Virginia, with a transient student population of approximately 15,000, also attracts a great number of conventions and conferences. These transients and visitors together with those drawn by university events, local, historic and scenic attractions must surely have difficulty in accessing emergency services. The magnitude of this delay is discussed in Chapter III.

C. Agency Response to Emergency Requests - Description

From an examination of communication facilities in terms of citizen access and agency operations, the following general statements relating to agency response can be made:

(a) There is a high level of informal mutual aid and co-ordination between dispatch agencies in the City and County.

(b) There is no explicit cross-training between personnel in different agencies to enable maximum effective service when a resident dials the wrong number.

(c) There exists a wide variation in the level of training and diversity of functions performed by dispatch personnel in the various agencies.

(d) Many agencies are currently unable to man their communications positions regularly with existing designated dispatch personnel.

(e) The existing hardware utilized by many agencies does not possess such basic features as the ability to hold a line open and the ability to disconnect a caller to free incoming lines.

D. Analysis

Having described agency response to emergency service requests, a very important question arises - what is the impact of the existing response system on the accessibility and delivery of emergency services? This question has many dimensions relating to ease and efficiency. However, for the present, we address the dimension of time.

Table 2 indicates that a substantial percentage of crimes requiring on-scene-assistance are reported by someone other than the victim. The elapsed time or time between detection and notification is indeed substantial. When an emergency has occurred, then the total time between detection and notification by someone who is not directly involved in the emergency would appear to reflect the ease with which such notification can be made. In a needs survey conducted by the Stanford Research Institute for Santa Clara County, California, it was concluded that between 25 and 40 percent of emergency calls had to be transferred to at least two agencies; considerably less than half the citizens had recorded their emergency numbers for convenient use and also considerably less than half the citizens knew their emergency 7-digit numbers [8]. (We examined the utility of conducting a similar type of survey for the Charlottesville/ Albemarle area. However, the requirements in terms of time, costs and anticipated response does not appear to justify the effort.)

Tables 3A and 3B indicate that the greatest percentage of fires are reported by means of a telephone. Consequently, making the telephone more

Type of Crime	Period	Incidents	Reported by Victim	Reported by Other	Elapsed Time Between Detection and Notification
Felonious Assault with Knife	1975	34	59%	41%	57 minutes
Felonious Assault with other dangerous weapon	1976 January - June	9	78%	22%	44 "
Disorderly Conduct	1975	72	26%	74%	23 "
Disorderly Conduct	1976 January - June	24	21%	79%	28 "
Felonious Assault with Gun	1975	35	40%	60%	58 "
Felonious Assault with Gun	1976 January - June	12	75%	25%	18 "
Attempted Rape	1975	4	100%	0%	22.5 "

Source: Charlottesville Police Department - Individual Records (1975-1976)

Table 2 Selected Police Statistics - Charlottesville (1975-1976)

Table 3A

Selected Fire Statistics - Charlottesville, 1975

Source of Report	Total Incidents	Percentage
Telephone	966	84
Street Box	75	7
Automatic Alarm	25	2
Other (Radio, Walk-ins, etc)	78	7

Table 3B

Selected Fire Statistics - Charlottesville, 1975

Type of Fire	Percentage
Building	40
Vehicle	22
Other	38

Source: Charlottesville Fire Department, 1975

accessible increases the likelihood of a prompt notification. 22 percent of all fires reported in 1975 were vehicle fires necessitating to a large extent the use of public pay phones and the associated coin requirement. Data were not available on elapsed time.

E. Identification of Needs

The information presented thus far provides the basis for an evaluation of needs. We attempted to solicit the participation of responding agency officials in a determination of what could or should be done with the existing communication system. From a series of meetings and discussions, the following needs were expressed:

(a) A reduction of confusion in notifying appropriate agencies in an emergency situation (whom to call? what number? what jurisdiction?)

(b) A procedure for co-ordinating existing resources to minimize duplication of equipment and enable greater utilization of existing manpower.

(c) The provision of improved communications system features to enable greater efficiency in providing community services.

(d) The provision of means whereby citizens can summon emergency assistance by public telephone without coins.

III. PROBLEM DEFINITION AND VALUE SYSTEM DESIGN ELEMENTS

Program planning is directed at a series of activities aimed at addressing the needs identified in Chapter II. We first attempt to identify problem definition elements: needs, constraints, alterables and societal sectors. Using unified program planning techniques developed by Hill and Warfield [9], we then seek to identify the relationships among these elements. Identification of these relationships enables us to postulate objectives which are defined in the framework of the problem definition variables such as to satisfy needs, and to define related objectives measures. Having developed objectives, we then proceed to examine emergency communications system concepts with respect to proposing alternative policies to better achieve objectives by satisfying societal needs.

A. Problem Definition Elements

Needs have been identified in Chapter I. We now direct our attention to constraints, alterables and societal sectors as defined in the methodology section. These problem elements were identified through discussion and review with the Project Review Committee and their interactions were estimated by the analysis team.

1. Constraints

(a) Telephone equipment-hardware

(b) Funding

(c) Public officials' acceptance

(d) General public acceptance

2. Alterables

(a) Implementation time

(b) System costs

(c) Operating procedures

(d) Cost distribution and recovery

(e) Types of emergency service provided

3 Societal Sectors

(a) General public

(b) Agency directors (City, County, University)

(c) Legislators (City, County, University)

(d) Telephone Company Officials

To illustrate the interactions or relationships between the various problem elements, interaction matrices are used - Figure 2. The self-interaction matrix describes the magnitude of interaction between elements comprising a set as opposed to the cross interaction matrix which describes the magnitude of interaction between elements comprising different sets. For example, the self-interaction matrix for constraints indicates that funding interacts strongly with the public and public officials' acceptance. Similarly, the cross interaction matrix between alterables and constraints indicates that operating procedures interact strongly with public officials' acceptance.

Careful evaluation of these interactions with the Project Review Committee led to the establishment of the following objectives which are structural and presented in Chapter VII with appropriate evaluation indices.

B. Objectives

1. To meet the national goal of a single emergency number

2. To facilitate easy citizen access

3. To coordinate existing resources

4. To provide service in a cost effective manner

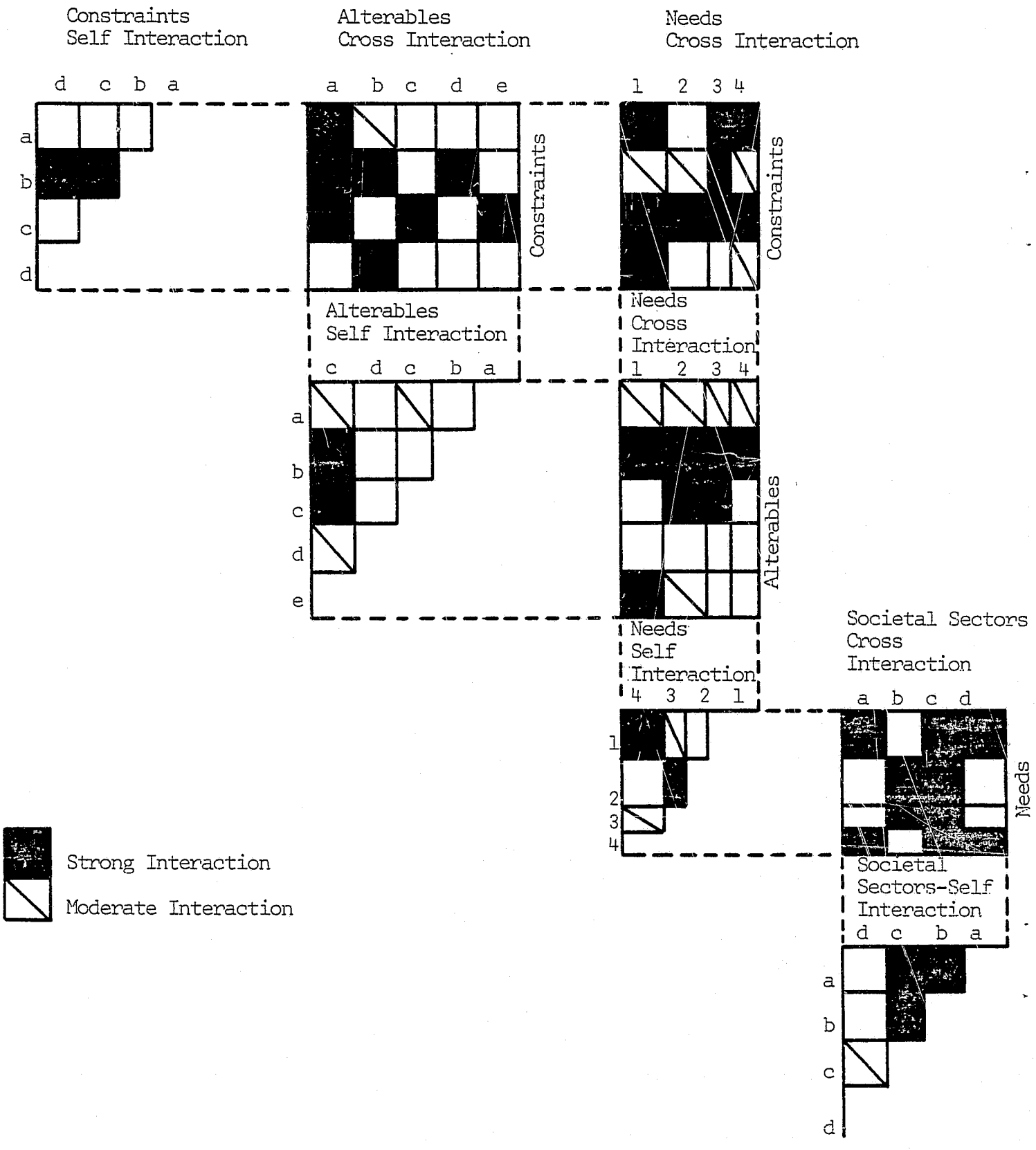


Figure 2 Interactions of Importance in Problem Definition
(For Further Information - See References [9] and [18])

5. To improve the existing level of service

6. To improve emergency communication and administration of services

7. To enable coin-free dialing

8. Maintain the authority of responding agencies

9. To minimize disruption of existing services

10. To reduce confusion in notifying appropriate agencies

11. To provide for growth in emergency communications requirements

We now seek to identify some alternative policies which might enable the achievement or attainment of our stated objectives. We address specifically the concept of alternative 911 systems as they relate to emergency communications and associated emergency service delivery.

C. Emergency Communications System Concept

Some concepts of emergency communications are illustrated in Figure 3 where an emergency begins with the occurrence of an event requiring on-scene-assistance. The total response time here is estimated to be $t_1 + t_2 + t_3$. Thus, any reduction in time between occurrence and detection, or detection and notification, or notification and dispatch effectively reduces that response time.

911 has been suggested as a national emergency number to be used throughout the United States. Presently, 712 communities with a total population of about 50 million either have the 911 number or are installing it [10]. Studies conducted by the Stanford Research Institute for Orange and Santa Clara Counties California, have suggested that response times could be reduced by 1.5 to 4 minutes with the introduction of 911 [11].

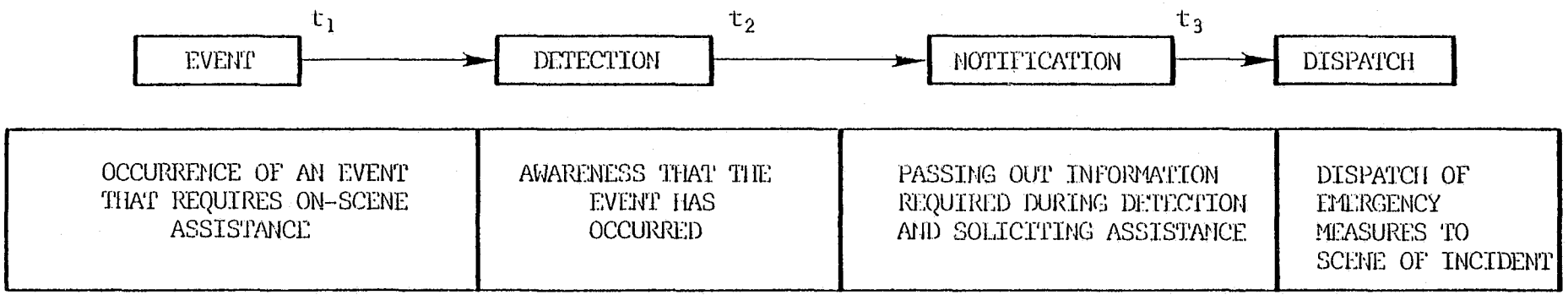
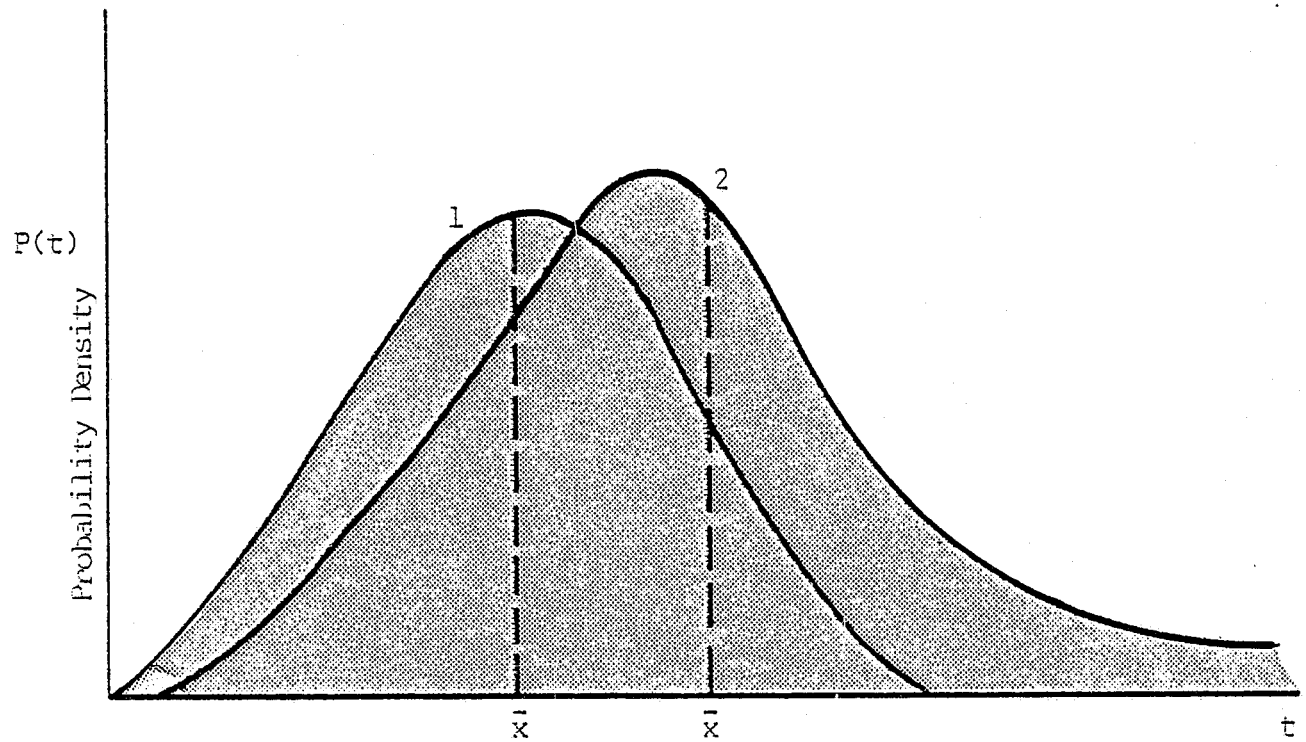


Figure 3 Emergency Communication System Concept

Such studies are usually very difficult to perform, largely due to the inadequacy of data. Indeed, the relevant data for such analysis in the Charlottesville/Albemarle area are non-existent. However, all available inferential information suggests that response time is often greater than need be. Reduction in total response time results invariably in a savings in life and property, and every effort should be made to accomplish this.

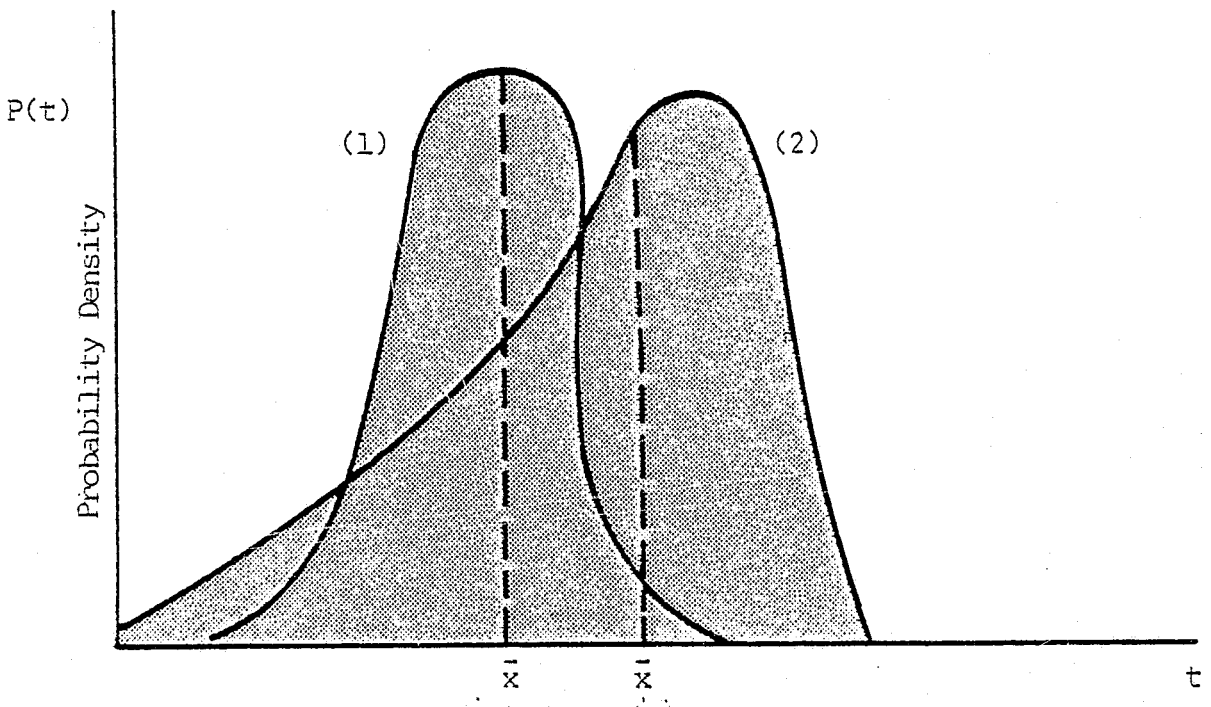
To illustrate this point, consider the following heuristic scenario of the random time variation between detection and notification. Given the existing system of citizen access, we can safely postulate that some people will access emergency services quickly and efficiently (they know the proper telephone number) and others will not (dialed the wrong number, dialed the wrong agency, no phone book, no coins, etc.). If one were to plot the frequency or probability of getting information to an agency, the resulting distributions would most likely approximate those presented in Figures 4(a) and 4(b). Figure 4(a) indicates that with the existing system of citizen access depending on the variety of numbers, emergency services, education, etc., some people will consume a substantial amount of time in accessing emergency assistance. There is great variability in the time required to notify an agency. Figure 4(b) on the other hand, indicates that by introducing a 911-citizen access system, the access time for those persons previously subjected to substantial delays is considerably reduced even though the average response time is little changed.

The needs of these persons are critical in the delivery of emergency services: for example, a study of heart attacks in Santa Clara County, California (1969) indicated that of 54 non-hospital deaths in men under 60 years, 46 percent were found dead and an additional 22 percent



time to notify agency, two hypothetical cases

(a)



time to notify agency, two hypothetical cases

(b)

Figure 4 Hypothetical Probability Distributions

(a) Existing Citizen Access System
(b) 911 Citizen Access System

died in less than 15 minutes of the onset of acute heart attack [12]. Also, a study of British heart attacks (1968) indicated that 34 percent died in 15 minutes and 54 percent in one hour after incidence of the heart attack [12].

The Stanford Research Institute has estimated that in Florida, a 30-second reduction in fire fighting response time would result in $1.7 million savings, thereby reducing residential fire losses by 7 percent. This does not include any savings from other types of fires [8].

Figure 5 further illustrates the true response time associated with the four basic methods of accessing emergency services [19]. The 911 communications system concept has three major advantages:

(1) It reduces confusion in notifying appropriate agencies, thereby reducing total time from detection to receipt of emergency services. This could conceivably result in crimes and emergency situations being more promptly reported and consequently increase the level of security experienced and/or perceived by residents.

(2) With the introduction of 911, basic communications system features such as called party hold, forced disconnect, etc. can be provided thereby improving the efficiency of emergency communications;

(3) A 911 communications system requires personnel with specialized training and the establishment of operating procedures which could enable comprehensive and efficient service to residents.

D. Provision Mechanisms for A 911 Communications System

In order to provide 911 communications in the Charlottesville/Albemarle area, we present a descriptive scenario for implementing such a system. This scenario specifically addresses the technical problem associated with 911. Questions concerning social and institutional problems will be addressed in subsequent chapters.

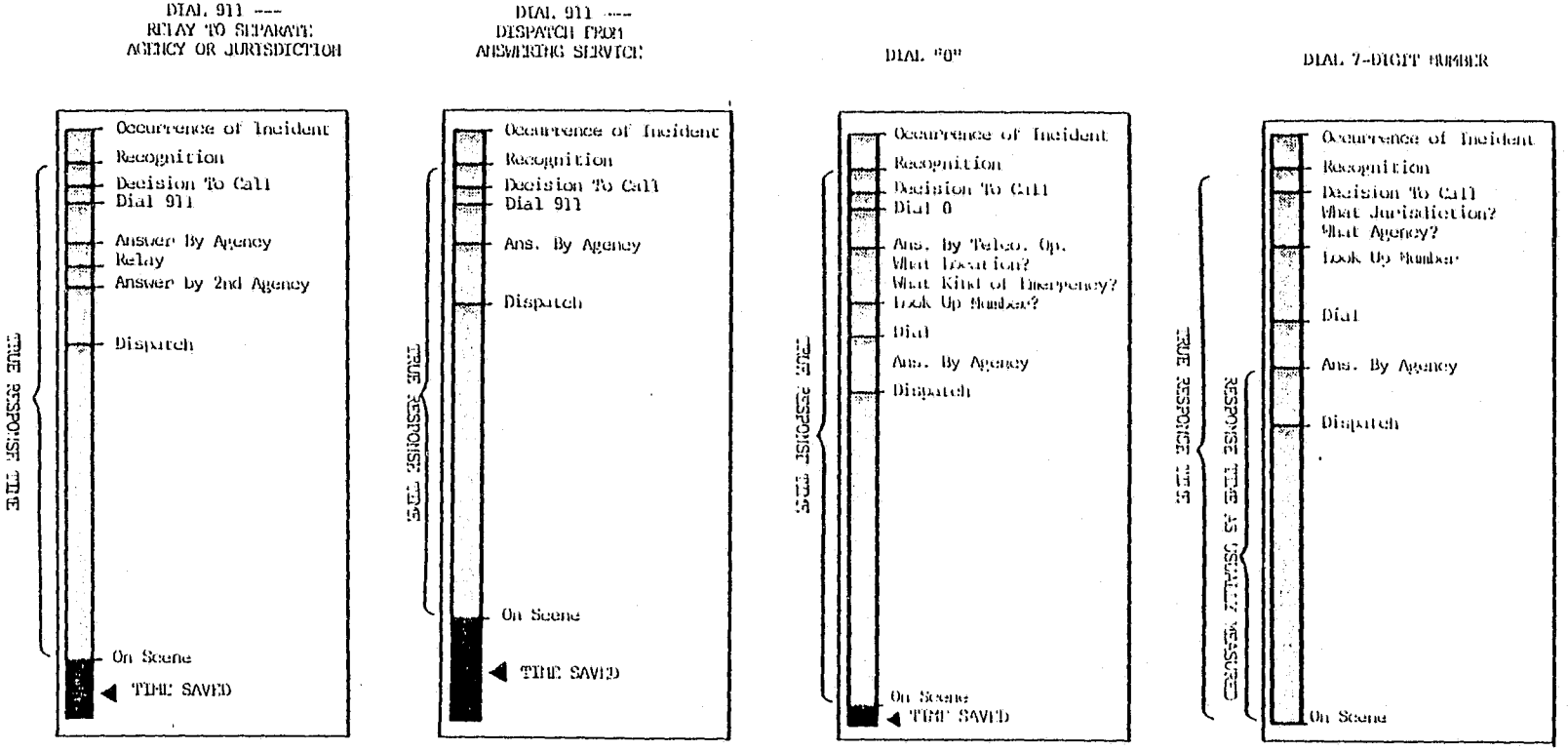


Figure 5 Time Saved by Dialing 911
(Office of Telecommunications [19]).

1. Service Agencies

Figure 6 shows the location of various emergency services accessible to residents in the Charlottesville/Albemarle area. Traditionally, mutual aid agreements and cooperation between jurisdictions have enabled residents located on the fringes of the county to summon help from rescue and fire services of nearby counties. Greene, Fluvanna and Nelson Counties have implemented 911 service. However, residents of Albemarle County cannot obtain fire and rescue services of these counties by dialing 911. Rather, they are required to dial the respective seven or eight-digit number for appropriate services. With the introduction of 911 into the Charlottesville/Albemarle area the method of accessing emergency services throughout this entire area will become uniform.

2. Boundary Problems

The Charlottesville/Albemarle area is served by two telephone companies. The Central Telephone Company of Virginia serves approximately 92 percent of the area while the Chesapeake and Potomac Telephone Company of Virginia serves the remaining 8 percent. Invariably, when more than one telephone company serves a community, boundary problems present themselves. A boundary problem exists when telephone service areas and county boundary limits are not coincident. Figure 7 shows the areas where a potential boundary problem exists. For example, the telephone exchange 456 serves residents of both Albemarle and Nelson Counties. If 911 was implemented in the Charlottesville/Albemarle area, then that entire region (Nelson and Greenwood) would access a 911 center in Charlottesville. This type of problem is not unusual and indeed exists in many of the communities which have implemented 911.

Figure 6 Location of Emergency Services

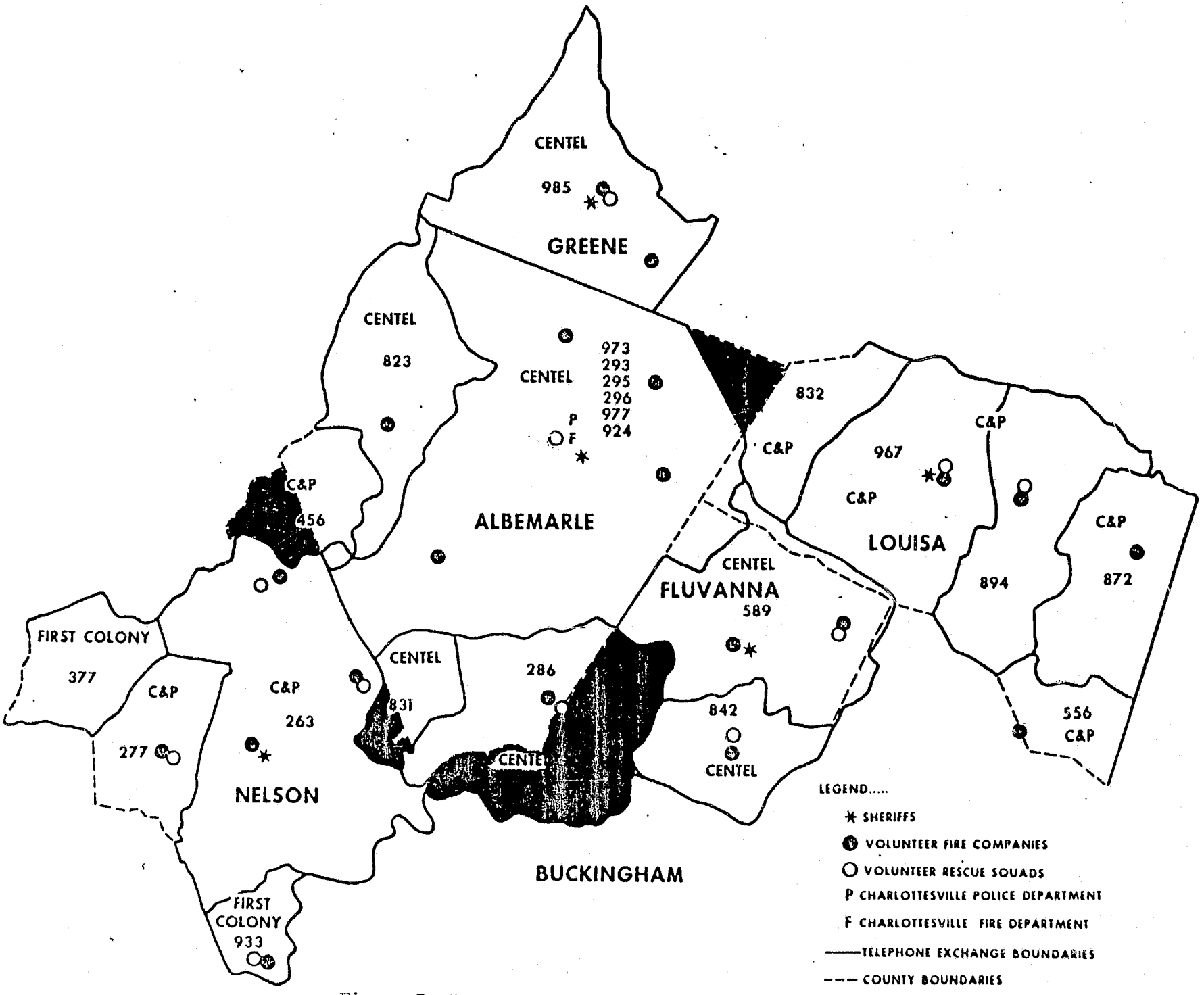


Figure 7 Telephone Exchange Boundaries

E. Solution Options to Boundary Problems

A variety of potential solutions can be conceived to eliminate boundary problems. These solutions span the realm of simplicity - neglect of these areas in planning 911 service-to complexity-structural modification of telephone equipment. We will not address the simplistic option of neglect. Rather, we assume that 911 service should be designed for the entire county.

1. Modification of Telephone Equipment

Present communications capability would suggest that the telephone company is able to split an exchange enabling residents in say, Greenwood (Exchange 456) to dial 911 and access a center in Charlottesville, while at the same time making it impossible for residents in Nelson County (with the same exchange, 456) to access that center in Charlottesville should they dial 911. The ease with which this can be accomplished depends on the existing switching equipment used by the telephone company. Presently, CENTEL is utilizing the old step switching equipment which is extremely costly to modify. However, within another 10 years or there abouts, they may be converting to ESS (Electronic Switching Systems) which will permit easy conversion. Splitting an exchange to enable telephone exchanges and political boundary lines to be coincident is basically a telephone system redesign. The cost of splitting an exchange under the present telephone company policy must be borne by the jurisdiction involved. For the Greenwood exchange, the cost estimated by the telephone company was somewhere in the vicinity of $20,000. This option is not recommended.

2. Operational Methods

This option considers what might be termed a non-structural solution where the operations , policies and rules are examined to

ascertain whether or not the problem can be addressed without the need for building or installing equipment.

Given that 911 service is not advertised in areas outside Albemarle County and the telephone company provides the type of directions similar to those being provided in their forthcoming telephone directory (special instructions for subscribers in areas where boundary problems exist) the volume of calls originating from these areas should be minimal. However, in the event that residents of another county (e.g. Nelson, Buckingham, etc.) dial 911, calls which should naturally terminate at the Charlottesville center can be handled as follows:

Scottsville Exchange - 286 - This exchange includes a small portion of Fluvanna and Buckingham Counties. Calls originating from these counties can be re-routed from the Charlottesville center to the appropriate dispatch agency in the respective counties. This applies primarily to police services since Scottsville provides fire and rescue services for this area.

Schuyler Exchange - 831 - This exchange includes a small portion of Nelson County. Calls originating from Schuyler will terminate at the Charlottesville center and re-route for fire and rescue services to Nelson County's 911 center which generally provides this type of service for Schuyler residents.

Greenwood Exchange - 456 - This exchange includes a small portion of Nelson County. Calls originating in Greenwood and terminating in Charlottesville are generally long distance. We recommend two (2) direct 911 lines from the Greenwood exchange which would enable residents to

obtain emergency services in Charlottesville at no cost. The method of accessing appropriate services for residents of Nelson County remains the same.

Orange Exchange - 832 - This exchange includes a substantial portion of Louisa County and indications are that relatively few Albemarle residents are located in this area. Ideally, this area could be handled in a manner identical to the Greenwood exchange. We have been unable to identify any requests for service in Charlottesville from this area. Consequently, we have not recommended any direct lines. For the sake of completeness, two direct 911 lines could be provided at a monthly cost of approximately $50-70 per line. This cost does not enter into our future analysis. This option would appear to be quite feasible and we therefore recommended that this service option be considered.

F. Method of Re-routing Emergency Calls

Presently, radio capability exists for reporting and requesting services in other communities and dispatch centers through the use of the common frequency 39.5 mHz. Such capability would naturally exist at the Charlottesville center. Added to this capability is a telephone capability. The center will be able to access other dispatch agencies in surrounding jurisdictions by:

(a) Dialing the appropriate 7-digit number and relaying information, and

(b) Dialing the appropriate 7-digit number and patching the caller to the appropriate agency.

This telephone capability is included in the basic 911 system. Alternatively, we could seek to improve telephone capability by the use of

"hot lines" to surrounding jurisdictions at a substantial additional cost (see Table 4). The use of hot lines for this purpose would perhaps enable a small time savings in dialing dispatch agencies. However, this time savings would be no greater than that which exists with radio communications. In view of the anticipated volume of calls requiring re-routing, it is our opinion that hot lines are unwarranted and therefore are not recommended.

A full description of the costs and requirements for implementing the 911 system in the Charlottesville/Albemarle area is presented in Chapters IV and VI.

G. Capital Costs of Implementing a 911 System

The capital cost of implementing a 911 system in the Charlottesville/Albemarle area as estimated by CENTEL ranges between $230,000 to $250,000. This cost, however, will be borne by the telephone company and not by the jurisdictions. The actual initial and operating costs for which jurisdictions are responsible is estimated in Chapters IV and VI.

Present policies relating to rate structure and recovery of telephone company's cost are such that with the implementation of 911 in Charlottesville/Albemarle, the actual increase in each subscriber's telephone bill would probably range between one and one-and-a-half cents per month. This is due to the fact that CENTEL's capital recovery costs are usually spread over its entire service area in the State of Virginia. Consequently, whether or not 911 is implemented in the Charlottesville/Albemarle area, should another community in the state implement a 911 system, the residents of Charlottesville/Albemarle will be subsidizing CENTEL's capital costs for implementing 911 in that area.

Table 4

Cost of Hot Lines for Accessing Dispatch Agencies in Surrounding Jurisdictions

Jurisdiction	Number	Cost	
		Monthly $	Initial $
Lovingston - 911 Center	1	151.50	54.15
Palmyra - 911 Center	1	90.90	54.15
Scottsville Fire and Rescue	1	80.80	54.15
Buckingham - Sheriff's Office	1	126.75	54.15
Stanardsville - 911 Center	1	95.95	54.15
TOTAL		545.90	270.75

Source: CENTEL

IV. SYSTEM SYNTHESIS

In this chapter, we present six alternatives for analysis and evaluation. The first three alternatives specifically address the question of accessibility and range from maintenance of the existing system to an emergency communication system involving call transfer and referral. The second three alternatives assume a 911 system and provide a variety of operational modes to satisfy various needs.

An emergency communication system must be viewed not only in terms of its accessibility but also in terms of its effectiveness. A 911 emergency number system addresses accessibility while the specific method of operation of the 911 system can be chosen for relative effectiveness. Alternatives were chosen to address the more important and less obvious questions relating to social and institutional desirability. In designing these alternatives, we attempted to incorporate the special operating requirements and needs of each responding agency.

The method of operation presented for the Charlottesville/Albemarle Rescue Squad in all six alternatives is that of call transfer and not direct dispatch from the communications center. This option was exercised in view of:

(a) The volunteer nature of the organization;

(b) The sophistication and specialized nature of their equipment;

(c) The high level of training required for rescue squad dispatch personnel, and

(d) The apparent efficiency of their dispatching facilities at the present time.

However, the proposed alternatives are flexible enough so that rescue squad dispatching could be incorporated into them should a need and desire develop.

A. Alternative #1 - Existing System

Alternative #1 (Figure 8) suggests that the existing system be maintained or that nothing further be done. It is presented to facilitate an easy reference point in comparing and evaluating the ensuing alternatives. The characteristics of this alternative are:

- Inadequacies in accessibility for many people needing emergency service delivery.
- No co-ordination in dispatch effort.
- No standardized dispatch procedures.
- No changes in administrative responsibility and accountability.
- Duplication of equipment and personnel on a continuing basis.
- Differing levels of service among agencies.
- The average monthly cost for this system is estimated at approximately $11,200 (see Table 5), a low value at present.
- In the next four years, it is anticipated that this cost will double, due mainly to the need for increased personnel to operate the present system.

B. Alternative #2 - A Seven-Digit Number and Alternative #3 - 911 Transfer and Referral

Alternatives #2 and #3 (Figures 9 and 10) are essentially the same in that they propose a central number for accessing all emergency services. Alternative #2 suggests a 7-digit number while Alternative #3 suggests a 911 number. The significant differences in these two alternatives lie in:

1. The time to implement (approximately three months for Alternative #2, and two years for Alternative #3).
2. Cost of conversion (this cost in either case is borne by the telephone company).
3. The simplicity of the number in terms of education and use.

The characteristics of these two alternatives are:

- No dispatch from center.

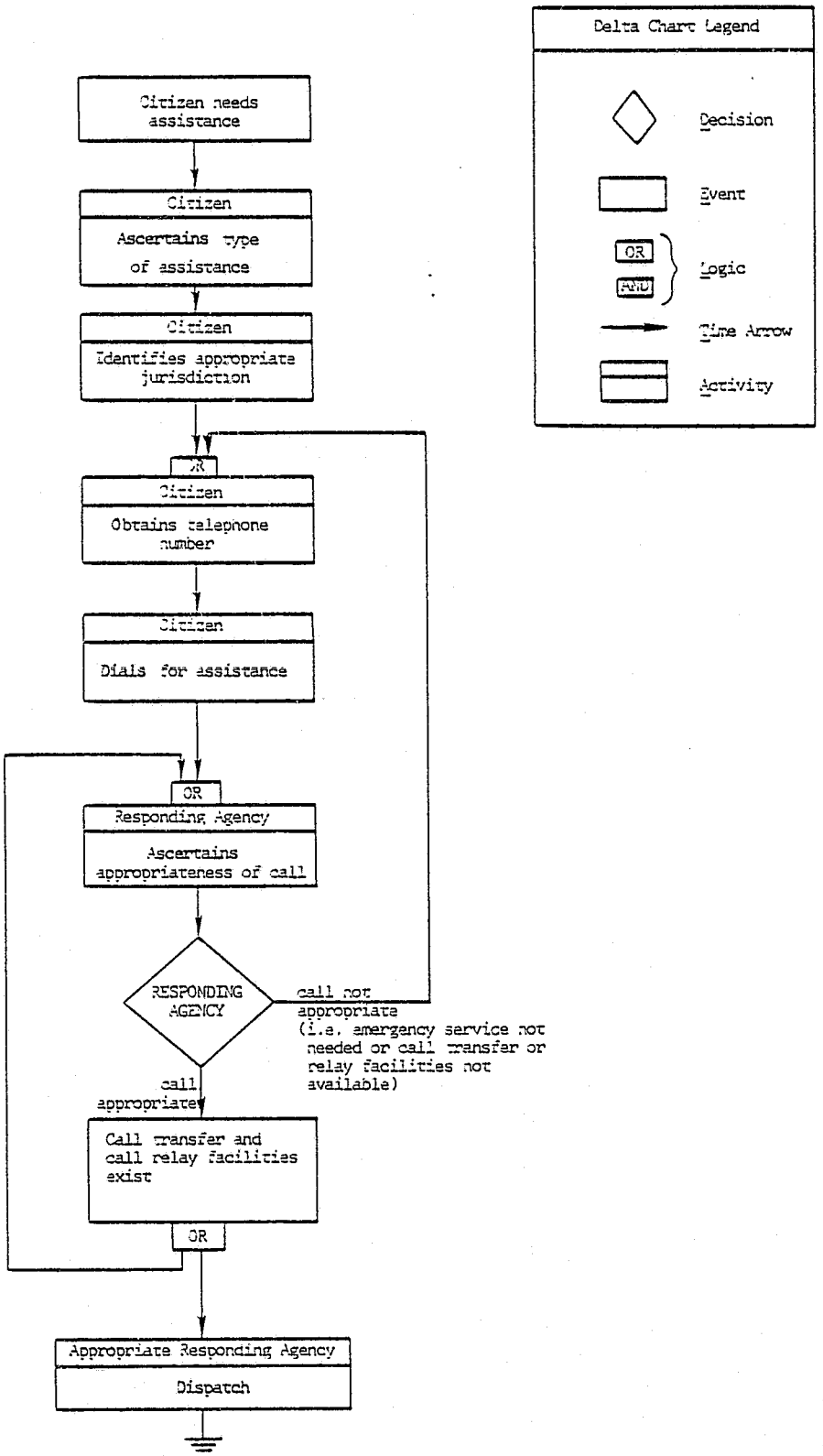


Figure 8 Delta Chart for Alternative #1 - Existing System

Table 5

Alternative #1 - System Costs

Item	Agency	Number	Average Monthly Cost (approx.)
Dispatch Personnel	Charlottesville Police	5 full time 1 part time	$3,102
" "	University Police	5 full time	2,940
" "	Sheriff	4 full time 1 part time	2,520
" "	Fire*	4 full time	---
Supervisors	Charlottesville Police	1 full time	1,000
"	University Police	1 full time	1,000
Telephone Charges	Charlottesville Police	--	74
" "	University Police	--	214
" "	Sheriff	--	127
" "	Fire	--	84
" "	Rescue	--	126
TOTAL			$11,187**

*Firemen function as dispatchers.

**Excludes firemen's salaries, miscellaneous costs associated with utilities, stationary, building, etc., since the actual proportion of these costs as they relate to emergency communications are marginal within the total context of each agency function.

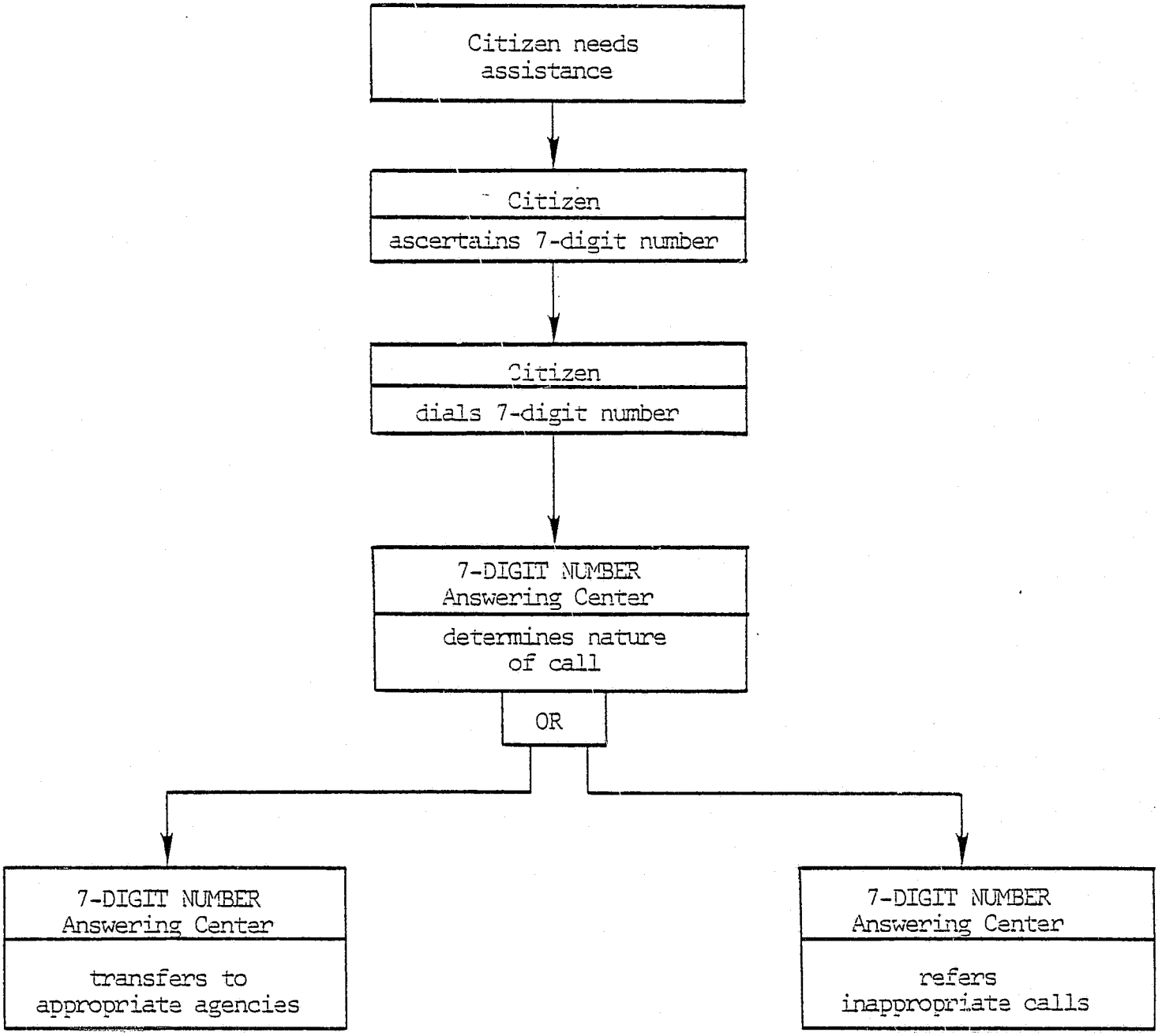


Figure 9 Alternative #2 - 7-Digit Number

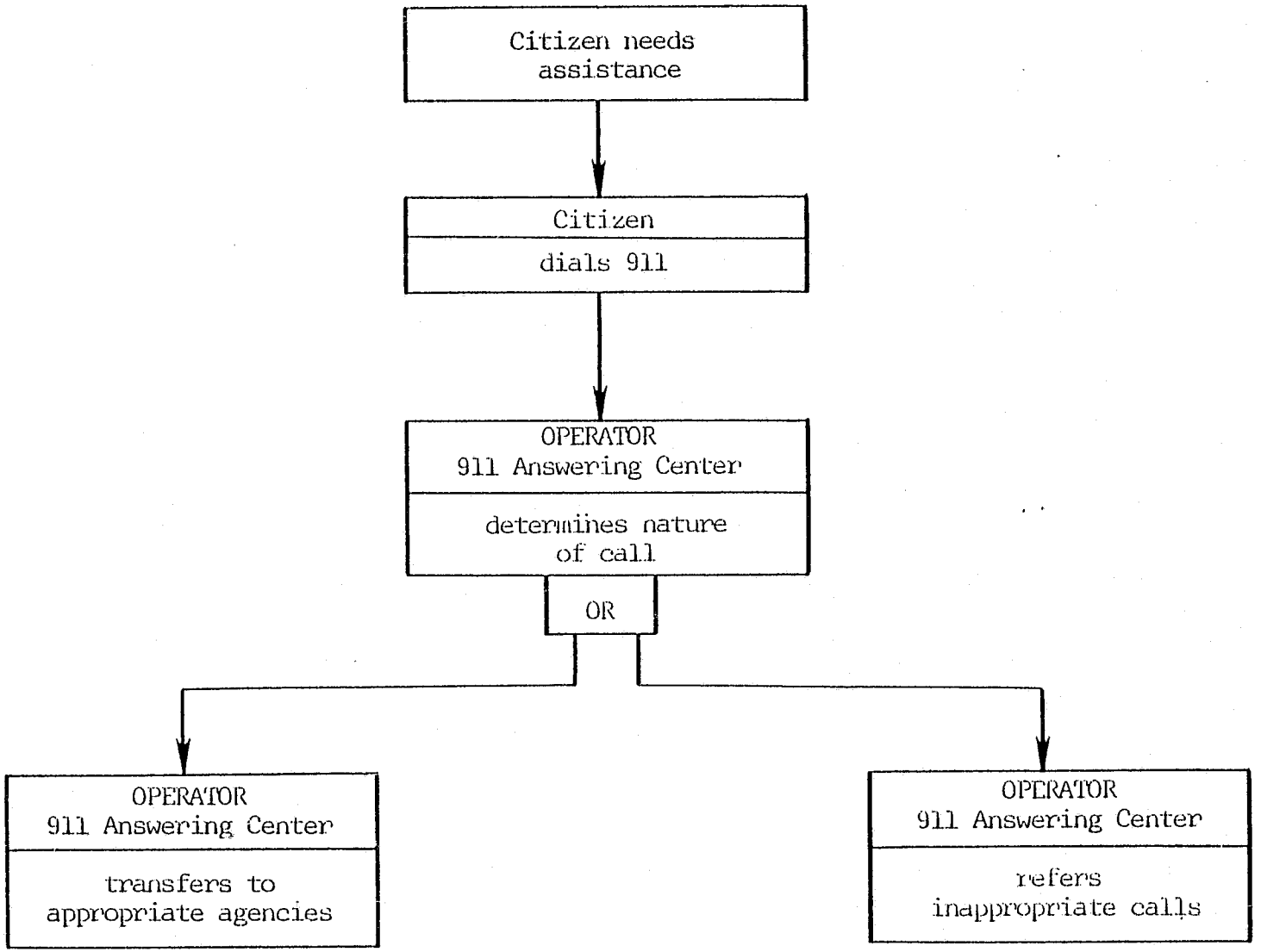


Figure 10 Alternative #3 - 911 - Transfer and Referral

- No change in existing dispatch procedures.
- No relocation of personnel and equipment.
- No changes in administrative responsibility and accountability.
- No need for personnel training.
- Duplication of equipment.
- Existing differing levels of service maintained.
- Increased cost - approximately $4,000 per month (see Table 6).
- Greater accessibility.
- No effective co-ordination.
- Marginal space requirements.

C. Alternative #4 - 911 - Specific Dispatch

Alternative #4 (Figure 11) proposes a 911 communications center with police and fire dispatchers working together in the same center but performing different functions. This alternative attempts to approximate a consolidated dispatch and while it holds significant advantages for police agencies, it offers no advantage to the fire agencies. The characteristics of this alternative are:

- Dispatches directly from 911 Center.
- Requires explicit description of dispatch procedures.
- Enables co-ordination of dispatch activities for police agencies.
- Need to re-locate personnel and equipment.
- Enables personnel savings among police agencies.
- Reduces duplication of equipment.
- Offers improved grade of service.
- Expands need for personnel training.
- Complicates administrative responsibility and accountability.

Table 6

Alternatives #2 and #3 - System Costs

Item	Number	Average Monthly Costs (approx.)	Initial Costs (approx.)
Incoming lines	10	$ 505	$ 230
Outgoing lines	13	100	250
Administrative	2	91	40
Telephone boards	2	130	306
Personnel	5	3,000	--
Tape recorder*	1	--	--
TOTAL	--	$3,825**	$ 826

*Existing equipment can be utilized.

**These costs are in addition to the cost of the existing system.

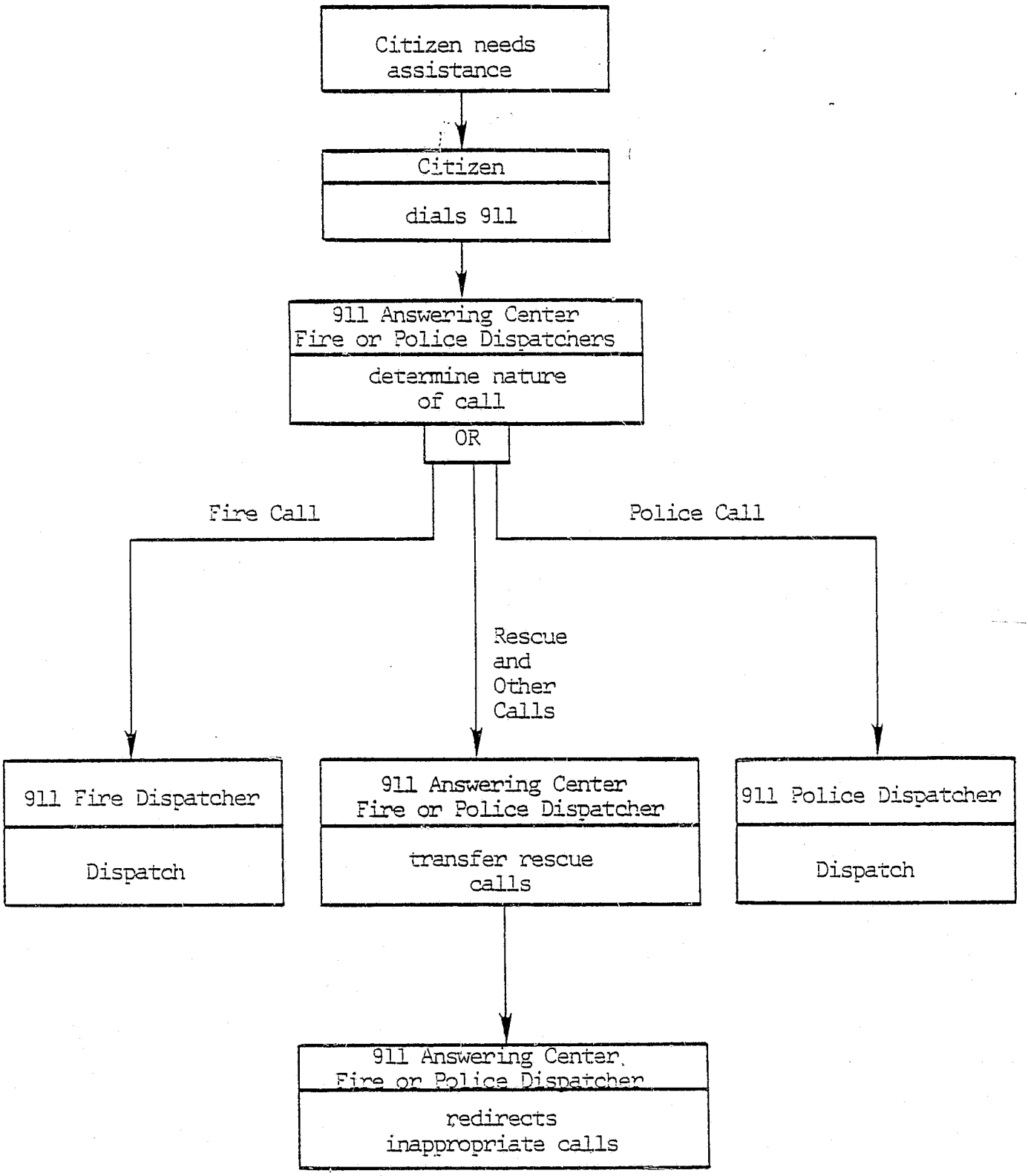


Figure 11 Alternative #4 - 911 - Specific Dispatch

- Requires at least 5 additional fire dispatchers.
- Increases cost significantly over Alternative #1 (see Table 7).

D. Alternative #5 - 911 - Police Dispatch

Alternative #5 (Figure 12) proposes a police dispatch with calls for fire being transfered to the fire department and is essentially a variation of Alternative #4. By eliminating fire from the dispatch function at the 911 Center, existing fire personnel are more fully utilized in the present capacity. This alternative was proposed to address the perceived problem envisioned by the Fire Chief in allowing personnel other than firemen to dispatch fire emergencies. The characteristics of this alternative are the same as those associated with Alternative #4. However, it further reduces:

1. The complexity in administrative responsibility and accountability, and
2. Significantly reduces operating cost as compared with Alternative #4 (see Table 8).

E. Alternative #6 - 911 - Multipurpose Dispatch

Alternative #6 (Figure 13) proposes a complete, consolidated dispatch effort between police and fire agencies. The characteristics of this alternative are the same as those associated with Alternative #5. However, fire agencies would be able to enjoy further advantages through reduction in dispatch personnel. Given the volume of fire calls, it is anticipated that with a consolidated police dispatch, the personnel recommended for Alternative #5 will be adequate to handle these calls, thereby eliminating the need for additional fire dispatch personnel. The costs associated with this alternative are basically the same as Alternative #5 with the addition of a status board. Figure 13 illustrates the routine functions of dispatch as it is envisioned with Alternatives #4, 5, and 6.

Table 7

Alternative #4 - System Costs

Item	Number	Average Monthly Costs (approx.)	Initial Costs (approx.)
Incoming lines	12	$ 505	$ 230
Outgoing lines	10	85	190
Administrative lines	3	136.50	60
Telephone boards	4	260	612
Radio consoles +	4	--	68,800
Status map ++	4	--	11,400
Terminal equipment*	1	--	--
Tape recorder*	1	--	--
Log recorders	4	--	--
Dispatch personnel**	17	17,416	--
Secretary	1		--
Administrator	1		--
Building***	--	--	--
TOTAL	--	$18,402.50	$81,292

*Existing equipment could be utilized.

**Personnel salaries were averaged at $11,000 per year to allow for differences in salaries and benefits, and assume 5 paid firemen/dispatchers.

***See Chapter VI.

+Includes 7 different base stations -- transmitters and receivers, 3 monitoring channels, head sets, log recorders, furniture.

++Includes spot light kits, card -- Panel to activate lights.

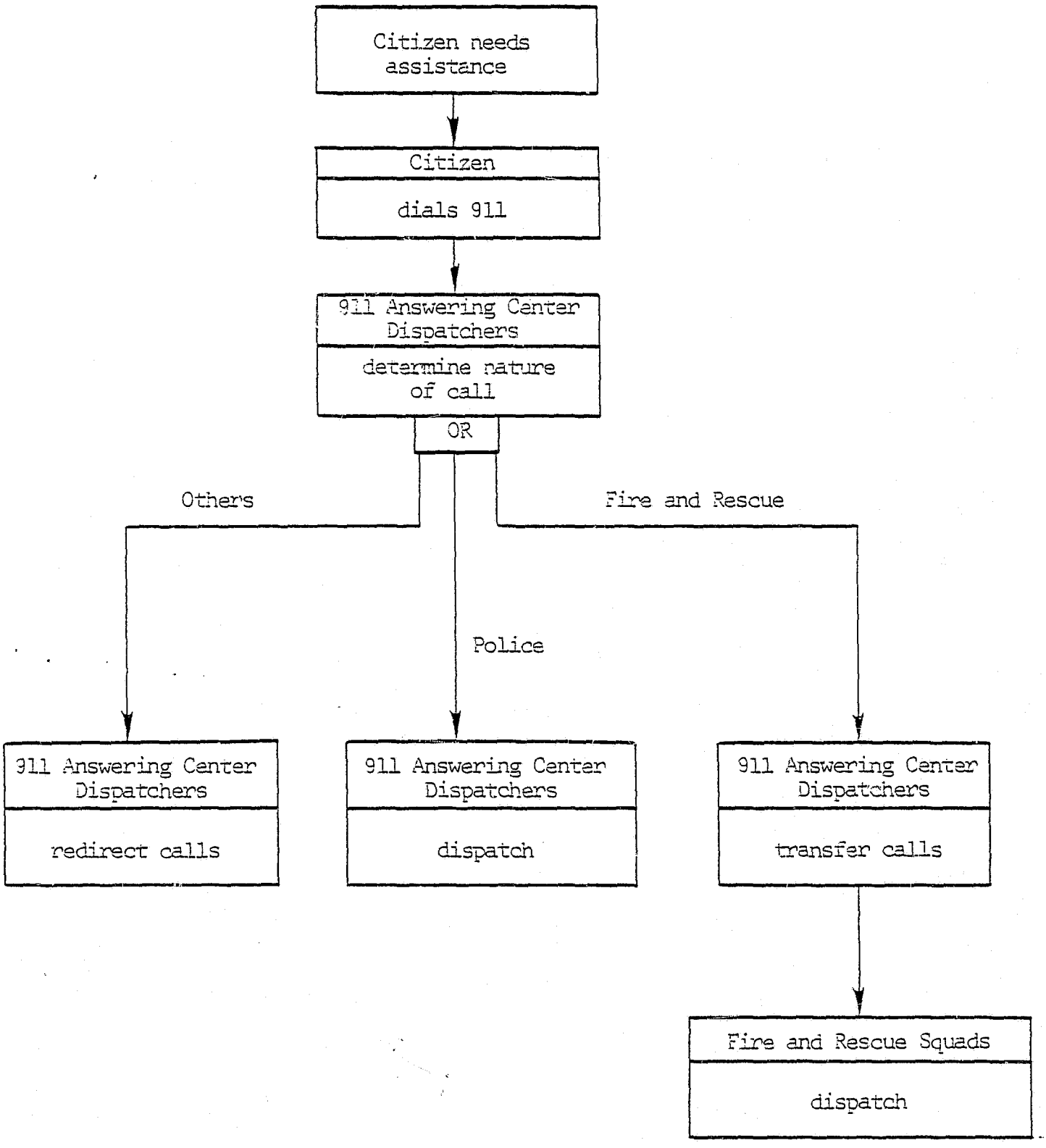


Figure 12 Alternative #5 - 911 - Direct Police Dispatch and call transfer for other agencies.

Table 8

Alternative #5 - System Costs

Item	Number	Average Monthly Costs (approx.)	Initial Costs (approx.)
Incoming lines	10	$ 505	$ 230
Outgoing lines	10	60	190
Administrative	3	136	60
Telephone boards	4	260	612
Radio consoles +	4	--	68,800
Status maps ++	1	--	11,400
Tape recorders*	1	--	--
Terminal equipment*	1	--	--
Log recorders	4	--	--
Dispatch personnel**	12	$12,833	--
Administrator	1		--
Secretary	1		--
Building***	--	--	--
TOTAL	--	$13,794	$81,292

*Existing equipment could be utilized.

**Personnel salaries were averaged at $11,000 per year to allow for differences in salaries and benefits, and it was assumed there would be 5 paid firemen/dispatchers.

***See Chapter VI.

+,++See Table 7.

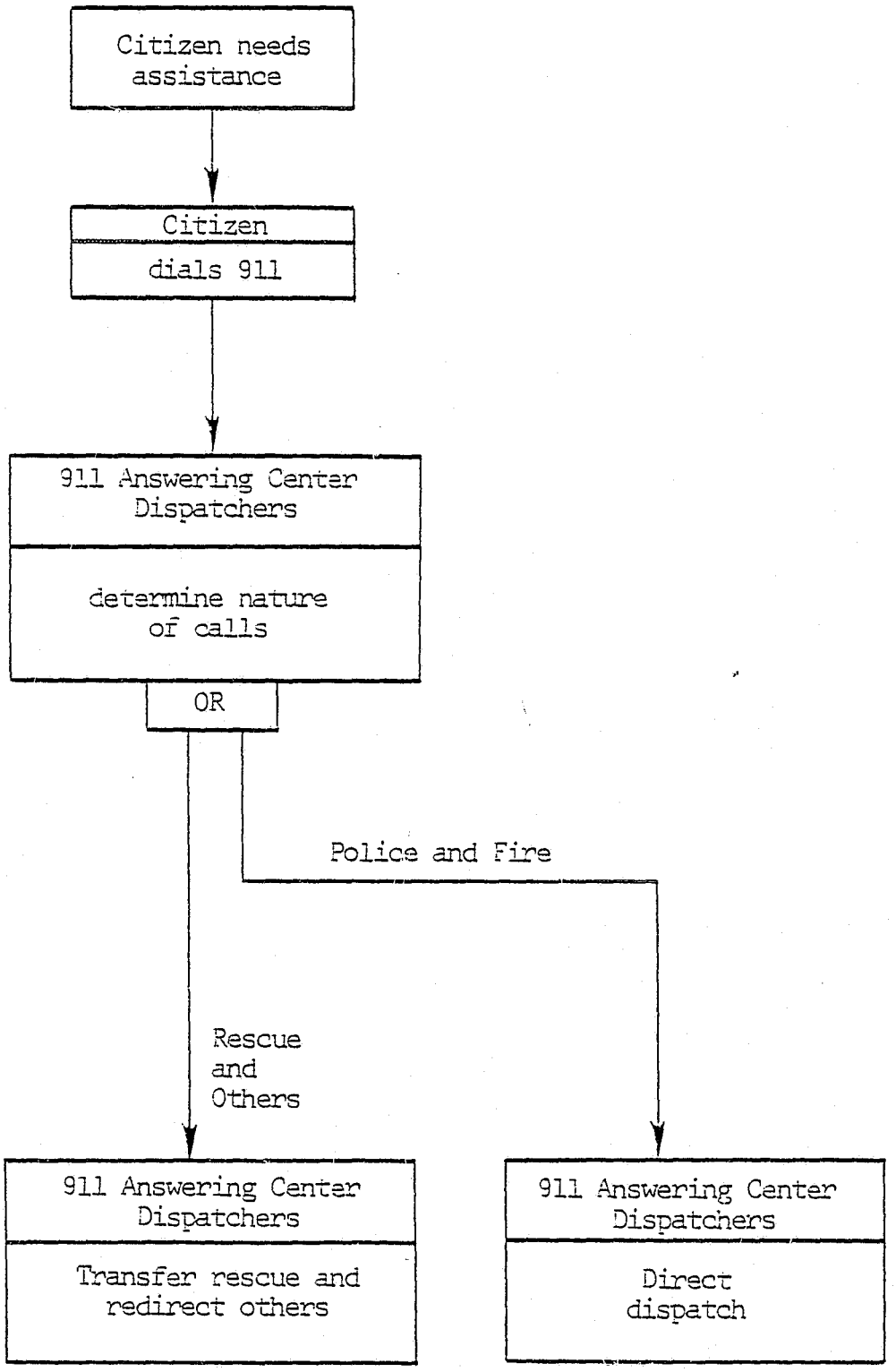


Figure 13(a) Alternative #6 - 911 - Multipurpose Dispatch

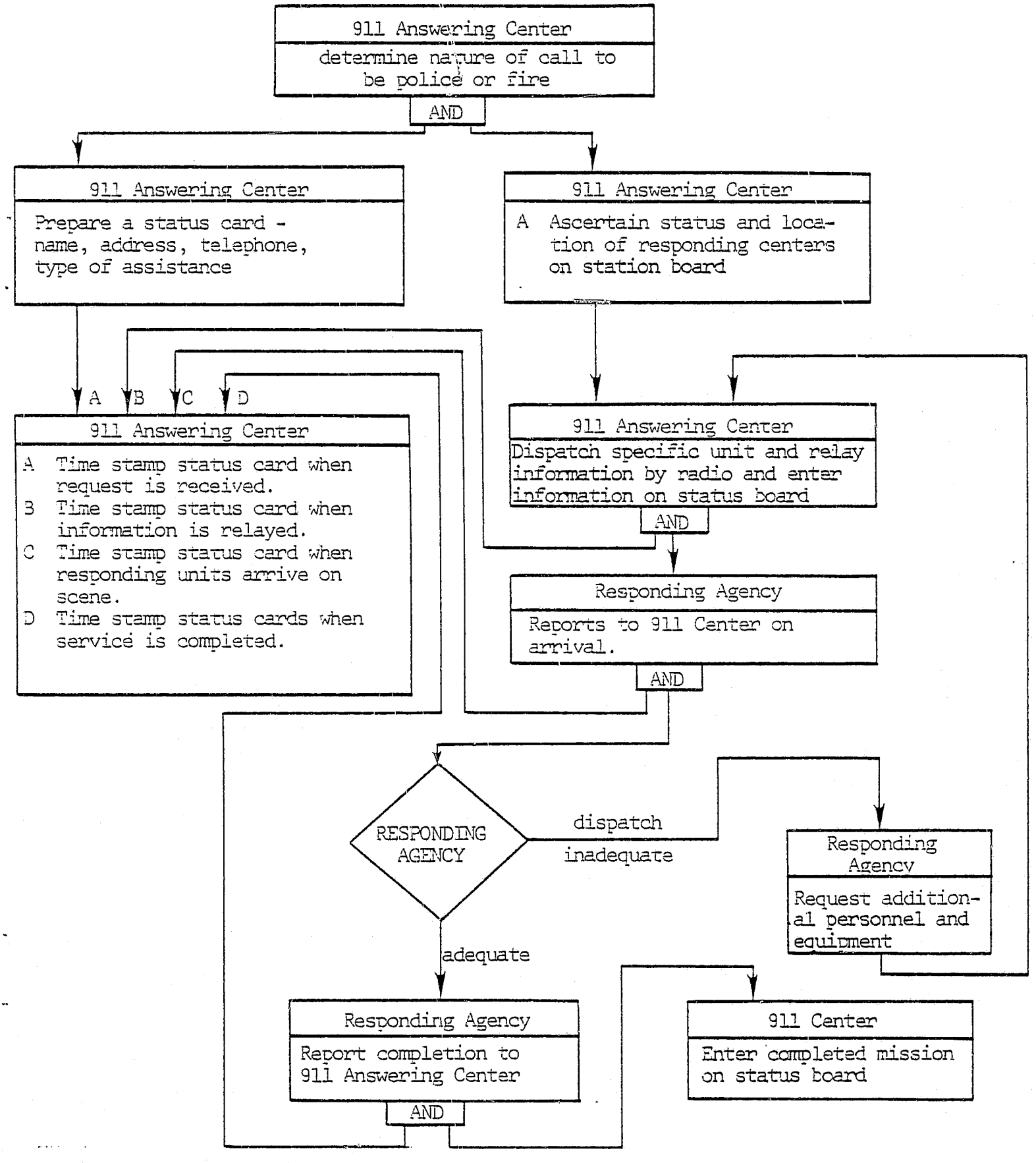


Figure 13(b) Direct Dispatch for Alternative #6 - 911 - Multipurpose Dispatch

V. SYSTEM DEVELOPMENT

In this chapter, we attempt to estimate call volumes, telephone lines and personnel requirements consistent with certain design objectives. These design objectives are:

(a) To ensure that no more than one call in every hundred receives a busy signal during the busiest hour.

(b) To ensure that less than ten percent of all busy hour calls are answered with delays greater than ten seconds.

The first objective ensures adequate system capacity while the second ensures adequate personnel to provide an improved level of service.

A. Traffic Analysis

The purpose of a traffic analysis or call-volume study is to ascertain the number of lines and personnel required to provide a satisfactory grade of service. The term 'grade of service' is used to define a probability factor which expresses the likelihood of a person's receiving a busy signal when a particular number is dialed. Usually a P:01 grade of service is deemed satisfactory. This can be interpreted to mean that no more than one (1) call in every hundred (100) is likely to receive a busy signal during the busiest hour.

Call volume in a 911 center is a function of the population which expresses the demand for emergency services. In addition, it is a function of the number and types of services offered. If 911 is construed as an emergency number to be dialed only when on-scene assistance is required, then the call volume at such a center can be reasonably approximated at one-third (1/3) to one quarter (1/4) of the existing call volume to the police agencies which are likely to receive between 75 and 85 percent of the total calls.

1. Call Volume Estimation

In an effort to estimate a realistic call volume for the Charlottesville/Albemarle area, the following factors were considered:

(a) Population.

(b) Proposed implementation date.

(c) Growth in demand for services.

(d) Nuisance calls.

(e) Services included.

A traffic study conducted by CENTEL (Central Telephone Company of Virginia) for a three-day period (June 17, 18, and 21, 1976) on incoming calls to the emergency numbers listed for Fire, Police and Rescue during the hours from 8 a.m. to 5 p.m. indicated that the busiest hour appears to be between 9 and 10 a.m., with about 20% of the total volume (nine hours) occurring during that hour (see Figure 14). The total number of calls during this hour was approximately 84. These calls include requests for on-scene assistance, information, reports, multiple calls on the same incident and calls for other agencies. The call distribution is nearly uniform at 64 calls per hour.

The existing population in the Charlottesville/Albemarle area is approximately 80,000. Assuming a call volume of 2.5 calls for 1,000 people with 25% occurring during the busiest hour, we have a call volume of about 50 calls per hour. By 1980, the estimated population will be approximately 86,000, therefore call volume will be approximately 54 calls. Assuming an additional 10% of the total calls during the busiest hour is included to account for nuisance calls, we have a busy hour call volume of approximately 59 calls. Further, assuming an additional 10% (e.g. snow

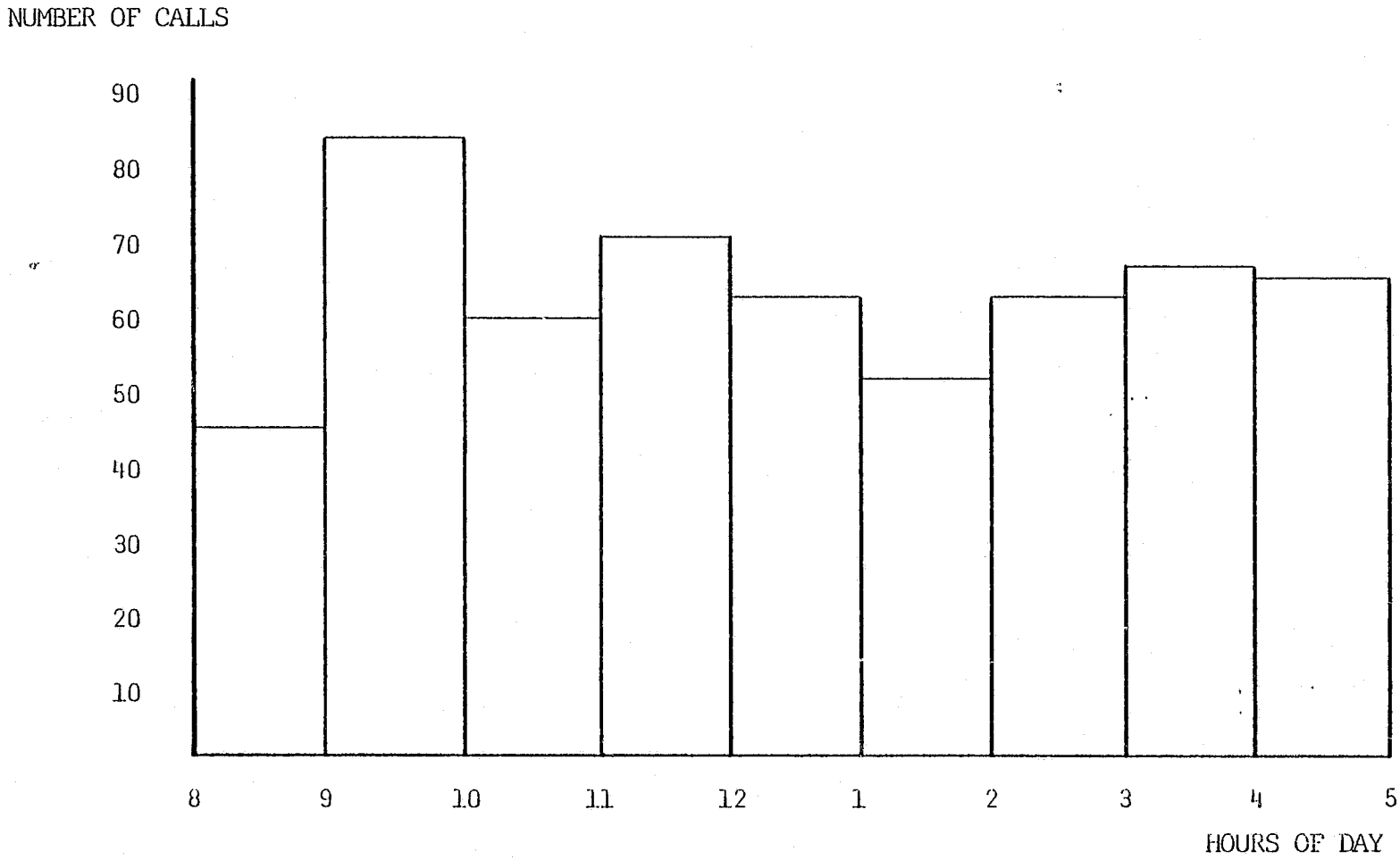


Figure 14 Average Calls - 3-Day Period (Police, Fire, Rescue)

storms, power failures, etc.) we have a call volume of 65 calls per hour.

This call volume appears to be reasonable from a demand-for-service viewpoint, and will be used together with other important factors such as the flatness of the call distribution (Figure 14) and the distribution of calls after 5 p.m. for estimation of lines and personnel.

2. Required Telephone Lines

There are basically two types of incoming communication lines to a 911 center: direct lines and tandem lines. These lines are necessary to facilitate public access and service delivery.

With direct lines, the 911 center would have to lease a number of lines between each CO (Central Office) and the 911 center. These lines would be designed to accept only 911 calls. In the Charlottesville/Albemarle area, there are eleven (11) central offices. This would mean that a minimum of 2 or 3 lines would have to be leased from each central office. Thus, some 33 lines would be required. It should be noted that if three (3) lines are made available in one CO area, then a person requiring service in that area has only three (3) lines available for reporting the emergency and not thirty-three (33). The main advantage of using direct lines lies in the ability of the 911 center operators to ascertain the area from which the call originates.

With tandem lines, the 911 center would have to lease a number of lines between one CO and the 911 center. These lines would not be dedicated, rather, they would be carrying regular traffic. Thus, if there are fifteen (15) incoming lines to the 911 center, a person requiring service anywhere in the City/County will have fifteen (15) lines available for use in reporting the emergency.

The cost of providing direct lines is substantially greater than that associated with tandem lines by virtue of the fact that they are more expensive, a greater number of lines is required, and the cost of lines represent a monthly recurring cost.

We, therefore, recommend the use of tandem lines. However, the use of direct lines is recommended for areas where the telephone exchange boundary does not permit the use of tandem lines or where operational efficiency is enchanced by their use.

3. Incoming Lines Estimation

In order to estimate the number of incoming lines required for the communications center, the following assumptions were made:

(a) Busy hour call volume is approximately 65 calls, and

(b) Dispatch is made while calling party is on the line, so that total answering and dispatch time approximates average holding time. Based on observations and interviews, we estimate this as 90 seconds.

Queuing models are generally employed to estimate the number of lines required such that a particular grade of service can be maintained. To estimate the number of lines required to provide a P.01 grade of service, the requirement is converted into a determined number of hundred call-seconds (CCS). The formula for this computation is [14].

$$CCS = \frac{(\text{No. of busy hour calls})(\text{Average call length in seconds})}{100}$$

Having calculated the CCS, this value was then input to a standard telephone trunk capacity table which lists the required number of lines for a particular grade of service and a given CCS. This table [20] indicates that for a CCS between 46.1 and 64.4, six lines would be

CONTINUED

1 OF 2

Table 9

Total Incoming Lines

Description	Number of Lines	Type of Lines
Based on call volume analysis for the immediate Charlottesville/Albemarle area	6	Tandem
Greenwood exchange	2	Direct
Growth and faulty assumptions	2	Tandem
	10	

Table 10

Total Outgoing Lines

Description	Number of Lines	Direct	Tandem
Nelson County 911 center *	1	✓	
Fluvanna County 911 center *	1	✓	
Green County 911 center *	1	✓	
Scottsville Fire Department *	1	✓	
Buckingham Sheriff's Office *	1	✓	
University of Virginia Hospital (emergency room, psychiatric ward)	2	✓	
Martha Jefferson Hospital (emergency room)	1	✓	
Charlottesville/Albemarle Rescue Squad	2	✓	
Charlottesville Fire Department	2	✓	
Charlottesville Police	1	✓	
University Police	1	✓	
County Sheriff	1	✓	
Administrative	3		✓

* As indicated in Chapter II, these lines may be eliminated with little performance lost as radio service will be available. Considerable cost savings will result and, as indicated in Chapter II this is recommended.

required to provide a P.01 grade of service. The actual CCS computed from our assumptions is 58.5. Thus, six lines are an appropriate number under assumed conditions to insure that no more than one of a hundred incoming calls receive a busy signal during the busiest hour.

4. Outgoing Lines Estimation

Outgoing lines serve a variety of functions, depending primarily on the operating characteristics and number of agencies associated with the 911 center. Private or direct lines are needed to transfer callers to the appropriate jurisdiction in the case of boundary mismatch problems. These lines are also necessary to access the various dispatch services (depending on operational methods) and serve as a means of coordinating the activities or various jurisdictions in the case of common emergencies. In addition, a number of administrative lines must be provided. A description of the type of outgoing lines required for Alternative #5 or #6 is of particular interest here.

Direct lines connecting the 911 center and police agencies are recommended to allow direct exchange of telephone requests for emergency dispatch. Thus, an emergency call directed to a police agency could be switched to the 911 center for other dispatch purposes. To provide this capability, the telephone company would need to modify switching equipment in the police agencies.

Additional switching capability should also be installed to permit all emergency calls to be rerouted to the 911 center at night, on weekends, or at other times when police agencies have no available operators.

B. Personnel Requirement Estimates

The number of operators required for the 911 system depends to a large extent on the same variables used in the estimation of incoming lines,

but more importantly on the functions and responsibilities of the 911 operators. In estimating personnel requirements, a queuing model was employed to determine the number of dispatchers needed during the busiest hour such that no more than 10 percent of the total calls originating in the busiest hours would be delayed more than 10 seconds. The formula for this computation utilizes the following Poisson queuing theory equation[13].

$$P(>t) = \frac{\left(\frac{\lambda}{u}\right)^c}{c!\left(1 - \frac{\lambda}{cu}\right)} \cdot \frac{1}{\sum_{n=0}^{n=c-1} \frac{\left(\frac{\lambda}{u}\right)^u}{n!} + \frac{\left(\frac{\lambda}{u}\right)^c}{c!\left(1 - \frac{\lambda}{cu}\right)}} \cdot e^{-(c - \lambda/u)t/t_a}$$

where $P(>t)$ = the probability of a 911 customer having to wait longer than time, t, with all dispatchers busy

u = number of service completions in busy hour

c = number of dispatchers

λ = number of calls in the busy hour

t_a = average holding time

Estimation of this equation indicates that 4 dispatchers will be required during the busiest hour. This analysis indicates that only 7.9 percent (approximately 4 calls) will be delayed greater than 10 seconds and the average delay time for all calls will be 3.9 seconds (approximately 1 ring) during the busiest hour using 4 operator dispatchers.

The operating personnel required depends on call volume distribution throughout the entire day. Traffic studies provided by CENTEL indicate the Charlottesville Police Department received an average of 72 calls between the hours of 5 p.m. and 8 a.m. on August 25 and 28. This is representative of typical call volume and approximates five calls per hour. Assuming the same call distribution for the other police and fire agencies, we have

approximately 20 calls per hour necessitating no more than two personnel. Since Charlottesville Police call volume is by far greater than any other emergency service agency, it is clear that two personnel on duty at any given time should be fully adequate for any but extreme disaster situations.

Therefore, with three (3) eight hour shifts, personnel requirements may be computed for 4 on duty personnel from 8 a.m. to 5 p.m. Monday through Friday and two personnel on duty at all other times. Smooth operation must be maintained seven (7) days a week on a twenty-four (24) hour basis.

There are two dimensions to personnel requirements:

(a) The number of personnel necessitated by call volume, and

(b) The number of personnel necessitated by efficient management principles.

We assume a 40-hour work week. The total dispatch people hours should be increased by 15% to 20% such that minimum dispatch force of 12 people is required. Thus, on any particular day, 8 dispatchers will be required with 4 available for swing shifts, sick leave, vacation relief and other contingencies.

In order to efficiently execute the functions of a 911 communications system employing 12 dispatchers, a communications administrator position should be made available with a secretarial position. This brings the total employment force to 14 personnel. This is actually somewhat high due to the performance criteria which indicates that only 4 calls during the busiest hour will have a waiting time greater than four seconds. Also we are using a rather large call volume that will probably not be realized. Thus 14 total personnel for a 911 center should be a very ample number indeed. Particularly during initial start up of 911 service it would be beneficial to err on the side of too many personnel rather than too few, especially since start up difficulties and public acceptance requirements are so interrelated.

VI. SYSTEM EVALUATION

In this chapter, we attempt to summarize the costs and benefits associated with the alternatives presented. Source of funding together with location considerations are discussed.

A. Cost Benefit Comparisons

1. Personnel

Personnel requirements indicated in Table 11 show that labor is the single most costly factor in the establishment of an emergency communications center. Alternative #5 costs approximately $12,833 per month as compared to Alternative #1, which costs approximately $10,562 per month. However, it should be noted that:

(a) Average salary assumed in Alternative #5 is $916/month as opposed to $621/month for Alternative #1. This higher salary was based on a realistic number necessary to attract and maintain personnel of the calibre necessary for emergency communications dispatch functions.

(b) The total number of dispatch personnel employed in Alternative #5 is 14 as opposed to 17 for Alternative #1.

(c) The design capacity of Alternative #5 (14 personnel) was based on 1980 requirements (likely implementation time). At such time, the total personnel force for Alternative #1, according to our estimates, will be between 21 and 23 at a minimum.

2. Telephone Costs

In order to implement Alternative #5, an additional monthly telephone cost of approximately $1,000 will be required (see Table 11), the total monthly cost being $1,586. This cost is relatively substantial but necessary in view of the fact that the existing telephone communications system cannot be discontinued immediately. The various agencies will still retain their respective members for administrative and possible emergency functions. However, as the system becomes operational and gains public

Table 11

Summary of Estimated Costs for Alternatives

Alternative	Personnel, per month	Dispatch Equipment	Building	Telephone Equipment		Total	
				Initial	Monthly	Initial	Annual
1	$10,562	--	--	--	$ 625	--	$134,244
2	13,562	--	--	$ 826	1,450	$ 826	181,344
3	13,526	--	--	826	1,450	826	181,344
4	17,416	80,200	--	1,092	1,611	81,292	229,524
5	12,833	80,200	--	1,092	1,586	81,292	173,228
6	12,833	80,200	--	1,092	1,586	81,292	173,228

acceptance, this cost can be reduced by at least 20 percent. In assessing the benefits associated with incurring the additional cost, it should be noted that:

(a) Alternative #5 presents a system with increased capacity. Presently, the County Sheriff's telephone facilities are inadequate based on a traffic study conducted by Centel for the three day period, June 17, 18 and 21. This study indicates that 2 additional lines are required to provide a P.01 grade of service which should be accepted as a minimum.

(b) Alternative #5 presents a system with new and improved features - call party hold, forced disconnect, conference calls, etc.

3. Radio Equipment Costs

Field trips and consultations with radio communications experts and consultants suggest that the existing radio communication facilities at the various police agencies cannot be easily adapted to centralized dispatching. This is due to the fact that:

(a) The existing equipment at police agencies are too diversified and different to consolidate and interface.

(b) Equipment providing greater capability, flexibility and reliability can be acquired and would enhance present operations.

Also, existing police agencies, with centralized or consolidated dispatch, will need some ability, independent of the 911 system, to communicate with their respective field agents. By keeping the existing radio equipment intact, this capability will be preserved.

We, therefore, recommend that a new radio communications system be acquired for use in the consolidated or central dispatch center. The costs estimated for radio communication are based on General Electric Services 2500 Command Control Consoles. These consoles provide a variety of features and options which are particularly appropriate for consolidated dispatch.

The actual cost of radio equipment is based on:

(i) The number of channels,

(ii) The number of operating positions,

(iii) The volume of calls, and

(iv) The variety of special options.

In our analysis of radio equipment costs, we include the cost of all other equipment associated with dispatching functions since potential funds are available for their acquisition.

4. Source of Funds for Dispatching Equipment

The Law Enforcement Assistance Administration (LEAA) often provides funding to communities establishing centralized or consolidated dispatch functions. These funds, however, are generally limited to the acquisition of radio and related dispatch equipment and do not provide for any operating or maintenance cost. The base of funding is 90 percent from LEAA, 5 percent from State and 5 percent from local sources.

In order to obtain these funds, the following procedure should be initiated:

(a) The consolidated dispatch center project must be identified as a priority project in the Local Planning District Commission Plans.

(b) This project must be incorporated into the State of Virginia's Comprehensive Plans.

(c) A proposal must be submitted to LEAA requesting the required funds.

If the City of Charlottesville, the University of Virginia, and Albemarle County decide on a consolidated dispatch center (and fulfill requirements of the crime control act of 1973 for funding) it is our recommendation that funding requests be made. Likelihood of funding may be enhanced by

the fact that this community will be the first in the State of Virginia to demonstrate consolidated dispatch between city and county.

B. Location Considerations

The space requirements for an emergency communications center vary with the functions and purposes for which the center is intended. For example, Alternatives #2 and #3 require considerably less space than Alternatives #4 and #5.

Typical space requirements [14] for Alternatives #4 or #5 are:

	Approx. Area (sq. ft.)
· 911 Operators	220
· Administrator's Room (office and conference)	400
· Rest and Locker Rooms	100
· Operations Store Room	200
· Equipment - tape recorder, terminal, logging records, etc.	60
· Telephone company equipment	150
· Heating and air-conditioning room	70
· Generator Room	100
· Miscellaneous Space	100
	1,400 sq. ft.

Our study has not included independent analysis of detailed space needs, but we believe that the total area is adequate for purposes of the investigation. In evaluating potential locations for an emergency communication center, the following considerations would appear to be particularly important:

· The existence of adequate space for expansion.

· The accessibility of the location.

- The attitudes of responding agencies to specific locations.
- The cost of constructing a new facility or renovating an existing one.
- Long-range plans for future construction investments.

1. Alternative A - Constructing a New Facility

The cost of constructing a new facility typically ranges between $36 and $40 per square foot*. This cost does not include utility and telephone connections, equipment, furniture, land, etc. A new facility for the purpose of emergency communications would be appealing:

(a) If the City of Charlottesville or Albemarle County has immediate or intermediate plans for construction investments; and

(b) If the concept of an EOC (Emergency Operations Center) is appealing.

An emergency operations center is basically a facility which provides adequate space, equipment and special features to protect, mobilize and co-ordinate resources in cases of national and local disasters. As such, the center requires emergency power, emergency water supply, protection against radiological fallout for at least 100 persons, heavy security, living accommodations and other special features as described in Appendix I. Fifty (50) percent of the cost for constructing an EOC is generally borne by the Federal Government. These costs range from $50 to $58 per square foot [15]. This could mean that the cost to the City, County and University would range from $25 to $28 per square foot.

The University Police Department is presently in the process of expanding their operations and have sizable commitments for new construction.

*This is somewhat higher than existing prices in the Charlottesville area for basic construction, but nonetheless, realistic for planning purposes. These are our best estimates of likely minimum costs around 1980.

However, to obtain matching federal funding for communications, the title to the facility must be owned by the City or County. Alternatively, federal funding could be provided in the event that the facility will be used as a regional E. O. C.

Should this alternative be attractive, federal funds are available for feasibility and cost studies. Requests can be made through the Office of the Emergency Services Co-ordinator in the City. The space requirements for such a center are considerably greater than those provided here and a reasonable approximation of the County and City's cost in such a venture would probably be a figure in excess of $200,000 based on a report by Ronny W. Dower, Civil Defense Co-ordinator [15].

2. Alternative B - Conversion of an Existing Building

The cost of renovating an existing facility to house emergency communication operations ranges from about 20 to 90 percent of the cost of constructing a new facility. The exact percentage depends on the existing facility in terms of structure, lay-out, utilities available, demolition requirements, etc.

In estimating the space requirements for emergency communications, we have allowed some 400 square feet for use in the event of local or national disasters. Depending on the alternative selected, however, spatial requirements and cost of renovating may be negligible or considerable. For example, System Alternative #2, described in Chapter IV, requires only about 100 square feet to accommodate operators and equipment with other support space being provided in the existing building. Alternative #5, on the other hand, requires minimum specifications of 1,400 square feet.

(a) Option 1. Conversion of Charlottesville Police Department Basement.

The conversion of a basement would involve a greater capital outlay than, say, the conversion of a few offices. The basement of the Charlottesville Police Department is large enough to house the emergency communications operations and meet the special requirements of even an EOC.

The cost of conversion, assuming 50% of the cost of constructing 1,400 square feet, lies in the vicinity of $25,000 to $28,000. Use of this location for emergency communications would facilitate:

- A gradual upgrading of communications facility to an EOC facility should this be desirable in the future.
- A great degree of security.
- Easy accessibility (City, County, University)
- A "back-up" personnel force in the case of disaster or unforeseen overloads on the system.
- Confidence and trust among agencies (officials) with respect to location.

(b) Option 2. Conversion of any City or County Building.

The cost of converting an existing building to house emergency communication operations would be relatively cheaper than conversion of the police basement, and should be examined in the event that the City or County is presently underutilizing any of its existing facility resources, for example, the City Courthouse Building.

It is suggested that a construction firm be engaged to provide comparative cost analyses for the conversion of three or four such facilities. However, such comparative analyses should be judiciously weighed against the special advantages related to accessibility, security, the EOC concept, etc.

VII. DECISION MAKING

In this chapter we draw together the analyses and ideas that have been presented thus far.

Decision-making in the public sector is a complex process for two reasons: first, many public decisions involve capital investment, and second, the process has many participants whose support and whose substantive contributions are needed.

Figure 15 shows a highly simplified sketch of policy and decision-making roles and of the types of "actors" who play them. A decision process may actually be initiated by any of the major actors (citizens, administrators, or legislators) who perceive needs in the society. However, to describe the process, we can assume that citizens have felt needs which they express, openly, and usually to officials with whom they have direct contact. Here, we postulate that direct contact with administrative agencies provides a ready channel for expressing the felt needs. The problem may be described in highly articulate ways or it may be extremely vague.

The decision process moves ahead as the agency sharpens issues from citizen expressions and translates expressed needs into alternative courses of action in accord with the expressed needs, variables over which the society has some control, and the invariable constraints. Agency mandates require practical proposals which are in accord with social, political, economic and physical environments. When several agencies are involved in a decision, their different perceptions of the situation must be credited so the decision most nearly addresses the

community needs. If, in addition, the decision requires increased operating interactions among the agencies, a high level of cooperation and mutual support must be achieved during the decision process.

In our postulated structure, the agency administrators play a major role as they choose an appropriate course of action for recommendation to the elected legislative bodies. We postulate that they produce a viable recommendation that is suitably drawn for enactment by the legislative bodies. In a small municipal setting, this postulation is appropriate because legislators have no technical staff other than their agency chiefs. We postulate that the agency chiefs, working together, can address the technical and operational issues, and that they can largely anticipate the political issues that must be addressed.

In this postulation, the legislators are responsible for responding to the recommended courses of action. In the simplest case, this task is one of "implementing" the recommendations by enacting legislation and appropriating funds. In the actual case, this oversimplified view of legislative roles is characterized by a process of review, modification and adaptation that is as complex as is that of agency chiefs. Nevertheless, their main role is one of review, perfection, and enactment, as contrasted to the role of generating recommendations and programs. Ultimately, the actions of legislators are subject to the scrutiny of citizens, both during deliberations over legislation (i.e., public hearings) and in the general tone of government (i.e., future elections). In this sense, the citizens are ultimate decision-makers through their expressions of satisfaction or dissatisfaction.

As shown in Figure 15, the role of the analyst is to facilitate the work of agency chiefs as they develop a proposal for the legislative bodies. The analyst assists by drawing from an array of tools and techniques such as cost benefit analysis, decision analysis and the like. The analysts' objective is to present a rational framework in which each participant can describe his or her values to other participants in order to ascertain magnitude of disagreement on specific items. Various tools and techniques can be used to evaluate both quantitative and qualitative problem elements to help facilitate the decision-process.

The analysts are not decision-makers. Their task is to reflect back the views of many actors in a consensus-development setting.

In conducting this study, we have attempted to use a methodology designed to offer a model for community decision making processes and even though this study has itself involved only a limited number of actors (analysts, agency officials, administrators), it represents a necessary link in the total community decision-making process as to whether an emergency communications system should be implemented, and if implemented, what safeguards are needed to assure the necessary support to achieve stated objectives.

A. The Decision Problem

The logical starting point for any decision process is at the objective step. Hopefully, decisions will enable the realization of some specific objectives. However, invariably, objectives are in conflict with each other. Some may be perceived as being more important than

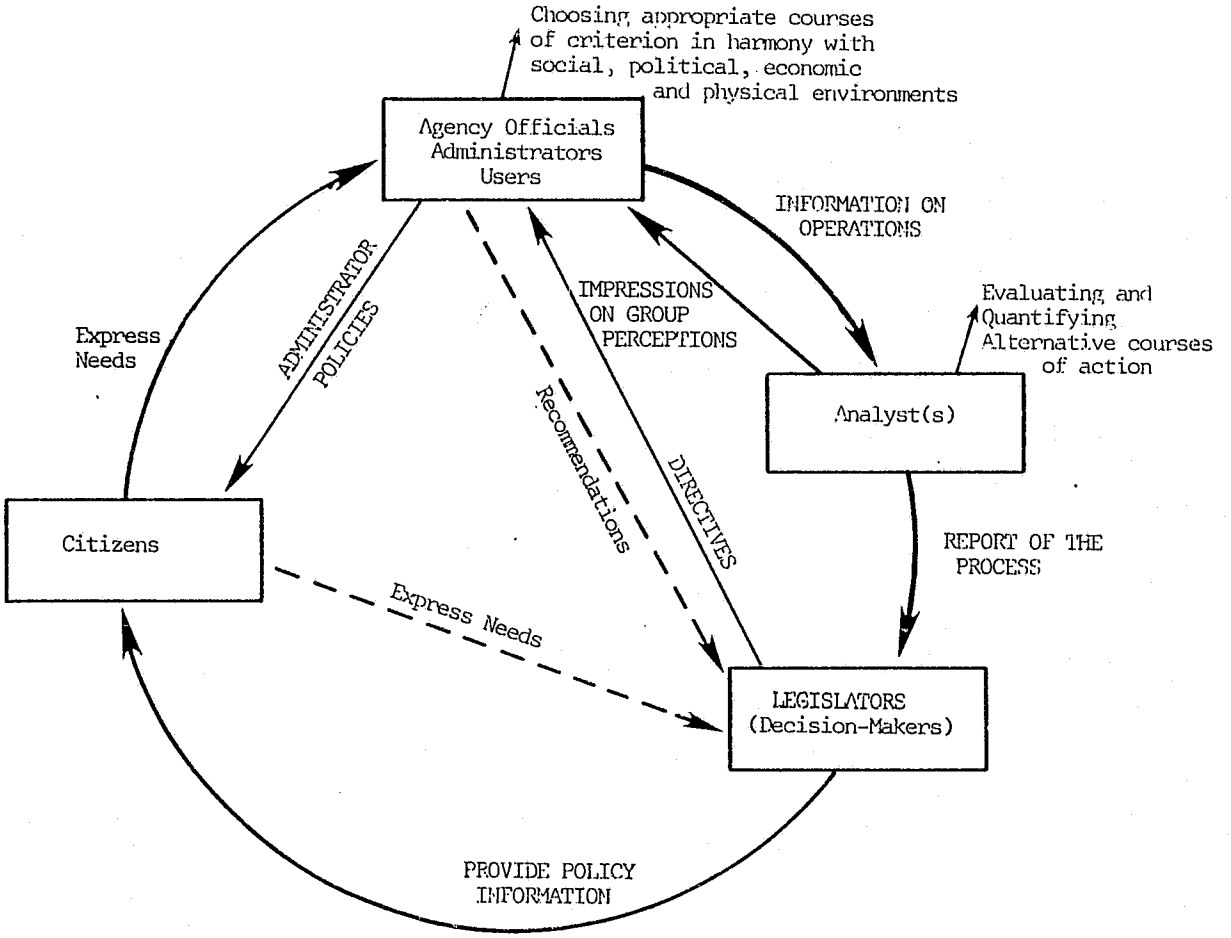


Figure 15 Policy Formulation Scenario

others. Indeed, some may well be unattainable within the existing political, social and economic environments. The decision problem may be stated as follows:

> "How does a group of legislators and decision-makers choose a common course of action within the existing social, economic and political environments in order to best achieve a set of stated objectives?"

3. Interpretive Structural Modeling and Worth Assessment

Interpretive structural modeling is a technique for developing a hierarchy of elements by means of some contextual relationship [16, 18]. It can be used for example to answer related questions among the problem definition, value system design and system synthesis elements in a problem. Worth assessment, on the other hand, is a formal procedure for determining preferences among alternatives when these alternatives must satisfy a variety of objectives. Worth scores are determined for attributes of an alternative or consequence. These are combined to produce an overall worth score for each alternative. Worth assessment was accomplished through the following specific activities:

(a) Each agency official was requested to review his or her agency's operation to identify characteristics of that operation which would be sensitive to changes in the emergency communication system.

(b) These concerns were then shared with other agency officials in open meetings and with the study team in interviews.

(c) Each agency official was then given the opportunity to examine interactions of each agency with others in order to establish a community perspective on adequacy and needs of present operating systems, and

(d) Each agency official was requested to review the probable enhancing and inhibiting impacts of a centralized communications system on existing agency operations. This task involved two stages:

(i) Review of alternative modes of operation, and

(ii) Review of initial plans developed by the study team based on first-round responses.

Intrepretative structural modeling and worth assessment can be divided into the following major activities for policy analysis purposes and follows the general procedure outlined by Farris and Sage [17].

1. List the Overall Performance Objectives

Performance objectives must be established which are mutually exclusive so that no objective encompasses (definitionally) any other objective. These objectives should also be worth independent so that the decision-maker is willing to trade partial satisfaction of one objective for reduced satisfaction of another without regard for the level attained by either. This task was accomplished through several personal meetings, discussions and presentations with the Project Review Committee.

List of Overall Performance Objectives

1. To meet national objective of a single emergency number.
2. To facilitate easy citizen access.
3. To co-ordinate existing resources.
4. To provide service at a reasonable cost.
5. To improve the level of service.
6. To improve emergency communications and administration of services. (Implies savings in life and property).
7. To enable coin-free dialing.
8. To maintain the authority of the responding agencies.

9. To minimize disruption of existing services.

10. To reduce confusion in notifying appropriate agencies.

11. To provide for growth in emergency communications requirements.

2. Construct a Hierarchy of Performance Criteria

Having developed a list of performance objectives and corresponding attributes, it is necessary to develop a tree-type hierarchy indicating the various levels of importance among objectives. This hierarchy is intended to provide decision-makers with a conscious, well-defined and easily articulated form for evaluating the decision problem. Interpretative structural modeling utilizing the contextural relation,

"the lower level objective is intended by, included within the meaning of, or an integral part of the higher level objective"

was the relation used by the research team to develop Figure 16.

3. Select Appropriate Physical Performance Measures

Having declared a hierarchy, it is necessary to establish some physical characteristics of performance. Figure 17 describes these performance characteristics where DWE may be interpreted as a direct worth estimate.

4. Define the Relationship Between Low Level Criterion and Physical Performance Measures

It is now necessary to specify worth relationships for low level criteria. This method of assessing worth is termed a scoring function. By utilizing the following simple rules, members of the Project Review Committee were instructed to use their intuition,

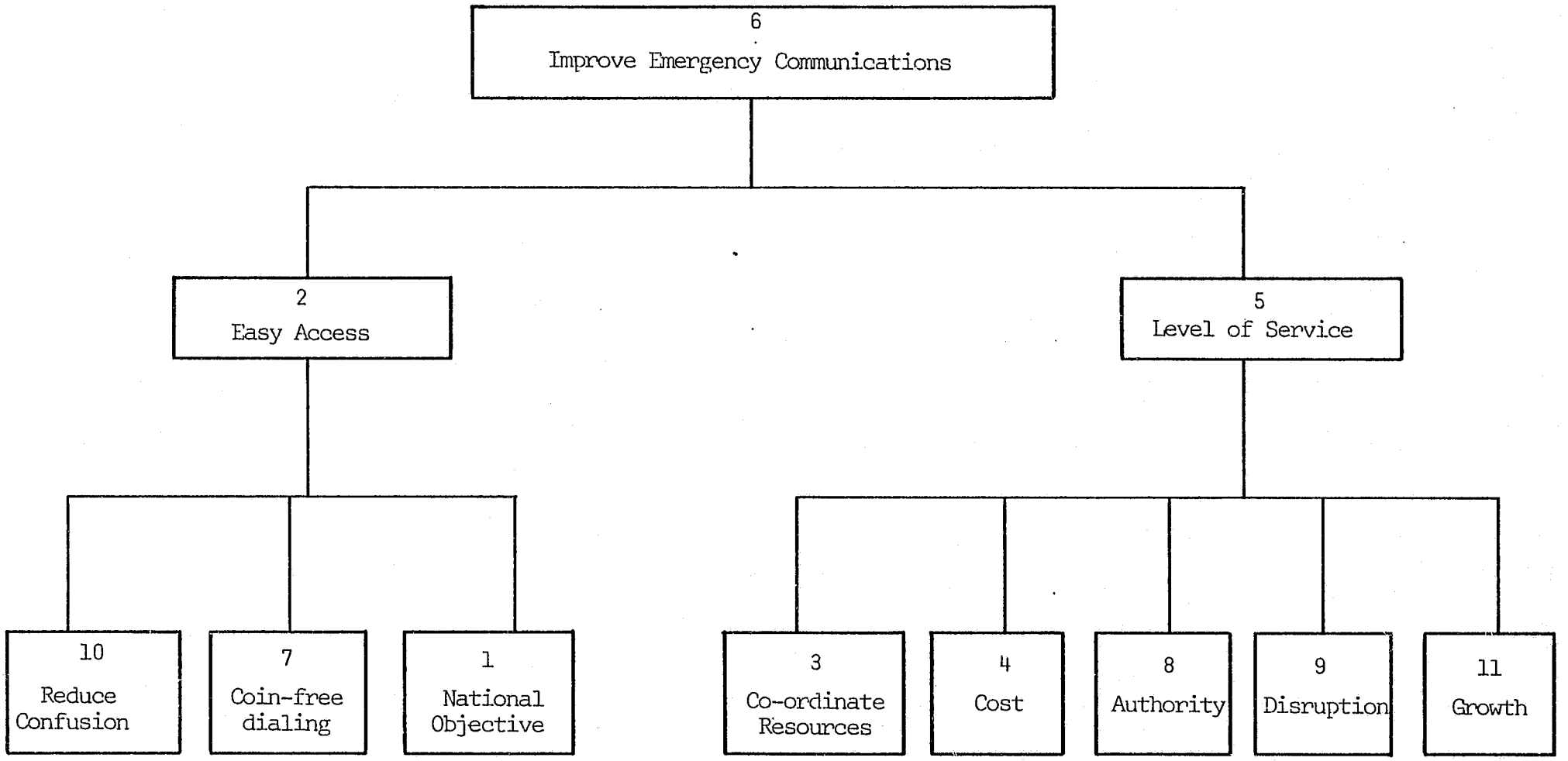


Figure 16 Hierarchical Structure for Objectives

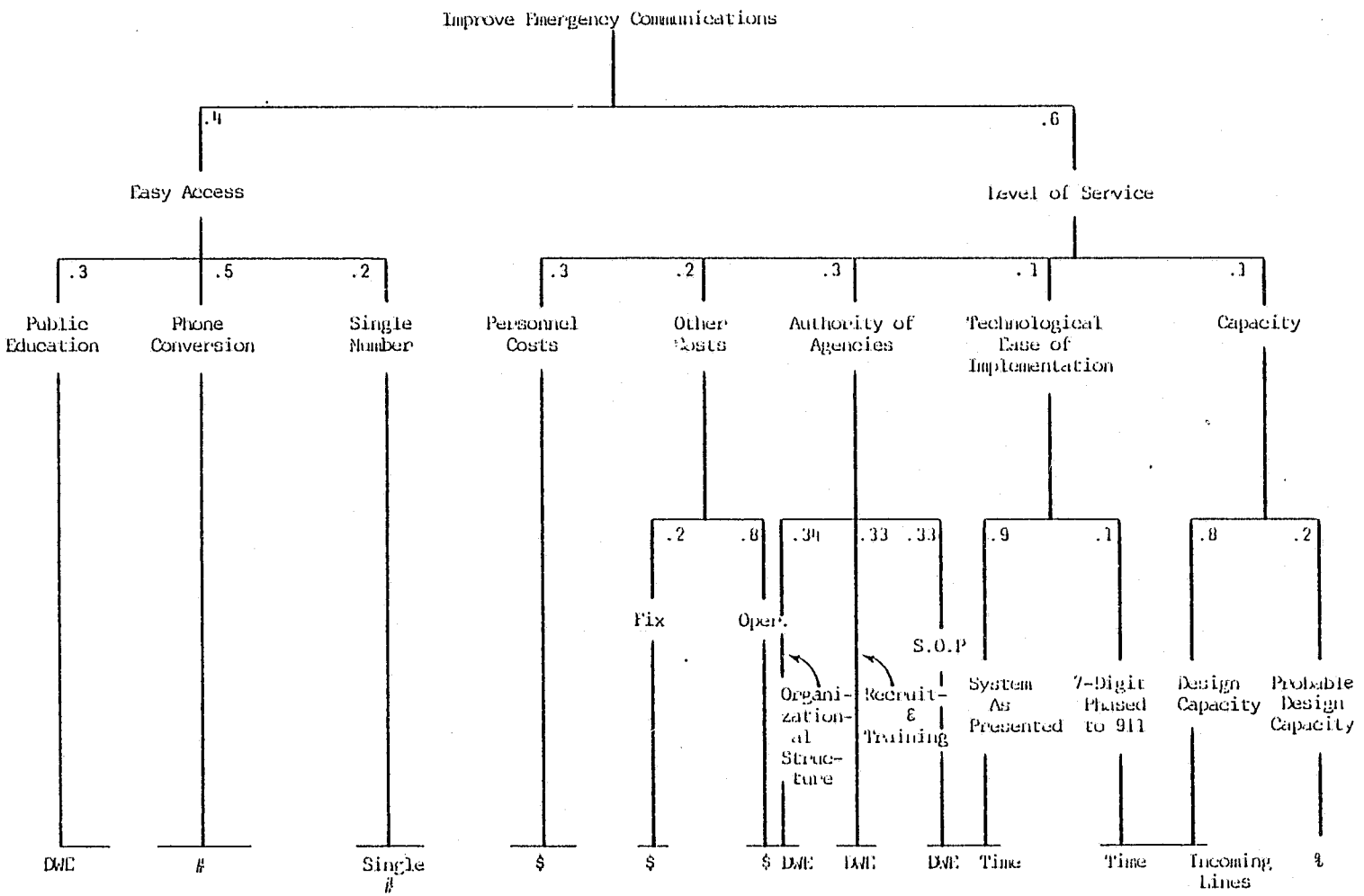


Figure 17 Performance Criteria for Attributes

experience and judgement to assign scores to each criterion. These rules are:

(a) A set is defined to be a collection of elements which lead directly to a higher level element.

(b) The total score for each set is 1.

(c) A number between 0 and 1 is assigned to each element composing a set.

(d) This assignment is based on:

(i) Whether two or more objectives/criteria /measures are assessed as providing the same or different utility in addressing the problem, and

(ii) Whether two or more objectives/criterion/measures are assessed as providing more or less utility in addressing the problem.

This assignment of values was done independently by each member of the Project Review Committee in a two-stage process. In the first stage, members prepared responses in a group-training session. In the second stage, members completed their assignments during interviews with members of the analysis team.

5. Establish Relative Importance Among the Performance Characteristics or Measures

Each performance characteristic or measure must now be scored on a comparative basis utilizing the procedure developed in step 4 above. This was accomplished by the Committee. Figure 17 shows a typical result.

6. Adjustment and Effective Weights

Having completed the five steps listed, the appropriate weights in the hierarchy are then multiplied together to represent an effective weight for each lower level criterion. Often these weights are then adjusted to reflect the degree of confidence placed on the performance

measures. This adjustment was not used here. The results are indicated in Table 12.

7. Assign Direct Worth Scores for Alternatives

Alternatives are now compared to ascertain their "worth" or value in accomplishing the stated criterion measure by possession of the assessed attributes. Members of the Project Review Committee were requested to use their individual evaluations together with the quantative information provided in Table 13 to individually assign scores for each alternative. The results of one assignment are indicated in Table 14. Typical questions enabling such evaluations and comparisons were:

(a) To what extent will each alternative through a public education program enable easier citizen access.

(b) To what extent does each alternative appear to be less burdensome in management and operations.

(c) To what extent does each alternative require extensive and specialized training.

(d) To what extent does personnel increase or decrease associated with each other value affect your choice.

(e) To what extent does fixed and operating costs for each alternative affect your choice.

8. Assign Total Worth Scores

Total scores were then assigned for each alternative by multiplying the individual adjustment weights by direct worth scores and summing to obtain the worth of a given alternative. Table 15 indicates the final total worth scores obtained by one member of the Project Review Committee.

Table 12

Effective Weights for One Individual

Attribute	Effective Weights
Education Program	.12
Pay Phone Conversion	.20
Single Number	.08
Personnel Savings	.18
Fixed Cost	.024
Operating Cost	.096
Organizational Structure	.0612
Recruitment and Training	.0594
Standard Operating Procedures	.0594
Implementation of System as Presented	.054
7-Digit phased to 911	.006
Design Capacity	.048
Probable Max Sustained Overload	.012

Table 13

Worth Assessment Information

Attribute	Achievement of Criteria by Alternatives					
	1	2	3	4	5	6
Single Number	No	Yes	Yes	Yes	Yes	Yes
Types of Services Included	1	At least 6	Same as 2	Same as 2	Same as 2	Same as 2
Participating Agencies	1	1	1	Fire and 3 Police	Same as 4	3 Police
Personnel Savings	None additional will be required	None - an additional 5	None - an additional 5	Significant at least 4	None - an additional 5	Significant at least 4
Fixed Cost						
Operating Cost						
% Calls Answered in busiest hour	Varies	100%	100%	90% w/n 10 sec.	Same as 4	Same as 4
Coin for Dialing	No	Yes	Yes	Yes	Yes	Yes
Organizational Structure	Existing	Simple	Simple	Complex	less degree of complexity	lesser degree of complexity
Recruitment and Training	Existing	Simple	Simple	Complex	less degree of complexity	lesser degree of complexity
Standard Dialing Procedures	Existing	Simple	Simple	Complex	less degree of complexity	lesser degree of complexity
System as Presented	--	2 Years	3 Months	2 Years	2 Years	2 Years
Phasing to 911	--	3 Months	3 Months	3 Months	3 Months	3 Months
Design Capacity	Inadequate	P.01	Same as 2	Same as 2	Same as 2	Same as 2
Excess Capacity	None	300%	300%	40%	60%	25%

Table 14

One Individual's Assignment of Worth Scores

Criteria	Alternatives 1	2	3	4	5	6
Education Program	.4	.8	1	1	1	1
Pay Phone Conversion	0	.7	1	1	1	1
Single Number	0	.7	1	1	1	1
Personnel Savings	0	0	0	.2	.8	1
Fixed Cost	-	.4	.4	.9	.5	.7
Operating Cost	-	.4	.4	.9	.5	.8
Organizational Structure	-	.9	.9	.3	.5	.7
Recruitment and Training	-	.9	.9	.2	.4	.6
Standard Operating Procedure	-	.9	.9	.3	.4	.5
Implementation of System as Presented	-	1	1	1	1	1
7-Digit Phased to 911	-	-	-	-	-	-
Design Capacity	0	1	1	.9	.9	.9
Probable Max. Sustained Capacity	-	.9	.9	.8	.8	.8

Table 15

Final Assigned Project Worth Scores for One Individual

Criteria	Alternatives 1	2	3	4	5	6
Education Program	.048	.096	.120	.120	.120	.120
Pay Phone Conversion	0	.14	.200	.200	.200	.20
Single Number	0	.56	.080	.080	.080	.080
Easy Access	.048	.301	.400	.400	.400	.400
Personnel Savings	0	0	0	.036	.144	.180
Fixed Cost	0	.0096	.0096	.0216	.012	.0168
Operating Cost	0	.0384	.0384	.0864	.048	.0768
Organizational Structure	-	.0551	.0551	.0184	.0245	.0428
Recruitment and Training	-	.0535	.0535	.0119	.0238	.0356
Standard Operating Procedure	-	.0535	.0535	.0178	.0238	.0297
Implementation of System as Presented	-	.054	.054	.054	.054	.054
7-Digit Phased to 911	-	-	-	-	-	-
Design Capacity	-	.048	.048	.0432	.0432	.0432
Probable Max Sustained Capacity	-	.0108	.0108	.0096	.0096	.0096
Level of Service	-	.323	.323	.299	.383	.488
TOTAL SCORE	-	.624	.723	.699	.783	.888

C. Results of Worth Assessment Analysis

Each member of the Project Review Committee conducted a worth assessment analysis. However, the total scores for each alternative were not directly comparable since each participant was allowed to ignore any criteria which appeared to be relatively unimportant to him or her in the evaluation and decision process. We converted each assessment to percentage points in order to facilitate comparison and evaluation. This was accomplished by assigning 100 percent to the alternative which received the highest score and representing the scores for the other alternatives in the form of a percentage based on that score.

Table 16 shows the total worth scores for each alternative as assigned by agency officials and indicates that alternative 5, 911 with coordinated police dispatch, is common to each group and ranks either first or second.

D. Group Choice Related to Alternative 5 and next Ranked Alternative

(a) Police: Alternative 5 was preferred over alternative 6 by 5.5 points. However, in our opinion, alternative 6 does not compromise any police operational advantages to be derived from Alternative 5. Nonetheless, with alternative 6, a variety of safeguards to assure full service to fire and rescue will be needed. Alternative 5 can be phased into alternative 6 without the necessity for additional hardware and system features.

(b) Fire: Alternative 5 was preferred over alternative 3 by 8.9 points.

(c) Others: Alternative 3 was preferred by 11.2 points over alternative 5. However, these participants exclude fire and police agencies and with the exception of rescue do not provide a direct service response function. It would appear that they are indifferent to the dispatch alternatives, 4, 5, and 6, placing maximum importance on accessibility. It should be noted, however, that alternative 5 provides the same level of accessibility as that provided by alternative 3.

Table 16

Total Worth Scores Assigned by Agency Officials

Agencies / Alternatives	Police	Fire	Others	Aggre-gate	Responding Agencies Police, Fire Rescue
#1	--	--	--	--	--
#2	80.0	85.8	68.8	81.8	91.2
#3	86.2	91.1	100.0	100.0	98.1
#4	91.1	84.3	88.7	93.1	92.4
#5	94.5	100.0	88.8	98.9	100.0
#6	100.0	85.7	81.3	81.5	97.6
Group Rankings	6, 5, 4	5, 3, 2	3, 5, 4	3, 5, 4	5, 3, 6
Difference Between 1st and 2nd Choices	5.5	8.9	11.2	1.1	1.9

E. Major Factor in Ranking

This single most important factor in the evaluation of alternatives from the viewpoint of worth assessment is PERCEIVED AUTHORITY OF AGENCIES - organizational structure, standard operating procedures and recruitment and training.

F. Recommendation

In the view of the researchers, Alternative 6 could offer the greatest long-range potential benefits in terms of cost. It offers no additional advantages in other factors related to level of service and to accessibility over Alternative 5. Its greatest disadvantage at the present time lies in its perceived complexity of management with respect to preserving authority of agencies.

We, therefore, recommend that Alternative 5 is the most beneficial system at this time.

This alternative, however, should be viewed as a demonstration system which hopefully would clarify the perceived complexities of management and, perhaps, facilitate acceptance and confidence over time in a system as presented in Alternative 6. Should such a situation arise, then a policy decision can be made to convert to Alternative 6 with a minimum of additional cost.

VIII. PLANNING FOR ACTION

This chapter attempts to address some planning for action questions associated with the establishment of an emergency communications center. These discussions are addressed in the context of alternative 5 - Police dispatch which envisages a central 911 communications center accepting emergency service requests for police (City, County and University), fire and rescue; dispatching all police agencies and transferring all fire and rescue request for service.

A. Management and Organization

Any system, regardless of the technology utilized and resources allocated, requires proper management principles and procedures. Since this system requires the support and co-operation of many agencies, it is clear that each agency must have some input into its management. It is also clear that each agency cannot manage and control the system if it is to serve all stakeholders.

System management is naturally influenced by the method of operation. Table 17 provides the recommended operational method.

Figure 18 illustrates the recommended management structure for the proposed communications center and was developed from consultations with the various agencies actually involved in delivery of emergency services. It is a system managed and operated by a new department or entity comprising representatives of the County, City and University. This has the decided advantage of a joint venture. This management structure visualizes a joint City, County and University venture operated and managed in a manner similar to other joint venture existing in the Community (e.g. Joint Security Complex, Airport,

Table 17

Recommended Method Of Operation

TYPE OF OPERATION	AGENCIES INVOLVED	TYPE OF COMMUNICATION AND EQUIPMENT
Direct Dispatch	Police University, Sheriff City	- Radio Communications Between Dispatchers and Mobile Units - Communication Consoles - Wall Map Display and Vehicle Status System - Tape Recording System - Computer Terminal
Transfers	Rescue Squad Fire, Other Dispatch Agencies	- Telephone Hot Lines
Referral	Non-Emergency Calls	- List of Appropriate Numbers for Referral

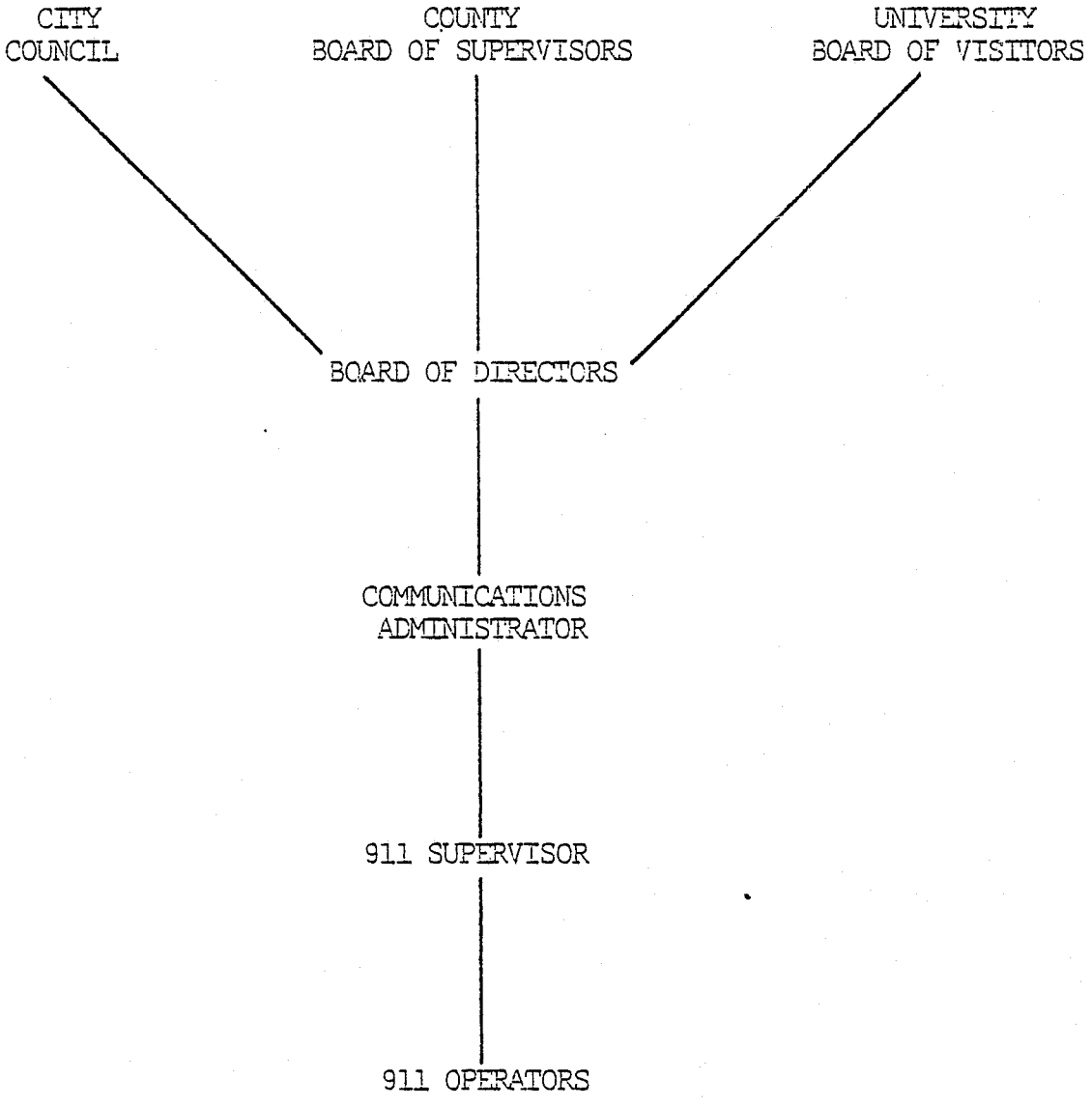


Figure 18 Recommended Management Structure For Communications Center -- Alternative #5

Library, etc.) For such a venture to be successful in administering the delivery of emergency services we recommend:

1. The communications center should be organized as a completely distinct agency independent of Police, Fire, Rescue, etc., and

2. A Board of Directors should be established. Such a board should include at a minimum:

   - Police Chief (Charlottesville)
   - Sheriff (Albemarle)
   - Police Chief (University)
   - Fire Chief (Charlottesville)
   - Representative (Jefferson Country Firemen's Association)
   - Representative (Rescue Squad)
   - *2 Representatives (Citizens Interest Groups)

B. Personnel Training and Recruiting

Consolidated dispatch requires personnel with a specific level of training and ability. Such personnel are often classified as communications specialists. There are many important considerations in recruiting and training personnel which must be addressed by agency officials involved in a consolidated dispatch effort. Some of these considerations have emerged during our study and are cited below:

Transition from existing system to recommended system.

- Use of existing personnel.
- Additional training requirements.
- Classification of personnel.

Functions of Communications Administrator.

- Recruiting and training.
- Planning and monitoring.
- Records and Budget.
- Co-ordinating and maintaining operating procedures.

---

*(or 1 representative from Scottsville's Rescue Squad and 1 citizen)

Career opportunities for advancement.

- Salaries.
- Relationship to other public service positions.
- Seniority and methods of promotion.

Training.

- Use of taped messages.
- Classroom instructions.
- Operations manual.
- Rotating dispatch functions between agencies prior to system implementation.

C. Standard Operating Procedures

Standard operating procedures should be designed jointly with all agencies either directly or indirectly involved with dispatch:

- Police (University, City, County)
- Fire (City, County)
- Rescue (City and County)
- Emergency services

These procedures should be of two types - GENERAL AND SPECIFIC

General Procedures should Include:

- Answering phones
- Receiving police emergency calls
- Obtaining information
- Releasing and referring information
- Receiving and referring fire calls
- Receiving and referring rescue calls
- Radio dispatch procedures
- Other

Specific procedures should include:

- Accident reporting and dispatching
- Specific crimes - bomb threats, burglary in progress, etc.
- Other

D. Status and Location Monitoring

In order to maintain and improve the existing level of service provided by responding agencies, procedures need to be developed for monitoring

the status of all units dispatched from the center. One possible method is suggested as an example of the type of plan needed:

- Officers in charge of location assignments report these assignments to 911 communications center personnel at the commencement of daily operations.
- Personnel in the field or responding units report their location directly to the 911 communication center at the commencement of daily operations. This would serve as a check to ensure, to the maximum extent possible, that assignments are not misunderstood.
- In the event that dispatch is initiated directly by Police agencies rather than by the center, the 911 center should be notified concerning the number of units and their location in order that the status board may be updated.
- Continuous dual recording of all radio and telephone connections with instantaneous playback capability would enable an evaluation of the communications center's performance and the ability to double check information.

E. Records Accessibility and Consolidation

With centralized police dispatch as envisioned by alternative #5, there is a need to access criminal information. Generally, this type of information is provided by the dispatcher through the use of computer aided facilities. These capabilities are desirable and have been suggested for the consolidated dispatch center.

The consolidation of all police records is a rather complex venture and needs careful analysis. Normally, the center would maintain appropriate records relative to its operation and have access to pertinent records needed by responding field units. The extent to which this recording function should be extended is questionable. The primary function of the communica-

tions center is to provide quick response to emergencies. Should the function be expanded to include a recording function (routine police records for the three jurisdictions), then the level of service anticipated would be impaired and the general concept of emergency communications and consolidated dispatch undermined.

The consolidation of police records may facilitate significant advantages in terms of production and retrieval. However, an extensive analysis is required to ascertain its desirability and utility. In any event, records consolidation should be viewed as a distinct and different function from that envisioned for the consolidated dispatch center in this planning effort.

F. Computerized Dispatch

Computerized dispatch has emerged in an effort to mechanize dispatch functions which could reduce total response time substantially under certain conditions. It is particularly appealing in communities where dispatch is initiated by a variety of independent agencies across a huge geographical area serving large populations.

With typical computerized dispatch, the dispatcher enters appropriate information through a keyboard with respect to location and type of incident into a computer. The computer then responds with a display of appropriate agency/agencies, the status of units and the number of units required. Generally, a signal alerts the required agency followed by a video display and a digital record. This operation is basically a call transfer one and has the system features associated with alternatives 3, 4, 5, 6 (patching, call part hold, etc). Alternatively, the information provided could be used directly at the dispatch center.

In terms of a centralized police dispatching center, computerized dispatch has the obvious advantages of providing a variety of information, reducing confusion and perhaps reducing total response time. However, the costs associated with implementing such a system would almost certainly outweigh any potential benefits one might assume in the Charlottesville/ Albemarle area. The acquisition and establishment of a data file on a continuing basis together with computer facilities and equipment would certainly not be justified when dispatch is centralized, the community is small and the array of services and functions are highly selective (Police, Fire, Rescue) as in the Charlottesville/Albemarle area.

G. Monitoring System Performance

Implementation of a system has often, in the past, been construed as a solution. However, nothing always works perfectly. Consequently, system design cannot be complete unless some provision is made for monitoring and evaluating the performance of any implemented system over time so that malfunctions can be identified and corrective procedures outlined to ensure smooth operations. The major system elements which need particular attention are:

·Network capacity

- Number of incoming lines.
- Number of outgoing lines.

·Operating efficiency

- Answering time.
- Dispatch time.
- Total response time.
- Personnel.

Throughout our analysis, system design was based on an anticipated traffic volume likely to be realized in two (2) years. As this volume increases

or decreases, a variety of short-term adjustments will be necessary. In order to anticipate these adjustments, the following functions are suggested:

(a) Capacity Analysis--Incoming/Outgoing Lines

- Estimation of the busiest hour.
- Estimation of traffic volume in busiest hour.

(b) Personnel Analysis

- Estimation of average answering time.
- Estimation of average service time (dispatch/referral/transfer).

(c) Evaluation of Operating Procedures

- Estimation of call volumes to the various receiving agencies.
- Percentage referred, dispatched, transferred.

These analyses should be performed by the communications center at regular intervals (for example, every 4 months for the first 2 years and at least every 6 months thereafter). Such analyses could provide the basis for a report to participating agencies for evaluation and review.

H. Public Education Program

In the event that 911 should be implemented as a uniform number for the City and County, it would be advisable to commence a public education program at least two weeks prior to its implementation.

During 1975-76, the University of Virginia's Medical Emergency Service (EMS) conducted an extensive public education program aimed at improving emergency medical care, training and public access. Funding for this project was provided through the Robert Wood Johnson Foundation. Consultation with the EMS has revealed that funds for a public education program in the event that 911 should be adopted in the Charlottesville/Albemarle area have been budgeted and a major portion of this effort will be undertaken by the EMS.

A public education program might include the following:

(a) Telephone Stickers

These may be for private phones and businesses. More importantly, however, stickers should be provided at public phones with some number or letter indicating the location of these phones. A list of numbers in letters corresponding to locations can be kept in the 911 center to facilitate prompt response.

(b) Inside Front Covers of Telephone Book

The advertising here would indicate the agencies and services which are accessible by dialing 911.

(c) Bumper Stickers

(d) Posters

(e) Newspaper Coverage

Special attention should be given to the objectives of 911 as an emergency number and emphasis placed on discouraging it misuse (e.g. crank calls, non-emergency situations, information,etc.)

(f) Public Service Announcement (Radio and T.V.)

I. Implementation Plan

The tentative implementation plan (Figure 19) suggested here will need some refinement as the project is undertaken. However, it does indicate the major activities and the approximate time associated with accomplishing them. It is suggested that a user board be established in

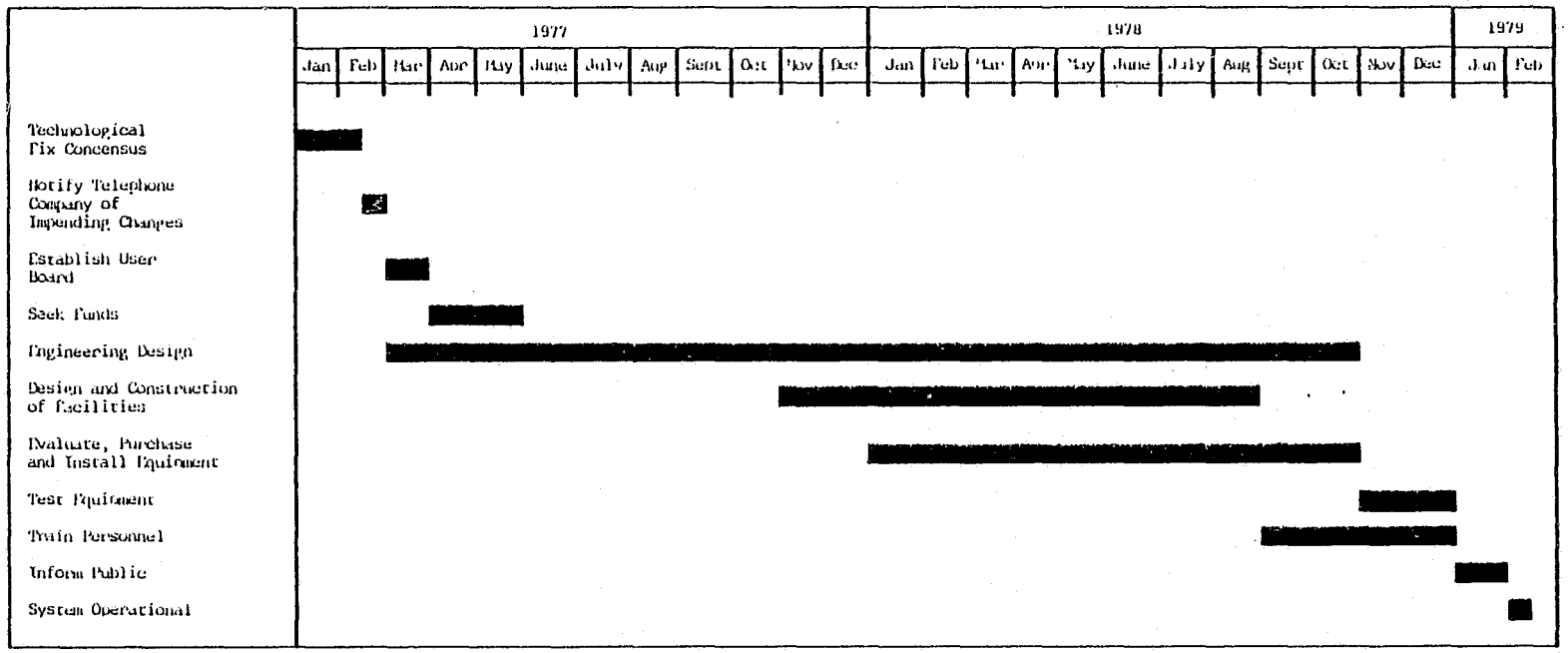


Figure 19 Normative Scenario of Possible Implementation Plan-Gantt Chart

early 1977 to undertake the task of planning, co-ordinating, securing funds and other related functions consistent with the development and implementation of the co-ordinated dispatch center.

The necessity for an early consensus is readily apparent since CENTEL estimates that telephone changes require approximately two years headway and requests for funding must be incorporated into the next Local and State Comprehensive Plans.

IX. CONCLUSIONS

In this study, we have attempted, using a systems engineering approach, to analyze the costs and benefits associated with various emergency communications systems for the Charlottesville/Albemarle area. We have examined the concept of a 911 emergency communications system, evaluated its desirability and feasibility, and have attempted a preliminary system design leading to a conceptual plan for implementation. This plan has identified specific actions needed to design and effect emergency communication improvements within the existing constraints imposed by technological, financial, social and institutional considerations.

It is anticipated that the major value of this work lies in the provision of a consistent and generalized method for studying and evaluating urban problems. Although we have applied it specifically to an emergency communications system, it is readily adaptable to the investigation and evaluation of a wide variety of urban service delivery systems.

From the analysis and studies conducted together with our perception and awareness of the problem, the following conclusions are presented.

- There exists a need in the Charlottesville/Albemarle area to improve the delivery of emergency services. Such improvements must be viewed in terms of (a) citizen access and (b) level of service.

- The existing communications capability of some responding agencies, especially the County Sheriff's department, is inadequate, not only when compared with that of neighboring communities, but more importantly, from an efficient service delivery standpoint.

- The nature of emergency communications and service delivery is such that continuing cost increases are inevitable. Our analysis indicates that considerable cost savings can only be accrued on a continuing basis if planned cooperation becomes a reality.

- Police agency officials - City, County and University - have indicated to us a desire for consolidation and explicit cooperation in the administering of dispatch functions. Our analysis has indicated that this is not only feasible, but particularly desirable.

- Fire and rescue squad officials, on the other hand, have expressed a desire to maintain their own dispatching functions. Our analysis indicates that there are major justifications at this time to sustain this separation of dispatch functions for fire and rescue squad operations.

- The establishment of a 911 communications system in the Charlottesville/Albemarle area is technically, socially and institutionally feasible.

Recommendation

We recommend that the 911 system Alternative 5 as presented in this report be implemented. An early decision is necessary if such a system is to become operational in the near future. Specific actions needed to enable implementation are presented in Chapter VIII of this report.

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APPENDIX A

CENTRALIZED COMMUNICATION SYSTEMS IN NEIGHBORING COMMUNITIES*

This appendix on centralized communication systems is presented here to facilitate a detailed description of operational modes in other communities. During this study it has become apparent that public officials directly involved in the delivery of emergency services as well as the research team could benefit by a brief study of existing emergency communication systems.

We, therefore, conducted interviews with various key officials in several centralized communications centers. Field trips to three neighboring centers were undertaken in order to appraise their operations and gain some insight into the operational problems, particularly those of organization and management. The centers visited were: Fairfax, Virginia, Rockville, Maryland and Washington, D. C. These centers demonstrate a wide variety of operation and management patterns. In describing these centers, we have attempted to address those specific concerns voiced to us by public officials in the Charlottesville/Albemarle area.

From our interviews and discussions, it would appear that the various agencies involved in communications and dispatch were pleased with their respective systems and that there were no major problems in daily operation and management.

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*The Authors acknowledge the helpful assistance of Mr. Terry Ricks in assembling information for and preparing a portion of this appendix.

A. Fairfax, Va.

General Description

The Fairfax County Emergency Operations Center (EOC) is located in the County Office Building basement. A single seven-digit telephone number dialed from almost any location within Fairfax County boundaries connects the emergency caller into a central dispatching room where any one of about 15 to 20 staff members can answer the call. The Fairfax County police and the County fire and rescue departments dispatch their personnel from this installation. The emergency medical ambulance service for Fairfax County is a division of the fire department which serves both the city and county of Fairfax.

In addition, the independent cities of Fairfax, Alexandria, Vienna, Falls Church, Arlington, and Herndon have their own police departments which have individual telephone numbers and dispatching headquarters. However, there are dedicated hotlines between all these centers so that misdirected calls can be forwarded to the correct agency.

History

It was explained that before construction six years ago of the Fairfax EOC, there were three large dispatching centers: one for the fire department, one for the county police, and one for the city police. After the advantages of centralization were realized, the County fire and police departments decided to merge dispatching operations, but the city police chose to remain independent. This arrangement still exists today.

Telephones

The telephone system used by this EOC includes 23 incoming emergency and business lines, 5 outgoing lines, and 26 emergency hotlines to the

various police stations, hospitals, nearby jurisdictions and other emergency departments. In addition there are leased lines to each of the 28 fire engine stations scattered around cities and county.

Personnel

The ECC has approximately 100 employees of which 65 are civilians. The various employee functions include call-takers, dispatchers, record clerks, police supervisors, fire supervisors, and head communications officers. All the call processing staff rotate among the call-taker and dispatching positions. They have been cross-trained and thus are able to dispatch any agency needed. The call-takers and dispatchers consist of civilians as well as police and fire personnel. Standard policy requires that experienced supervisors from both police and fire departments must be present on each shift in order to handle the more complicated situations. There are 4 shifts per day and 2 uniformed supervisors are assigned to each shift. There are 8 police supervisors responsible to the Police Captain, and six fire supervisors responsible to the Fire Chief. The Police Captain is ultimately responsible for the operation of the EOC facility.

Salaries and Training

Training of these communication personnel is conducted while on the job with the help of procedures manuals and tape recordings to simulate crisis situations that require rapid and logical decisions. Once employed, an individual is on probation for a year or more to assure quality dispatching. There are 25 civilian communications clerks who are all at the same salary level--$10,000 plus overtime. If benefits are included, the average salary for these individuals is about $13,000. The police Captain reports to the County Police Chief's Assistant while the Fire Captain reports to the Fire and Rescue Chief's Assistant. The Fire and Rescue Depart-

ment employs over 700 individuals with a few volunteers as support personnel. The EOC and its staff are under the scrutiny of the Fairfax County Public Safety Communications Division, a subdivision of a larger County-wide communications department which manages the radios for schools, buses, and public works as well as the County telephone accounts and operations.

Console and Radio Equipment

Emergency calls terminate on the call-takers' switchboards and a light goes on at the dispatchers' consoles. As the call-taker asks the initial questions, the dispatchers listen in on the call and, if needed, dispatch the necessary agency. The call-takers and dispatchers keep manual records on computer cards. These records are compiled by computer each month. It is important to note that although each dispatcher has been trained in the dispatching rules and procedures for each agency, there are designated dispatching consoles for each agency. In other words, on every shift there are communications clerks who are assigned to handle only the dispatching for a certain agency but they may switch to another agency's console or become a call-taker at any time. Therefore, a communication clerk is responsible to any one agency or function during the shift but this assignment changes on a regular rotating basis or when the staffing situation requires flexibility.

Features

There are no automatic number identification devices, nor is there computer-aided dispatching. The status board and map lights are operated manually. Also, each dispatch is written on a card that is time-punched

as follows: call received time, dispatch time, arrival time, and cleared time.

The fire and rescue consoles are equipped with microwave tone encoders that can sound tones, ring sirens, open doors, and turn on lights at the 28 fire engine stations. These notification and alerting procedures permit the dispatcher to initially command the necessary personnel and vehicles until a field officer assumes direction. Leased lines to all 28 stations are used as back-ups to the microwave systems. The EOC monitors automatic bank alarms only. Other businesses and buildings with alarms instruct their private alarm monitoring agencies to call the EOC when their alarms designate breaking and entering, fire, etc. All telephone and radio communications are continually recorded by a dual dictaphone tape recorder with an instant playback made to allow review of garbled, misunderstood, or legally relevant conversations.

Funding and the EOC

This Emergency Operating Center was funded six years ago by a combination of grants from the Law Enforcement Assistance Administration, the Virginia Office of Emergency Services (Civil Defense), as well as state and local funds. The Civil Defense Department provided 50% federal matching funds to construct the EOC. The general construction guidelines followed involved two distinct groupings of space function-operations and support. About 60% of the EOC space was allocated to emergency operation functions such as a central operations room, communications and message centers, and executive office space. Approximately 40% of the EOC space has been designed to provide appropriate living and working conditions to

support operations of the emergency staff. These areas are designated for eating, sleeping, mechanical equipment, health, and sanitary facilities.

The County of Fairfax provides all operational appropriations annually including salary payroll. These funds are raised through personal property and real estate taxes.

Future Plans

Future modifications and planning have been necessitated because the communications room has become very congested and noisy. The communications equipment and personnel will be divided and placed in three different rooms according to function: call-takers, police services and fire/rescue services. Of course, these rooms will still be able to coordinate their emergency responses with the proposed conference lines between them. Other separate rooms presently in the EOC are for computer records, training police supervisors, and fire supervisors.

B. Rockville, Maryland

General Description

The 911 Central Dispatch Center for Montgomery County, Maryland is located in Rockville, about ten miles north of Washington, D. C. The Center is located in the basement of the County Office Building. Practically all County emergency services are dispatched from this emergency operating center (EOC). The 911 emergency telephone number began operation for the 600,000 (approx.) residents of Montgomery County on October 31, 1974.

911 Call Processing

The Montgomery County EOC is the answering point for all 911 calls in the County. These calls come from homes, businesses, and are toll-free

from public telephone booths. Eighteen different telephone exchanges are in the County, and four lines from each exchange's central office terminate on the 911 switchboard. These seventy-two lines are grouped on the switchboard and when a call is received, the call-taker can identify the exchange of origin. This switchboard has six identical operator positions. Usually only one operator is needed to answer the 911 calls in the County. If he becomes overloaded with calls, then other personnel are nearby to staff the switchboard.

The 911 call-takers simply answer saying "911 center--do you need police, fire or ambulance service?" Depending on the caller's request or situation, the call-taker immediately transfers the 911 caller to the appropriate group of dispatchers or clerks. The 911 operators can transfer the caller to any of four (4) different areas: police dispatch, fire and rescue dispatch, routine non-emergency service clerks, or the County administrative switchboard. Crank or abusive callers are warned that they are committing a crime and are forcibly disconnected, or are traced so that the caller can be prosecuted. Any 911 call other than an emergency call is discouraged either by informing the caller that this is an emergency call center only and referring the caller to the phone book or by verbally informing the caller of the seven-digit number to be dialed.

The 911 call-taker works with a headset, a set of cord plugs, and a telephone dialing device. When a call is received by the switchboard, the call-taker answers the call and transfers the caller to the appropriate emergency agency that is needed. Eighty percent of all 911 calls are for police assistance. Multiple agencies can be linked to the emergency caller by appropriate circuit connections. The time necessary for the operator to

route the 911 call to the appropriate service agency is a matter of 2-4 seconds, hence one operator per shift can manage the needs of the entire county.

Routine Service Clerks

Behind the switchboard in the same room there are several routine service clerks who receive calls from the 911 operator. Such routine service calls are not of an immediate emergency nature but still require responses within several hours or days by one of the public safety agencies. Examples of routine service calls include: police administration, fire inspections, or requests for standby services at crowded events. These individuals often must fill out forms that require more time than the dispatchers can reserve between calls, thus allowing the dispatcher to attend to higher priorities in his job.

Police Dispatchers

When the 911 call requires rapid police response, the call is transferred to the police dispatch and records area consisting of two separate rooms--one for record check and incident card processing and one for the radio dispatchers themselves. The records room fills out incident cards with significant information given directly by the caller relevant to the emergency; likewise, this information is cross-checked with local, state and national law enforcement records by means of computer and file systems. The incident card, when completed, travels to the dispatcher room by a small conveyor belt, and the dispatcher takes appropriate actions and sends officers and equipment to the scene using two-way radio to communicate with the cars in the field and to maintain status reports. There

are four satellite police stations in the County communications, still the Rockville EOC is the command center.

Fire and Rescue Dispatchers

The emergency medical services for the area are part of the fire department. Thus the ambulances are located with the fire engine companies distributed throughout the county. The radio dispatchers for fire and rescue services have their own separate room in the EOC and receive their 911 calls from the call-taker's switchboard. Their relatively low volume of calls permits the fire dispatchers themselves to complete any necessary report cards and record checks while directing all fire and rescue operations by radio until a senior officer arrives on the emergency scene.

These dispatchers have both radio and dedicated hot-line two-way communications with thirty-one fire engine companies, four hospitals, three public utilities, and two adjacent jurisdictions. The EOC also can communicate with many public safety agencies and jurisdictions in the large metropolitan areas of northern Virginia, Washington, D. C., and Maryland.

EOC

As mentioned before, all the above activities take place in the Montgomery County Emergency Operating Center (EOC). The large public safety facility is underground and has been constructed according to standards established by the Civil Defense Preparedness Agency(CDPA) of the federal government. A brochure covering these standards for EOC is available from the State Office of Emergency Services in Richmond, Virginia. Funding for this huge installation has come from a variety of sources: Law Enforcement Assistance Administration, Civil Defense Preparedness Agency,

Emergency Medical Services (a division of Health, Education, and Welfare Department), and some state and local monies.

The EOC has standard radiological protection factors, emergency power generators, food, sleeping rooms, kitchen, water supply, working areas and total telephone and radio communications with all county services as well as state and federal radio systems. The completely isolated and protected command center will provide the Montgomery County government officials an operating base with enough supplies for thirty days in case of natural or man-made disaster.

Organization

The large, comprehensive Montgomery County EOC is the result of a single government having an organizational hierarchy with individuals who know they must cooperate, communicate, and search for solutions together in order to provide a large array of public safety services to the residents of Montgomery County.

Police dispatchers, record processors, and call-takers are under the supervision of a police communications officer who reports to the chief. The county fire and rescue service have a parallel organizational structure. Each set of dispatchers is supervised by their respective agency communications officers. The police communications officer and the fire and rescue communications officer work together toward the improvement of the overall communications system. They are members of a regional communications committee consisting of public safety communications officers from Northern Virginia, Maryland, and Washington, D. C. The fire and rescue services of

the County have a policy making board consisting of the head of each engine company along with an elected representative from each company.

Future Plans

The size of this County necessitates continual change and additions to the EOC. The rapid advances in communications technology have provided highly sophisticated equipment to assist the communications officers in devising new, more efficient and complete systems. Future expansions in the EOC will be in two major areas: emergency medical services and computerized dispatching.

The new federal push for emergency medical services (EMS) has greatly increased the techniques, equipment, personnel, and overall magnitude of the County's paramedic service. A concomitant increase in communications capability is required, hence the single fire and rescue dispatch room will be transformed into two separate rooms: one for fire and one for rescue. The expanded utilization of radio communications by the paramedic has further complicated the dispatcher's function. The dispatcher must now have a basic medical knowledge of advanced first aid so as to assist the paramedic in the field. More and more hospitals are acquiring radio communications so that the doctor and paramedic can communicate. The helicopter ambulance service provided by the Maryland State Police will soon have communications with the EOC. This is the Maryland Air Med-Evac Helicopter System. Furthermore, the transmission of electrocardiograms and telemetry is becoming routine and requires new radio frequencies and equipment. With the monitoring capabilities for voice communications and telemetry, the dispatchers will be able to provide valuable consultation to both paramedics and physicians in regards to efficient usage of equip-

ment and frequencies as well as proper medical treatment protocols and expeditious routing of emergency patients to the most accessible and best equipped acute care hospital facilities.

C. Washington, D. C.

General Description

The 911 system of the District of Columbia offers another design for public safety emergency telecommunications and radio networks. All 911 emergency telephone calls are answered by the police department located in the D. C. Municipal Building. Jurisdictional problems because of non-coincident telephone exchange and political boundaries do not exist since D. C. has its own area code and distinct telephone circuitry. The 911 calls for police service are handled and dispatched by the command center; however, if the emergency caller needs fire or rescue services, these 911 calls are transferred to the fire and rescue dispatching headquarters in the northern section of Washington, D. C. The 911 caller then speaks directly to the fire and rescue dispatcher.

The communications division of the police department is divided into three rooms--an operator room, a 911 call-room, and a dispatcher room. The 911 calls are automatically distributed first to available dispatchers. There are seven dual consoles in a row manned by a maximum of 14 dispatchers during peak traffic hours. Each dual console corresponds to one of the seven police districts in D. C.

If all dispatchers are busy, the call distributor device chooses an available call-taker in the adjacent room. There are 12 call-taker positions. The call-takers have two alternative activities depending on the nature of the 911 call. If the call is an emergency or requires a dis-

patcher's attention, a report card is filled out with pertinent information (name, phone number, location, incident), and placed on a conveyor belt that transfers it to the dispatcher room. If a 911 call is of a non-emergency or business nature, the call-takers and dispatchers either refer the caller to a business number or to the operator room adjacent to the call-takers' room.

Each console is equipped with a computer terminal (CRT) that provides access to the National Criminal Information Computer (NCIC) which has data regarding stolen cars, criminal records, and other relevant law enforcement information. All telephone and radio communications are taped.

There are 3 shifts of personnel. All call-takers and operators are civilians. Dispatchers are either civilians or uniformed officers. Supervisors are present during each shift and are all uniformed officers except for 1 experienced civilian. Training consists of 2 weeks of classroom work as well as probationary on-the-job training.

Fire and Rescue Center

The D. C. Fire and Rescue Department receive their emergency calls over 911 telephone lines, telegraph alarm street boxes, and telephone street boxes. All 911 calls for fire and rescue services are first answered by the D. C. Police Center who in turn forward the 911 calls to the fire and rescue center over dedicated lines. The fire and rescue center has also retained its original seven-digit telephone number so that they can be called directly.

Dispatchers are either civilian non-uniform employees or restricted duty fire or rescue officers. There are 6 individuals assigned to each of

the 3 daily shifts. The entire D. C. fire department has 1500 firefighters and 85 ambulance personnel.

Special hotlines connect the fire and rescue center to the various fire engine and ambulance stations in the city. These hotlines, in conjunction with radio communications, permit the center to dispatch any station. This center has specially tariffed telephone lines that are only switched on when all other incoming lines are jammed.

Future Plans

The current electromechanical alarm devices used by the fire and rescue center are over thirty years old and replacement parts often made of brass, must be handmade. New computerized alarm and dispatching equipment totalling over two-million dollars is scheduled for installation in late 1977. Also, the old telegraph street boxes will be replaced by telephones.

APPENDIX B

SENSITIVITY AND MARGINAL COST BENEFIT ANALYSIS

In this appendix, we perform a sensitivity and marginal cost benefit analysis with respect to the recommended number of lines and personnel. In estimating these quantities the parameters used were busy hour call volume and average holding time. Our sensitivity analysis examine the effects on costs and benefits of likely variations in these parameters on the recommended quantities.

A. Personnel

In estimating the number of personnel required, we used the criterion - no more than 10 percent of the busy hour calls will be serviced with delays greater than 10 seconds (approximately 2 rings). This implies that 90 percent of these calls will be serviced in no greater than 2 rings. We now examine the sensitivity of this criterion with respect to the number of dispatchers and average holding time.

Average holding time was estimated at 90 seconds. This means that a telephone line and/or dispatcher will be tied up or unavailable for an average of 90 seconds for each call during the busy hour. Table B-1 shows that, with an average holding time of 90 seconds, utilizing 3 dispatchers result in 26 percent of the calls being delayed greater than 5 seconds, 24 percent greater than 10 seconds, 22 percent greater than 15 seconds and 20 percent greater than 20 seconds with an average delay time of 18.5 seconds (approximately 4 rings) per call. When on-scene-assistance is required, an average delay of 4 rings per call with 20 percent having to

Table B-1

Sensitivity of Personnel to Level of Service Criteria
and Average Holding Time

Personnel in Busiest Hour	Probability of a Call During the Busiest Hour Being Delayed Greater Than n Seconds				Average Delay for all Calls During Busiest Hour (secs)	Average Holding Time (secs)	
	n = 5	n = 10	n = 15	n = 20			
3	.150	.133	.118	.105	7.16	72	
4	.042	.034	.028	.023	1.31	72	(-10%)
5	.009	.007	.005	.004	.22	72	
3	.205	.187	.170	.154	11.9	81	
4	.060	.051	.044	.037	2.2	81	(-20%)
5	.014	.012	.009	.007	.41	81	
3	.261	.242	.224	.207	18.5	90	
4	.090	.079	.069	.061	3.9	90	(Estimate)
5	.026	.021	.018	.015	.83	90	
3	.330	.311	.292	.275	28.5	99	
4	.112	.010	.090	.080	5.6	99	(+10%)
5	.033	.028	.023	.020	1.2	99	
3	.457	.435	.414	.395	49.4	108	
4	.174	.158	.144	.131	10.1	108	(+20%)
5	.055	.047	.041	.036	2.23	108	

wait longer than 4 rings would tend to indicate a low level of service. By increasing the dispatch force to 4 personnel, Table B-1 indicates that the average delay would be approximately 1 ring with only 8 percent of the calls having to wait longer than 2 rings. To afford this improved level of service requires an additional monthly cost of approximately $900. To further improve this level of service by increasing the dispatch force to 5 appears to be unwarranted since the average delay time would be considerably less than 1 ring and dispatchers cannot routinely perform with such efficiency.

Assuming a 10 or 20 percent reduction in average holding time (Table B-1) indicates that 4 dispatchers are still required to ensure that no more than 10 percent of the busy hour calls are delayed greater than 10 seconds with the average delays being within the vicinity of 1 ring. Utilizing only 3 dispatchers with this reduction in average holding time results in 13 and 18 percent of the calls being delayed greater than 10 seconds, respectively. On the other hand, assuming a 10 percent increase in average holding time, utilizing 4 dispatchers just satisfies the criterion with an average call being delayed a little more than 1 ring. Further, assuming a 20 percent increase in average holding time indicates that 16 percent of the calls will be delayed greater than 2 rings with the average call being delayed approximately 2 rings. To improve this level of service such that only 10 percent of the calls are delayed greater than 2 rings requires an additional dispatcher. This will result in about 5 percent of the calls being delayed greater than 10 seconds and an average delay time of 2.3 seconds.

An average holding time of 108 seconds (20% increase in average requirements) is felt to be quite large since fire and rescue calls will be transferred. This would mean that the dispatcher's average holding time would be in the range of 5 to 10 seconds for these calls. Thus, while telephone lines will be tied up as calls are transferred to fire and rescue, the actual time for which dispatchers are tied up at the communications center will be reduced.

B. Number of Lines

The number of lines were estimated such that no more than 1 call in a hundred is likely to receive a busy signal during the busiest hour. Assuming a 20 percent decrease in call volume, Table B-2 shows that 6 lines are still required to provide a P01 grade of service. On the other hand, assuming a 20 to 30 percent increase in call volume requires an additional line at a monthly cost of approximately $50 per month. Table B-2 shows that by designing for an inferior grade of service such as 2, 3, or 4 calls in 100 being likely to receive a busy signal results in a reduction of only 1 line.

A 911 communications center is intended to accept only calls for on scene assistance, nonetheless, it would be unrealistic to expect that inappropriate calls will not be received. However, if a large number of inappropriate calls are received, the average holding time should still not increase substantially since these calls will be redirected or disconnected. Assuming a 50 percent increase in call volume and the same holding time of 90 seconds for all calls, 8 lines provide a P01 grade of service. Table B-2 shows that the number of lines required to provide a

Table B-2

Sensitivity of Telephone Lines to Busy Hour Call Volume and Grade of Service

CCS	Busy Hour Call Volume	Lines Required for a Particular Grade of Service					
		P01	P02	P03	P04	P001	P005
46.8	52 (-20%)	6	5	5	5	7	6
58.5	65 (Estimate)	6	6	5	5	8	7
70.2	78 (+20%)	7	6	6	6	8	7
76.0	84.5 (+30%)	7	6	6	6	9	8
87.7	97.5 (+50%)	8	7	7	6	9	8

particular grade of service is relatively insensitive to call volume especially when increases in call volume do not consume any significant answering or dispatch time.

APPENDIX C

SIMULATION OF RECOMMENDED 911 SYSTEM FOR CHARLOTTESVILLE/ALBEMARLE AREA

A detailed explanation of the system will not be given since this is available in the body of the final study report "System Engineering Study of Emergency Communications Systems for the City of Charlottesville, University of Virginia and Albemarle County" by G. G. Yorke, O. A. Gianniny, Jr., and A. P. Sage. The alternative chosen was alternative five which is shown in Figure 12, page 53. Briefly, incoming calls are answered by a police operator who then transfers fire and rescue calls to the respective dispatchers. Police calls are dispatched by the operators. The police operator stays on the line until the call gets the appropriate dispatcher or call for a police is dispatched. Fire and rescue dispatchers stay on the line until their service is dispatched. Some of the specific information is as follows:

Number Incoming Lines	-	10
Number Operators	-	4
Number Transfer Lines to Fire	-	2
Number Transfer Lines to Rescue	-	2

The report found that the number of calls during the busiest hour was about 65. Calls were almost uniformly distributed throughout the day. An arrival time distribution which is uniform over the interval 0-112 secs is used. This gives an average of 65 calls/hour and also allows for two calls to arrive at the same time. Average service time was found to be 90 sec. A uniform distribution over the interval 67-113 sec was used for the service time for the dispatchers. The time to ascertain the type of call and transfer was taken as 15 ± 5 sec uniformly distributed. It appears that a reasonable distribution of incoming calls is as follows:

Fire - 5%

Rescue - 5%

Wrong Number - 5%

Police - 80%

Wrong numbers take between 67-113 sec to complete.

Results of the simulation runs are given in figures C.1 and C.2. Runs for various inter-arrival rates were obtained for the proposed system under the nominal operating conditions mentioned in the body of the report. Besides the 65 call/hr rate the following rates were tried to see when congestion started to occur. Each simulation ran for 1000 calls.

Call/Hr.	Distribution Range
65	0 - 112 sec
85	0 - 84 sec
100	0 - 72 sec
125	0 - 56 sec
150	0 - 48 sec

For 65 calls/hr disabling two lines had no effect. 98% of the incoming calls were answered on the first ring. Calls that were not answered on the first ring (2%) rang for an average of 23 seconds. No call received a busy signal. However 2% of the fire calls had to wait an average of 9 sec for a fire dispatcher transfer line to become available.

Analysis of the results for high average arrivals/hr show that the incoming lines can handle a call rate of 150 calls/hr with a small busy rate (.3%). Even with two lines disabled, the busy rate increases to 1.1% which is within design standards. However the number of calls that are not answered on the first ring is significant. At 150 calls/hr 50% of the incoming calls wait an average of 30 sec to get an answer. At 125 calls/hr (which has been

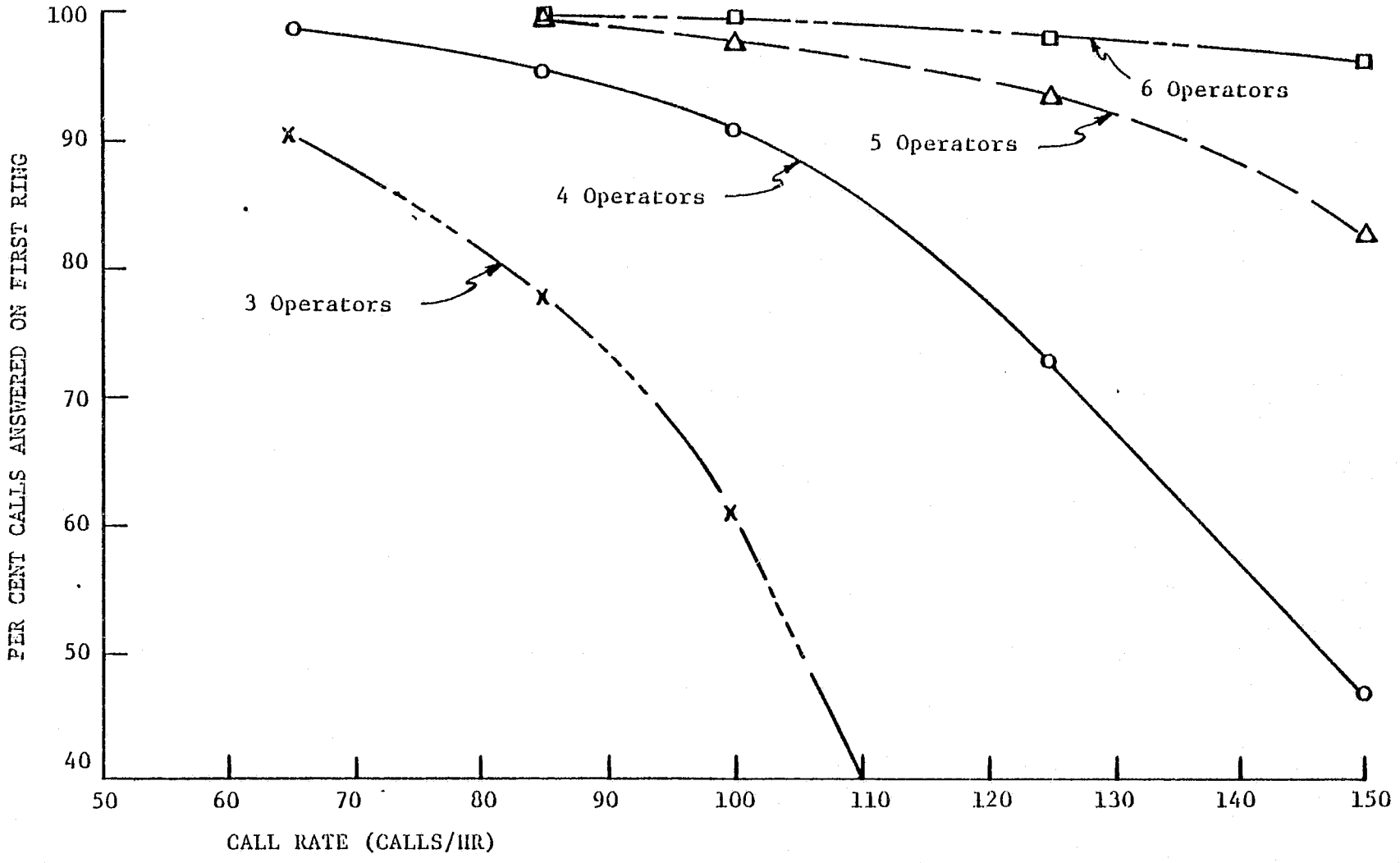

Figure C.1 Calls Answered on First Ring vs. Call Rate

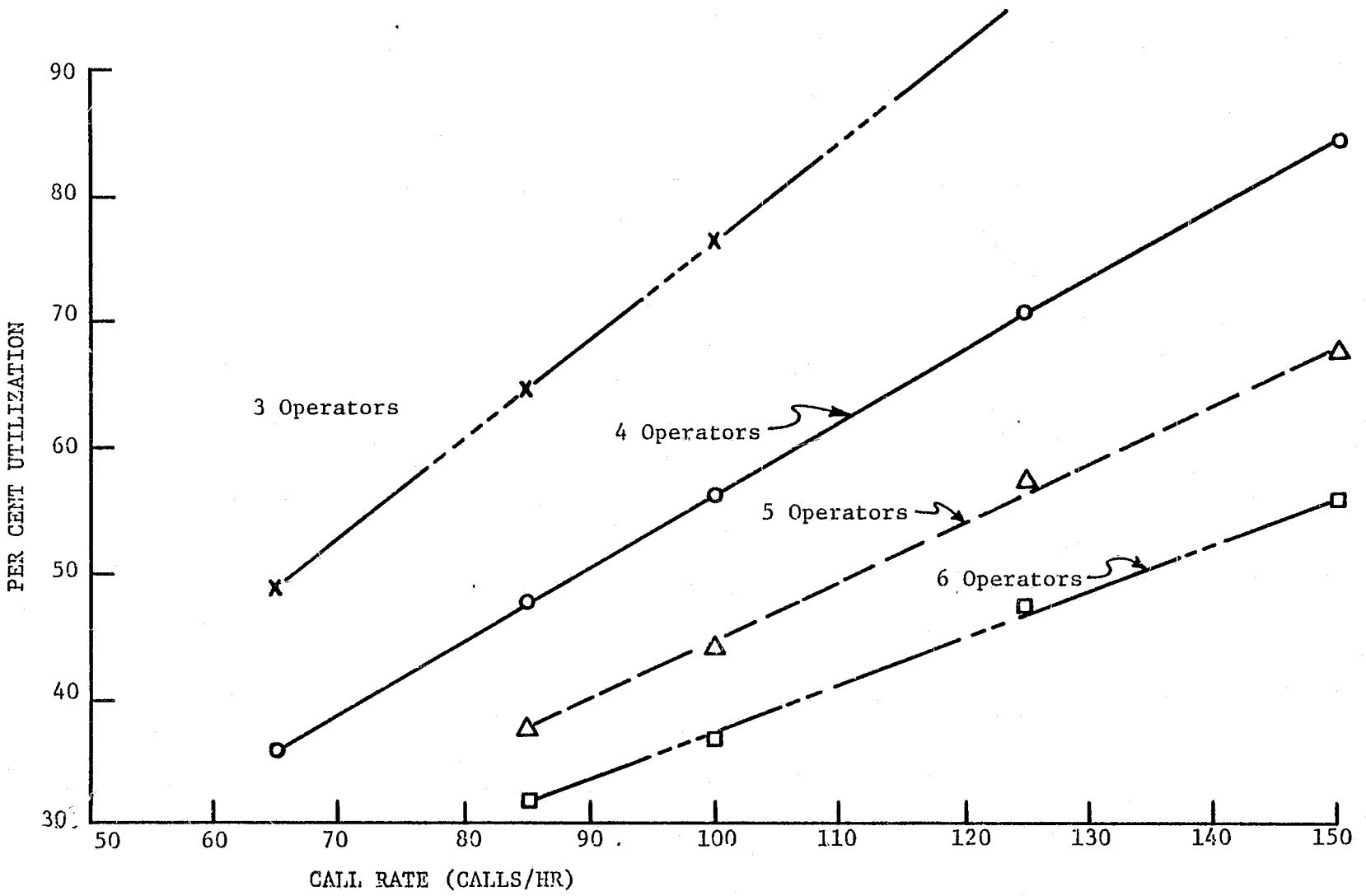

Figure C.2 Operator Utilization vs. Call Rate

observed at times) 5% of the calls wait approximately 22 sec for an answer. The number of calls that must wait for transfer to another dispatcher is very small 0-3% and not affected as the arrival rate increases. This indicates that the number of outgoing lines to these dispatchers is sufficient.

The results indicate that number of lines will handle rates up to 150 calls/hr tops but at rates over 100 calls/hr. more operators will be needed to handle the increased volume. Such an increase does not appear likely. Illustrations of calls answered on the first ring and operator utilization versus call rate are shown for different number of operators in Figures C.1 and C.2. All data were obtained using GPSS, a standard discrete event digital simulation language.

END