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A National Assessment of Police Command, Control, and Communications Systems

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James K. Stewart
Director

A National Assessment of Police Command, Control, and Communications Systems

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PREFACE

This report addresses the use and evaluation of computer-based technology as it relates to police command, control, and communication (PCCC) systems. It is the Final Report for a two-year grant to Public Systems Evaluation, Inc. (PSE) to conduct a Phase I National Evaluation Program (NEP) assessment for the National Institute of Justice. The focus is on four PCCC technologies: Computer-Aided Dispatch, Mobile Digital Communications, Nine-One-One, and Automatic Vehicle Monitoring; and two related application areas: Regional Communication Systems and Formal Deployment Methods.

The evaluation is not intended to offer a detailed review of particular systems but instead provides a general assessment of the issues and problems of PCCC systems. In particular, the document examines the historical background and evolution of the PCCC technologies; reviews the existing evaluation literature on PCCC systems; discusses a number of cost considerations; presents a possible PCCC evaluation framework; and outlines areas where further research is indicated. As such, the report provides useful information for police departments considering the implementation of one or more of these PCCC technologies, for police analysts, for independent evaluators, and for vendors of PCCC technologies.

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance of the National Institute of Justice (NIJ), the many cities and police departments which participated in our assessment both orally and in writing, the members of the PSE Working Group on PCCC systems, and the officers and supervisors of the Huntington Beach Police Department who assisted us in the field assessment of the Single Project Evaluation Design.

Phil Travers of the National Institute of Justice has served as the project monitor for the research and has provided important substantive and administrative assistance throughout the effort, and Jan Hulla, also of the National Institute of Justice, has provided general support in relating this project to the overall NEP Program. Norbert Schroeder, of the National Telecommunications and Information Administration, also supplied us with useful feedback during the course of the project.

In order to provide an outside review of our work, we established a PCCC Working Group--a group of experts on the use and application of computer technology in police command, control, and communications. Included in the advisory panel were Anthony V. Bouza, Chief of Police, Minneapolis Police Department; Charles R. Busby, Deputy Chief of Police, Dallas Police Department; Kenneth F. Fortier, Inspector, San Diego Police Department; Dr. Mark McKnew, Department of Industrial Management, Clemson University; and Earle W. Robitaille, Chief of Police Huntington Beach Police Department. These people not only met to review an interim draft of this report but they provided valuable insights throughout the project.

A number of other people at PSE, along with outside consultants, have made essential contributions to the project. Dr. Richard C. Larson and Gilbert C. Larson provided conceptual assistance and conducted a number of site visits for the project; Michael F. Cahn provided important administrative and substantive support; Dr. Robert L. Sohn, Jet Propulsion Laboratory, California Institute of Technology, conducted essential research on the costs of PCCC systems; Dr. Floyd J. Fowler, Director of the Survey Research Program at the University of Massachusetts, contributed to the development of various survey instruments; and Jo Ann Wescott and Martha Cleary provided skillful typing and editing of the report.

Without the assistance noted above, this project would not have been possible, but the final responsibility for the contents of the report rests with the authors and PSE.

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EXECUTIVE SUMMARY

This report addresses the use and evaluation of computer-based technology as it relates to police command, control, and communications (PCCC). It is the Final Report for a two-year National Evaluation Project (NEP) Phase I Study funded by the National Institute of Justice to conduct a national assessment of PCCC systems.

Background

PCCC systems were specifically highlighted by the President's Commission on Law Enforcement and the Administration of Justice in 1967 as a possible means of improving police service. Since then there has been a steady movement toward the design and implementation of a wide variety of PCCC-related technologies. However, the initial rate for implementing automated PCCC systems was quite slow--far below early predictions--and results often fell below expectations. In recent years there has been an increase in the number of implemented PCCC systems and applications. There are now more than 80 police Computer-Aided Dispatch (CAD) systems throughout the country which are operational or in the process of being implemented, some 30 Mobile Digital Communication (MDC) systems, approximately 800 Nine-One-One (911) systems, and 3 Automatic Vehicle Monitoring (AVM) systems. However, the success of and approach toward PCCC seems to vary significantly among police departments, and a number of questions remains as to the benefits and impacts of such efforts.

Project Scope

Initially the focus of the project was on police command and control systems. However, we have expanded the study area to include communications as it overlaps with command and control. To highlight this change, we are using the term police command, control, and communications (PCCC) to refer to the overall topic area. The primary focus of the evaluation still remains on command and control; police communications have been included only to the extent that they directly impact command and control issues. Thus, certain telecommunication and data-sharing issues--such as radio signal reception and distortion, radio spectrum allocation, facsimile transmission, and speech scrambling--are not considered in this report. Similarly, switching and sharing of data between different jurisdictions (i.e., through the National Law Enforcement Teletype System, the National Crime Information Center, or the various state and local justice information systems) are also not considered.

Our focus within the expanded topic area is on four PCCC technologies--Computer-Aided Dispatch (CAD), Mobile Digital Communications (MDC), Nine-One-One (911), and Automatic Vehicle Monitoring (AVM)--and two related application areas--Regional Communication Systems (RCSs) and Formal Deployment Methods (FDMs). Our main focus is on CAD, since CAD is at the heart of the PCCC process and provides a framework for bringing together the other command control technologies. CAD has also been more widely implemented than MDC or AVM. An important part of the CAD area is the use of information from CAD for management purposes, and in conducting the study we have not only examined CAD technology, but also the use and impact of the information it creates.

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However, we are certainly interested in the other technologies, especially as they relate to CAD. MDC, often an extension of CAD, has been an important study area. 911 was another area of study, but since there are some eight hundred 911 systems in operation around the country, our ability to look at 911 in much depth has been limited. Therefore, we have examined 911 primarily as it intersects with CAD and the other PCCC technologies/applications. AVM has also been a priority study area, but while AVM potentially ties in very closely with CAD, it has received only a few applications and therefore has received only limited examination. Finally, Regional Communications Systems (RCSs) and Formal Deployment Methods (FDMs) have received modest consideration in this study, particularly as they tie into the PCCC process.

Research Methodology

One of the primary purposes of this project, as an NEP Phase I study, was to review completed evaluations of PCCC systems. However, in the police command and control area, we have found that there have been very few formal evaluations. During the first eleven months of the project, PSE carried out an extensive literature search. We found that while there was much literature available in the PCCC area, the literature was primarily descriptive in nature, and the evaluations which did exist were often incomplete or unreliable. For this reason, we devoted a substantial amount of resources to direct information gathering in the PCCC area. Thus, the findings of this study are based not only on existing information, but also on information gathered directly by PSE.

In order to collect additional data concerning the use and impact of PCCC systems, four different "samples" or data sources were used. Collection of the first sample, the preliminary sample, was an effort to identify all existing PCCC applications. As such the preliminary sample, which included 100 cities, provided the initial set of projects from which the other samples were drawn. It was developed from a review of the available PCCC literature and a series of letters to police departments inquiring as to the status of their PCCC system. The preliminary sample included all cities identified as having CAD, MDC, or AVM, as well as several manual dispatch systems, several advanced 911 systems, and several Regional Communication Systems. The second sample level, the study sample, consisted of 36 jurisdictions drawn from the preliminary sample. The study sample was selected in order to yield a representative mix of systems nationwide. Telephone interviews and follow-up mail surveys were conducted with this group of 36 jurisdictions in order to gather further information concerning the use and impact of PCCC technology. The third sample level was the analysis sample. The analysis sample consisted of 19 cities (chosen from the study sample) selected for site visits. Finally, the test sample--one city--was selected in order to perform a field assessment of our single project evaluation design.

During our surveys and site visits we found that the lack of evaluation data in the literature was also reflected in the field; very few police departments have collected systematic data for the evaluation of their PCCC systems. As a result, this study does not provide detailed evaluation data, but instead provides a general assessment of the problems and issues of PCCC.

Summary of Key Findings

As indicated, there have been very few evaluations of PCCC systems. Further, where evaluations have been done they have focused on process rather than outcome or systemic measures. Most cities seem to have little in the way of good cost data or other PCCC-related data which could be used for system evaluation. It seems that the state of the art of the technologies has not yet advanced to the stage where the calculation of second-order performance measures is considered necessary; instead departments generally seem satisfied if their systems operate smoothly. Therefore, *there is a strong need for comprehensive evaluations and for agreement on a common framework to use in the evaluation process.* Nevertheless, the available information contained in the literature and collected by PSE through surveys and site visits does allow for a general assessment of the problems and issues of PCCC systems.

Computer-Aided Dispatch (CAD) systems have generally been well accepted in the departments using them. There are now more than 80 police CAD systems nationwide which are operational or in the process of being implemented, and a number of police departments are currently planning CAD systems. *The use of CAD technology by the police is undoubtedly a permanent part of law enforcement operations.* In implementing CAD, different police departments have stressed at least three different philosophies or approaches: CAD as a tactical tool for dispatch, CAD to aid in the development of management data, and CAD as one component of an entire computerized police information system. Depending on the philosophy, the focus and nature of CAD seems to vary widely from police department to police department.

In a number of police departments, however, computer-based CAD applications have to a large extent simply replaced previous manual operations. The potential of the computer has not been fully utilized and, in fact, many CAD systems are little more than expensive and fast "electronic conveyor belts." A CAD system may be used not only to assist in the traditional *reactive* response/adjustment function, (such as assigning the closest unit to an emergency call), but also to provide the necessary information for a more *proactive* decision-oriented dispatch operation (such as checking the validity of calls for service, providing information so the complaint officer can advise the citizen on how long to expect before an officer will arrive, standardizing dispatch procedures, etc.).

Strong potential exists for better management--both tactical and strategic--of police field resources and dispatch personnel through the use of the information generated from the elements of a PCCC system, especially CAD. However, *the ultimate impact of PCCC technology will depend on the ability of law enforcement administrators to analyze and use this information effectively.*

Mobile Digital Communications (MDC) systems have also been fairly well accepted in cities where they are used, although MDC has received less than half as many applications as CAD (around 30 as compared to 80 for CAD). *Use of MDC for data base access seems to be farily successful, but when used for dispatching, MDC systems have met with varied results.* In fact, a few departments have tried MDC and decided against it. In terms of benefits, MDC systems can provide easier and quicker access to data bases, more rapid communications, and more secure communications. Many police departments also expect MDC to help reduce voice congestion, but it appears from the results to date that this may not be a realistic MDC objective, although MDC may allow for increased *air communications*. There are also a number of potential problems associated with MDC use. It is also important to realize that putting a terminal in the patrol car may eventually result in a significant change in police work and raises questions about citizen privacy and policy philosophy.

Automatic Vehicle Monitoring (AVM) systems have received only a handful of applications, and these have met with mixed success. *Most departments seem to feel that AVM systems have potential but question whether the benefits of such systems justify the cost.* The three cities which currently have AVM are all experiencing some combination of technical and behavioral difficulties. The potential of AVM may be there--especially if AVM for police becomes part of an overall AVM system for a wide range of transportation users (i.e., taxis, buses, delivery systems, etc.)--but it has yet to be realized.

The concept of *Nine-One-One* (911) seems sound, and the use of 911 is far-reaching and growing. However, full-scale implementation of 911 is being hindered by both political and technical problems, and there seems to be a wide range of opinion as to whether the benefits will outweigh some of the problems and costs. One of the greatest barriers to 911 implementation appears to be the disparity between telephone exchange boundaries and political boundaries. A second set of 911 implementation problems relates to funding; many police departments feel that the state should pay for 911, since 911 is often state-mandated, while the states feel that the jurisdictions themselves should be responsible for 911 funding. Most 911 implementations appear to have been essentially independent where local agencies have planned and implemented 911 on their own. *There is a strong need in the 911 area for states to provide policy guidance, technical assistance, and funding provisions for local agencies.*

Most of the 800 existing 911 systems are basic systems. However, there are also a handful of 911 systems nationwide which include advanced features such as automatic number identification, automatic location identification, and selective routing. Further evaluation is needed regarding these advanced features, and the impact of these options on personal privacy and confidentiality has not yet been fully resolved.

Relating to the above four technologies, *many cities believe that new PCCC systems (especially CAD) will reduce response time. However, we have found no solid, substantive data (regarding CAD or other PCCC technologies) to support this.* In fact, where studies have been done they seem to show little or no reduction in response time. For example, several evaluations have been done regarding AVM in St. Louis, but they show no significant improvements

in travel time due to AVM. Furthermore, there are questions as to what effect, if any, reductions in response time will have on apprehension rates, since citizen reporting delays are often quite long.

In the study we also examined the general *implementation process* for computer-based PCCC applications. *We found that the implementation of PCCC technology requires more than technical expertise and that the consideration of behavioral and institutional factors (both in system design and system implementation) is also critically important.* In discussing communication problems, many cities emphasized problems relating to personnel and training. The emphasis on such problems highlights the fact that new technology alone is not enough to resolve communication problems. In fact, many problems are behavioral and can only be resolved by better management and greater sensitivity to personnel-related issues.

In terms of system design, systems in which line personnel were involved in system planning seem to have fewer problems than systems in which the intent of the new technology was not communicated adequately during the development stages of the system. In terms of system implementation, the nature of the relationship between police departments and computer vendors is also critical to system success; departments with carefully defined vendor performance specifications in general have more successful PCCC systems than those departments with uncertain or ill-defined vendor performance specifications.

For departments interested in implementing PCCC systems, it appears that a seven-step approach is appropriate. These steps include: (1) needs assessment; (2) a careful identification of PCCC philosophy and approach (e.g., a management versus operational perspective); (3) preparation of a needs statement, generally in the form of a request for proposal (RFP); (4) responses from vendors to the RFP and selection based not only on cost but also on quality concerns; (5) a specific commitment of vendors to a measurable level of performance; (6) careful orientation, training, and involvement of operational personnel in the development of the system; and (7) evaluation and revision to assure that the system continues to meet the ongoing needs of users.

Based on these findings, it is worth noting once again that this report stresses the need for specific evaluations of PCCC systems--evaluations to examine not only input and process measures but also outcome and systemic results. A framework for conducting such evaluations has therefore been developed as a part of the project, and key hypotheses/issues have been identified. The report also points out the need for a PCCC information clearinghouse to facilitate the transfer of ideas and technologies. Such a clearinghouse could include the development of up-to-date PCCC planning documents, an ongoing effort to remain abreast of PCCC developments, and specific efforts to facilitate the transfer of knowledge through newsletters and workshops.

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1 INTRODUCTION

1.1 THE FACT OR FANTASY OF PCCC SYSTEMS

At 7:16 p.m. on a Thursday night in August, a passerby notices two gunmen holding up a neighborhood liquor store. The passerby, wanting to notify police as soon as possible, walks quickly to an outdoor public telephone located approximately one-half block away. Without having to search for a dime, the caller picks up the phone and calls 911--the standardized U.S. emergency number--by pushing appropriate buttons on the telephone instrument. A voice on the other end answers quickly, "Public emergency, may I help you?" This 911 telephone operator handles emergencies related to police, fire, and ambulance. As soon as the telephone connection is made, the caller's telephone number and geographical location are automatically displayed on a digital display board above the call-taker, who is seated in front of a computer terminal. Within seconds the call-taker ascertains that a felony is in progress and assigns top priority to the call by pressing the DISPATCH button on the computer terminal.

The computer rapidly selects two patrol units to respond to the location of the caller. By searching its geographical files, the computer determines that the passerby is calling from a phone booth located in police beat number five. However, the computer also has up-to-the-second location information regarding each of the patrol units in the city. Utilizing this information the computer determines that Cars Three and Six in contiguous beats are two to three minutes closer than the beat car (Number Five), which is on a far corner of the beat away from the incident. Within seconds, the computer sends a digitally dispatched message to Cars Three and Six; this message is displayed on a small television screen located just below the police radio in each of the two police patrol cars. The total elapsed time between pushing the digits 911 and the dispatch of Units Three and Six is approximately 15 seconds.

As Units Three and Six are travelling to the scene, the actual location of the incident (rather than the location of the public telephone) is broadcast over voice channel radio from the call-taker to the responding units. The first unit arrives on the scene within one and a half minutes and the other arrives in two and a half minutes. The two suspects in the case are arrested at the scene.

Is this scenario fact or fantasy? As the contents of this report will demonstrate, each of the technological elements utilized in this particular situation has been implemented in one or more police departments in cities in the United States. For instance, the telephone number 911 is currently implemented in many cities throughout the United States; however, 911 as outlined in the incident above has two advanced features--ANI (Automatic Number Identification), and ALI (Automatic Location Identification)--which are currently utilized in only a few cities. The ability of the call-taker to notice the telephone number and location of the caller was dependent upon these advanced features of 911.

Also in the illustration, the call-taker sat in front of a computer terminal which consisted of a television-type display tube and a typewriter-like set of keys. This terminal is connected directly to a high-speed digital computer which acts as the heart of a Computer-Aided Dispatch (CAD) system for this particular police department. Many cities in the U.S. currently have some form of CAD system. However, we are aware of no CAD system which automatically integrates the identification capability of an advanced 911 system--a capability which was hypothesized in the above scenario.

The computer quickly determined that Units Three and Six were closer than the beat car and selected them for dispatch. This was done using an Automatic Vehicle Monitoring (AVM) system which provides real-time location estimates of each patrol vehicle. Only three cities in the U.S. have currently operating AVM systems, and none is tied in automatically to the dispatching function in the way we have described. The capability of forwarding the dispatch order instantaneously and digitally to the police vehicles requires integration of the CAD system with a Mobile Digital Communications (MDC) system. Such a system requires a mobile digital terminal in each police car and either one-way or two-way digital communication capabilities between the dispatcher and the police cars. A number of U.S. cities are now employing MDC systems.

Thus, the scenario above is in some sense both fact and fantasy. It is fact in that the technology for each of the components exists, and parts of the scenario are implemented in departments throughout the country. It is fantasy to the extent that no department has an integrated system which encompasses all of the capabilities discussed. It is fact because several departments have successfully determined how to integrate portions of such technological innovations with concerns for personnel, training, morale, incentives, and reward structures. It is fantasy because no department has yet to implement such major technological innovations without experiencing some form of personnel resistance or negative institutional inertia.

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At 7:27 p.m. on the same evening, Mrs. Jones calls 911 and reports that upon returning to her house for the day it is obvious that someone has broken in and stolen various articles of personal property. However, there is no evidence that the burglar is still on the scene, and the actual crime could have taken place up to 10 hours earlier. Mrs. Jones, located in the beat associated with Car Nine, is advised by the call-taker that Car Nine is currently busy on a previous call for police assistance. Moreover, the busy period of the entire department is just commencing, so Mrs. Jones is given the following alternatives: either

she can schedule an appointment with Car Nine at 10:00 a.m. or 11:00 a.m. the following morning, or she can have Car Nine come to her home that evening, but the delay estimated by the CAD system is 60 minutes. Mrs. Jones chooses the latter alternative, willing to accept the 60-minute delay in order to file a police report and have this matter behind her when she goes to bed that evening. By 8:27, Car Nine has been assigned to another high priority call and is still not available to travel to Mrs. Jones's location. A nonbusy call-taker is notified of the excess delay over that anticipated and predicted to Mrs. Jones. Using the Automatic Number Identification feature of 911, the computer has automatically recorded Mrs. Jones's telephone number for situations like this in which a citizen has to be called back and notified of unanticipated delay. Indeed, she is called back and told that an additional 15 minutes delay can be anticipated. Then, roughly 13 minutes later, Car Nine is dispatched to Mrs. Jones's location. The car arrives on the scene about 4 minutes later and gathers the necessary information on the burglary from Mrs. Jones, who has been continuously appraised of delays in response to her call.

In this case the call-taker has assigned a lower priority to the call reported by Mrs. Jones than to the earlier call which was a felony in progress. With the aid of the CAD system, the call-taker and the dispatcher can better manage the demands for police service. In this case, such management means the offer to Mrs. Jones to either schedule an appointment with the police sometime during a relatively slack period during the mid-morning hours or to delay service on her call until the current level of congestion is greatly reduced. In this case she chose the latter alternative. Since it actually required roughly 75 minutes until the police car was dispatched, the police department utilized the ANI feature of the 911 system to obtain Mrs. Jones's phone number and to call her back to advise her of the unanticipated excess delay.

Again, this scenario is both fact and fantasy. It is fact in that studies have shown that callers seeking police assistance for relatively low priority or nonurgent calls will be quite satisfied with police response if they are advised of any anticipated delay in response. Further experiments concerning the management of police demand have already been successfully tried, for example in Wilmington, Delaware. However, it is fantasy because no police department has linked advanced PCCC technology with the concepts of managing police demand (noted above) to form what we will refer to later as an "intelligent PCCC system." Rather, technological innovations such as Computer-Aided Dispatch, Mobile Digital Communications, and Automatic Vehicle Monitoring have given police departments the potential means for responding more effectively and more efficiently to citizen demand, but in many cases this potential has not been met.

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At 9:10 that evening, Mr. Smith calls 911 and reports a disturbance in the adjacent apartment in his building. He reports that a husband and wife seem to be yelling at each other and throwing objects around the apartment. Approximately 3 minutes later, a dispatcher sends a nearby available police car to the scene, and the car arrives approximately 7 minutes later. The total response time in this case is about 10 minutes. However, past statistics have shown that once at the scene, 90 percent of similar incidents are successfully handled by the police within 30 minutes of time at the scene. In this case the dispatcher has heard nothing additional from the officer by 9:50 p.m., which is the 30-minute mark at the scene. The dispatcher attempts to contact the responding officer by radio and fails to achieve contact. At that time the dispatcher contacts two additional nearby patrol cars to respond quickly. Upon arrival, the new officers find that the originally dispatched officer is in a serious situation with the husband and wife who turned on the officer and injured him seriously. The new officers manage to subdue the husband and wife and call for ambulance assistance for the injured officer.

In this case, again both fact and fantasy, accurate management statistics on the distribution of time required to handle various types of police events allowed the dispatcher to notice a situation in which the officer's safety was in jeopardy. The CAD system automatically tested for such circumstances and notified the dispatcher when the possible problem arose. This, too, is a potential capability of most current CAD systems, but a capability which is not widely implemented or utilized.

1.2 THE PURPOSE AND SCOPE OF THE STUDY

The scenarios outlined above provide an illustration of both the current use and the potential of PCCC systems. In many cases our expectations and the potential still exceed the reality. Within this context the purpose of this report is to focus on the actual use and evaluation of computer-based technology as it relates to police command, control and communications (PCCC). What is the state of the art? To what extent is this technology being applied successfully? What issues and problems do we face? And what is the potential for the future?

PCCC systems were specifically highlighted by the President's Commission on Law Enforcement and the Administration of Justice in 1967 as a possible means of improving police service. Since then there has been steady movement toward the design and implementation of a wide variety of PCCC-related technologies. The initial rate for implementating automated PCCC systems was quite slow--far below early predictions--and results often fell below expectations. In recent years there has been an increase in the number of implemented PCCC systems and applications. There are now more than 80 police Computer-Aided Dispatch (CAD) systems throughout the country which are operational or in the process of being implemented, some 30 Mobile Digital Communications (MDC) systems, and approximately 800 Nine-One-One (911) systems. Despite this growth trend, the success and approach towards PCCC seems to vary significantly among police departments, and a number of questions remains as to the benefits and impacts of such efforts.

The time is therefore appropriate for a national assessment of PCCC systems--to review the Commission's initial focus, to determine what has occurred over the last decade, and to identify what can be learned from past experiences. On October 1, 1978, Public Systems Evaluation began such a nationwide assessment. The project was a two-year Phase I National Evaluation Program (NEP) assessment funded by the National Institute of Justice. This document is the Final Report for the project.

Although this project is part of the National Evaluation Program (NEP), it differs somewhat from other NEP studies. The primary objectives of an NEP Phase I study* are: accumulation of knowledge in the study area, both in terms of identifying existing projects and reviewing results of such projects; identification of "knowledge gaps" in the area; estimation of the cost and value of filling those gaps; development of experimental evaluation designs to obtain further information; and refinement and limited pre-testing of such evaluation designs.

In most NEP Phase I studies, the first task (collection of information in the study area) involves a review of completed evaluations; generally only a limited number of site visits are made, and extensive data collection and analysis is not carried out. However, in the police command, control, and communications area, we found that there have been very few formal evaluations. As the first part of the study, PSE carried out an extensive literature search to identify the existing knowledge and the "knowledge gaps" in this area. We found that while there is a great deal of literature available in the PCCC topic area, most of the literature is primarily descriptive in nature, and the evaluations which do exist are often incomplete or unreliable. For this reason, we have also devoted a substantial amount of our resources to direct information gathering to identify all cities having any of the technologies in question (through a series of letters to police departments), to gather further information on use, cost, and impact from a subset of these cities (through telephone and mail surveys and site visits to selected cities), and to assess the feasibility of a single project evaluation design for PCCC systems (through an on-site assessment in one particular city). Thus, the findings of this study are based not only on existing information, but also on information gathered directly by PSE.

We also found that the lack of evaluation data is reflected in the field, as very few police departments have collected systematic information for the evaluation of their command and control systems. For this reason, the study does not provide detailed evaluation data, but instead provides a general assessment of problems and issues--and in some cases our findings are based on PSE's informed judgment rather than extensive data.

Before proceeding it is important to comment briefly on the scope of the PCCC topic area. The initial focus of the project was on police

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*As outlined in the preliminary Request for Proposal: "Announcement for Preliminary Proposals to Conduct a National Assessment of Police Command and Control Systems," National Institute of Law Enforcement and Criminal Justice, April 1978.

command and control systems. However, we expanded the study area to also include communications as it intersects with command and control. To highlight this change, we are using the term police command, control, and communications to refer to the overall topic area. The primary focus of the evaluation remains on command and control; police communications have been included only to the extent that they directly impact command and control objectives. Thus, certain telecommunication issues, such as radio signal reception and distortion, radio spectrum allocation, facsimile transmission, and speech scrambling are not considered in this report. Similarly, switching and sharing of data between different jurisdications (i.e., through the National Law Enforcement Teletype System, the National Crime Information Center, or the various state and local justice information systems) are also not considered.

This study focuses on four PCCC technologies--Computer-Aided Dispatch (CAD), Mobile Digital Communications (MDC), Nine-One-One (911), and Automatic Vehicle Monitoring (AVM)--and two related application areas--Regional Communication Systems (RCSs) and Formal Deployment Methods (FDMs). In the following chapters, the report will:

- examine the historical background of these technologies (Chapter 2)
- provide a general assessment of existing systems (Chapter 3)
- summarize the implications of the research (Chapter 4)
- outline areas where further research is needed (Chapter 4)
- In addition, a review of a number of cost considerations for such systems will be considered in a separate Appendix (A).

Also, as a part of this project we developed a Single Project Evaluation Design to evaluate PCCC systems and conducted a field assessment of this design in the Huntington Beach Police Department. The results of this effort are published in a separate volume and are available from the National Institute of Justice, U.S. Department-ment, Washington, D.C.*

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*Kent W. Colton and Bruce T. Dunn, A Single Project Evaluation Design for PCCC Systems, Cambridge, MA: Public Systems Evaluation, Inc., December 1980.

2 BACKGROUND ISSUES AND STUDY FRAMEWORK

This chapter describes some of the key factors which have led to the development of PCCC technology, develops a study framework to be used in the assessment, and outlines PSE's study methodology.

2.1 FACTORS IN DEVELOPMENT

PCCC applications during the past decade have been influenced by three critical factors: (1) the active role assumed by the federal government in encouraging the adoption of new technology; (2) the availability and use of computer technology; (3) and a strong desire on the part of police departments to improve the performance of their PCCC system.

2.1.1 FEDERAL GOVERNMENT

PCCC systems were specifically highlighted by the President's Commission on Law Enforcement and Administration of Justice (the Crime Commission) as a possible means of improving police service. In their final report [1967 (a), p. 252] the Commission stated:

> "The entire police command-and-control function should be subjected to a basic reexamination taking full account of the promising new technologies offered by computers and communications links . . . An experimental program to develop a computer-assisted command-and-control system should be established with Federal support."

The creation of the Law Enforcement Assistance Administration (LEAA) added large-scale federal resources to help purchase such equipment, and the pressure of vendors to sell their products (starting prior to 1967 but heightening as the Vietnamese War ended and technology-oriented industries sought to increase their domestic market) also contributed to the expansion of computer-related innovations.

2.1.2 COMPUTER TECHNOLOGY

Contributing to the growth of computer technology has been a steady decrease in the cost of computers, accompanied by increased computational capabilities. Two primary reasons for these changes are device miniaturization and efficient memory media. New types of memory devices have also helped to make computers smaller, cheaper, and more efficient. Both miniaturization and innovation in memory media have changed computer technology so that computers no longer need to be used as systems unto themselves, but can be used as components of larger systems (such as command and control systems).

Since the Crime Commission's recommendations, the number of computer applications established by the police has been steadily increasing.

However, despite the implementation of the technology, the large majority of computers used by police are still "routine" applications in which the technology is used to carry out straightforward, repetitive information processing activities, such as maintaining traffic records or real-time police patrol and inquiry files. When computer use extends to "non-routine" efforts--such as resource allocation models or computer-aided dispatching (CAD) systems, in which the machine begins to become a tool for decision making, control, and strategic planning (for example the scenarios included in Chapter 1)--the results to date have been more disappointing.

2.1.3 PCCC INNOVATIONS

In an effort to improve and modernize PCCC, a variety of technological innovations were proposed and implemented. Computer-Aided Dispatching (CAD) systems provide the framework for bringing together many of these new tools through the partial automation of the call answering, processing, and dispatching activities of the police communications center. CAD automatically matches the address of a call-for-service and a police patrol beat through a computerized geographic file, and instantly recalls dispatch data. CAD by itself does not track the location of police vehicles, so Automatic Vehicle Monitoring (AVM) systems were also suggested, along with other technological changes. These included "911" emergency telephone systems; computer-based formal deployment methods to assist in the allocation of police resources; regional communication systems; and mobile and portable digital communication terminals to allow officers in the street to communicate digitally with the dispatch center.

Many of these PCCC innovations are "routine" where the technology basically replaces a previously manual activity such as the transfer of information from the telephone operator to the dispatcher. However, some innovations also allow for a number of "non-routine" activities, such as tracking and monitoring vehicle location, automatically timing the length of calls and raising a "flag" if a call takes longer than a specified time, or providing new information to be used for management.

2.2 STUDY FRAMEWORK

As mentioned earlier, we have expanded the focus of the project to include communications as it intersects with command and control. However, the PCCC function has too often been lumped solely with the communications functions, or at best viewed in a fragmented manner in terms of its parts (e.g., communications, patrol force allocation, vehicle location, telephone answering, etc.). These approaches, if not broadened, can be misleading and incomplete. In this project we have defined PCCC more broadly than just communications. Our focus is on managing, directing, and controlling police activities with the overall intent of responding and delivering services to the public. Therefore, broad functional components, which correspond to this

more comprehensive view of PCCC have been identified: needs identification, status monitoring, response/adjustment, and management.

We have selected four basic PCCC technologies which are related to these functional components, for primary emphasis in our study: Computer-Aided Dispatch (CAD), Mobile Digital Communications (MDC), Nine-One-Nine (911), and Automatic Vehicle Monitoring(AVM). In addition, there are two applications related to these technologies which we have also reviewed as appropriate: Regional Communication Systems (RCSs) and Formal Deployment Methods (FDMs).* Taken together these four technologies and two applications encompass the PCCC process.

As illustrated in Exhibit 2.1, the approach adopted by this study is based on a three-dimensional framework consisting of four basic functions of the PCCC process; six distinct technologies and applications that have been recently implemented in the PCCC area; and four sets of evaluation measures that should be applied during the assessment. Thus, ideally, one could consider the PCCC assessment problem as being composed of 96 separate assessments, each one focusing on a set of evaluation measures which are employed to assess the impact of a specific application on a particular PCCC function. Unfortunately, it appears from our review of the PCCC literature that the available information does not allow for such detailed assessments. Nevertheless, in an effort to provide a more *definitive definition* of the PCCC topic area, it is enlightening and systematically convenient to view the PCCC assessment problem in terms of the three components identified in Exhibit 2.1. With this in mind, the subsections which follow will delineate the specific steps and functions involved in the command and control process; discuss the PCCC technology and application areas that will receive specific attention in our study; and describe the measures that will be used to examine the various command and control technologies.

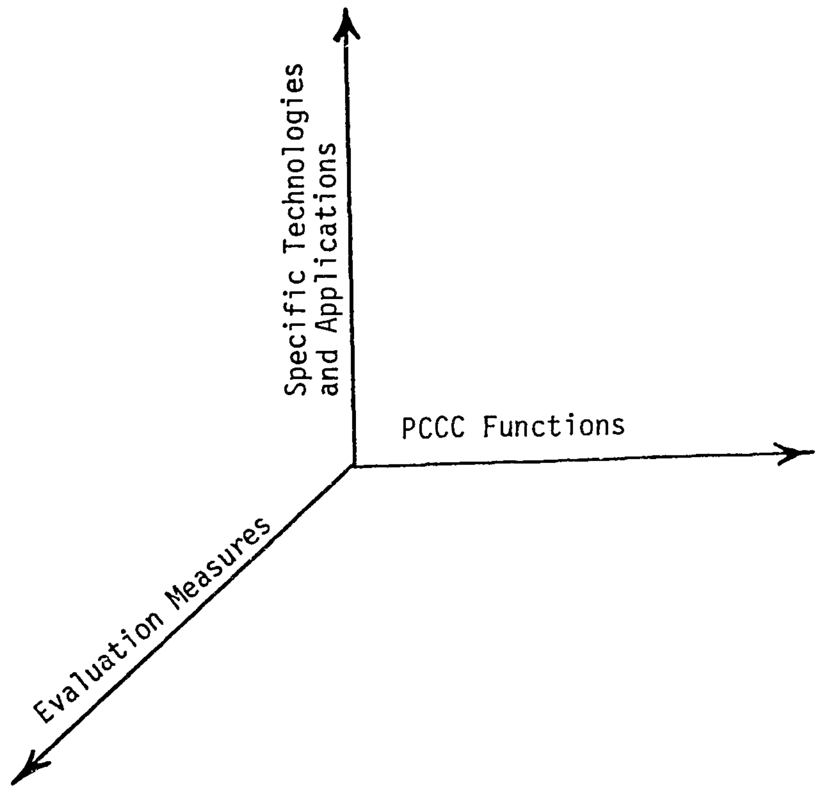
2.2.1 PCCC FUNCTIONS

Functionally, an effective PCCC system must be able to *monitor*, on an immediate or tactical basis, the status of the available police resources so that appropriate actions can be taken to *respond* to the needs that are *identified*. Additionally, on a longer-term or strategic basis, the PCCC system must be able to *manage* the resources so as to ensure their productive deployment and use. In summary, the four PCCC functions are needs identification, status monitoring, response/adjustment, and resource management; these functions are further detailed in

*Formal Deployment Methods (FDMs) refer to formal methods or techniques of deploying resources, particularly as these decisions relate to the command and control process. They include hazard formulas and more sophisticated models such as the Hypercube and PCAM (Patrol Car Allocation Model) models.

Exhibit 2.1

PCCC Study Framework



PCCC Functions:

- Needs Identification
- Status Monitoring
- Response/Adjustment
- Resource Management

Evaluation Measures:

- Input
- Process
- Outcome
- Systemic

Specific Technologies and Applications:

- Nine-One-One (911)
- Computer-Aided Dispatching (CAD)
- Automatic Vehicle Monitoring (AVM)
- Mobile Digital Communications (MDC)
- Formal Deployment Methods (FDM)
- Regional Communication Systems (RCS)

Exhibit 2.2 in terms of specific PCCC actions, related time measures, and PCCC technologies and applications.*

2.2.2 PCCC TECHNOLOGIES AND APPLICATIONS

As noted previously, we have selected six major PCCC technologies and applications for consideration. These six technologies are arranged by priority in our assessment process. Our main focus is on CAD, since this technology is at the heart of the PCCC process and provides a basis for bringing together the other command and control technologies. CAD has also received greater nationwide application than MDC or AVM. An important aspect of CAD is the use of information generated from the system for management purposes. In conducting the study we have not only examined the technology itself, but also the actual use and impact of the new information it creates.

MDC, often an extension of CAD, is a second important study area. Nine-One-One is another area of study, but since there are some 800 Nine-One-One systems in operation around the country, our ability to look at 911 in much depth is limited. Therefore, we are interested in 911 mainly as it intersects with CAD and with other PCCC technologies/applications.** AVM is also a priority study area. However, while AVM potentially ties in very closely with CAD, it has received only a few applications and therefore can receive only limited examination.

Regional Communications Systems (RCSs) are an important application of the above four technologies. As noted in Exhibit 2.2, RCSs may relate indirectly to all phases of the PCCC process and may utilize all the various PCCC technologies. Although we have not been able to devote major resources to the review of RCSs, they are of interest in this study in that they extend the use of command and control technologies to regional and multi-jurisdictional situations.

Formal Deployment Methods (FDMs) will also receive modest consideration in the study. While FDMs do not necessarily relate to PCCC technologies per se, the allocation and deployment of resources are obviously tied closely to the command, control and communication process. Our concern in this study, then, is with FDMs only as they relate to PCCC processes and technologies, especially CAD.

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*Although some police administrators do not consider the needs identification function as being within the command and control area, the identification of a need for police assistance is the basis for nearly all command and control decisions. Thus, it seems appropriate to include needs identification as one of the PCCC functions.

**Another reason we have not carried out an in-depth study of 911 is because SRI International was commissioned to conduct such an effort. Reference to their work is included as part of Chapter 3.

Exhibit 2.2

PCCC Functions

PCCC Functions	Specific PCCC Actions	Related Time Measures[1]		Technologies and applications as they relate to PCCC[2]
•Needs Identification	•Incident occurs	•Incident occurs →	Reporting Time	
	•Citizen calls for police service, patrol officer identifies activity requiring response, or citizen contacts police officer directly	•Call-for-service initiated →	Telephone Delay Time	911
	•Police telephone operator or complaint evaluator receives call, determines the facts, and records the essential information	•Call answered →	Operator Processing Time	CAD
•Status Monitoring	•Police dispatcher determines the status (i.e., location and availability) of resources based on ongoing monitoring activities	•Status information assessed →	Dispatcher Processing Time	CAD, MDC, AVM
•Response/ Adjustment	•Police dispatcher determines the appropriate response (e.g., patrol unit response, detective unit response, call-back response, etc.) to the incident, including a possible delay in response			CAD, AVM
	•If appropriate, police dispatcher communicates instructions to appropriate unit(s) to respond	•Response unit(s) dispatched →	Travel Time	MDC, CAD
	•Response unit(s) travel to the incident	•Response unit(s) arrive at scene →	On-Scene Time	AVM
	•If necessary, police dispatcher makes tactical adjustments (e.g., assignment of back-up units, re-assignment of units to a higher priority incident, ect.) Also, communications center may make support check on field unit requests for information (e.g., license check, person check, etc.)			CAD, AVM, MDC
	•Response unit(s) report completion of service	•Service completed →		MDC, AVM, CAD
•Resource Management	•Police department maintains data generated in the course of performing the above 3 PCCC functions for subsequent analysis			Data generated from 911, CAD, AVM, MDC
	•Police administrator decides on the overall allocation of police resources, based on the analysis of the above data and supported by appropriate resource allocation models			FDM, using data generated from 911, CAD, AVM, MDC

[1]The time measures are *not* drawn to scale. Other composite time measures include *dispatch delay time* (i.e., sum of the operator and dispatcher processing times), *response time* (i.e., sum of the dispatch delay and travel times), and *service time* (i.e., sum of the travel and on-scene times).

[2]Regional Communications Systems (RCS) may relate indirectly to all phases of the PCCC process and may utilize all of the various PCCC technologies noted above, since they extend the use of these technologies to regional and multi-jurisdictional situations.

2.2.3 EVALUATION MEASURES

Four sets of evaluation measures are identified in Exhibit 2.3. In our PCCC system assessment we have attempted to identify and collect evaluation measures within each set, but in many cases information concerning all four--especially outcome and systemic data--is not available.

Although the first three sets of measures--input, process, and outcome--have been proposed and discussed at length in the evaluation literature, the literature is not consistent regarding their respective definitions. For this reason, Exhibit 2.3 identifies the measures in greater detail. It should be noted, for example, the performance measures are a part of the *process*--not outcome--measures. Thus, response time is a *process* measure, although it may in turn affect outcome measures such as the apprehension rate as well as the attitude and/or behavior of citizens, criminals, or police. Outcome measures include only those relating to attitudes, behavior, and crime, since the ultimate aim of any police-related program, including PCCC programs, is to effect a change in one or more of these subgroups of outcome measures.

In general, the input and process measures serve to "explain" the resultant outcome measures. Input measures alone are of limited usefulness since they only indicate a program's *potential*--not actual--performance. On the other hand, the process measures do identify a program's performance but do not consider the impact of that performance. Finally, the outcome measures are the most meaningful observations since they reflect the ultimate results of the program. As might be expected, most of the available PCCC assessments or evaluations are fairly explicit about the input measures, less explicit about the process measures, and somewhat fragmentary about the outcome measures.

The fourth set of evaluation measures--the *systemic* measures--can also be regarded as impact measures but have been overlooked to a large extent in the evaluation literature. The systemic measures can be regarded as broad impact measures; they allow the program's impacts to be viewed from a total systems perspective. As listed in Exhibit 2.3 Tien and O'Donnell [1978] have identified three contexts in which to view the impact of a program. First, the program's impact on the immediate organization and on other organizations can be assessed. For example, a management information system may change or may be changed by the power structure of an organization.

Second, the pertinent input, process, and outcome measures can be viewed over time, from a longitudinal perspective. In this manner, the impact of the program on a particular system can be assessed not only in comparison to an immediate "before" period but also in the context of a longer time horizon. Thus, the successful implementation of a CAD system in a police department which has had no technological innovations during the past ten years is more significant than an equally successful implementation of a similar system in a department which has recently implemented a number of other innovations.

Exhibit 2.3

Program Evaluation Measures

INPUT

. Program Rationale (Objectives, Assumptions, Hypotheses)
. Program Responsibility (Principal Participants, Participant Roles)
. Program Funding (Funding Level, Sources, Uses)
. Program Constraints (Technological, Political, Environmental, Legal)
. Program Plan (Performance Specifications, System Design, Implementation Schedule)

PROCESS

. Program Implementation (Design Verification, Implementation Cost)
. Program Operation (System Performance, System Maintenance, System Security, System Vulnerability, System Reliability, Operating Cost)
. Concurrent Programs (Technological, Physical, Social)

OUTCOME

. Attitude (Citizen (Fear), Criminal, Police)
. Behavior (Citizen, Criminal, Police)
. Crime (Detection, Deterrence, Apprehension, Displacement Level)

SYSTEMIC

. Organizational (Intra-Organizational, Inter-Organizational)
. Longitudinal (Input, Process, Outcome)
. Programmatic (Derived Performance Measures, Comparability, Transferability, Generalizability)

Source: [Tien and O'Donnell, 1978]

Third, in an overall programmatic context, the systemic measures include: (i) second-order systems performance measures (e.g., cost-benefit and productivity measures); (ii) a comparison of program results with other findings of similar programs; (iii) an assessment of the potential of transferring the program to other locales or jurisdictions; and (iv) a determination of the extent to which the program results can be generalized. In terms of generalization, it is important not only to make, for example, a police recommendation that CAD should be promulgated, but also to define the limits of such a recommendation.

2.3 STUDY METHODOLOGY

Information about PCCC for this report was collected in a two-stage process: first an extensive search of the literature and available information, and second, a direct collection effort of surveys and site visits. During the first eleven months of the project, substantial time was spent collecting PCCC-related literature and other information relating to current applications of PCCC technology. A variety of information sources were used, including: letters and phone calls to police departments and suppliers of PCCC technology; a review of the documents available from the National Criminal Justice Reference Service (NCJRS), PSE, and other research firms; reviews of magazine indices; and discussions with informed persons. Our literature search netted 239 PCCC-related documents; selected items are listed in the bibliography at the end of this report.

We found that there have been very few formal PCCC evaluations and that little is known about the actual impact of PCCC systems. Most of the available literature consists of feasibility studies, trade journal articles, and subjective assessments made by police administrators. For this reason, we devoted a substantial amount of effort in this study to direct information gathering in the PCCC area utilizing a range of research samples. As outlined in Exhibit 2.4, four sets of research samples were used: the *preliminary sample* which included all cities identified as having any of the relevant PCCC technologies; the *study sample* includes those cities which received telephone and mail surveys; the *analysis sample* where we made the site visits; and the *test sample*. The various samples were not used to collect detailed evaluation data from particular PCCC systems but instead were used as a basis for a general assessment of the problems and issues of PCCCs. As such, the study methodology does not include rigorous control measures (for example, no control group of cities was used), and to a certain extent our findings are somewhat subjective.

The largest sample, the *preliminary sample* (shown in Exhibit 2.5), was the initial set of projects from which the other samples were drawn. The preliminary sample was developed based on a review of the available PCCC literature and a series of initial letters which were sent to a number of different police departments. Because of focus of the project

Exhibit 2.4

Assessment Sample and Task Relationships

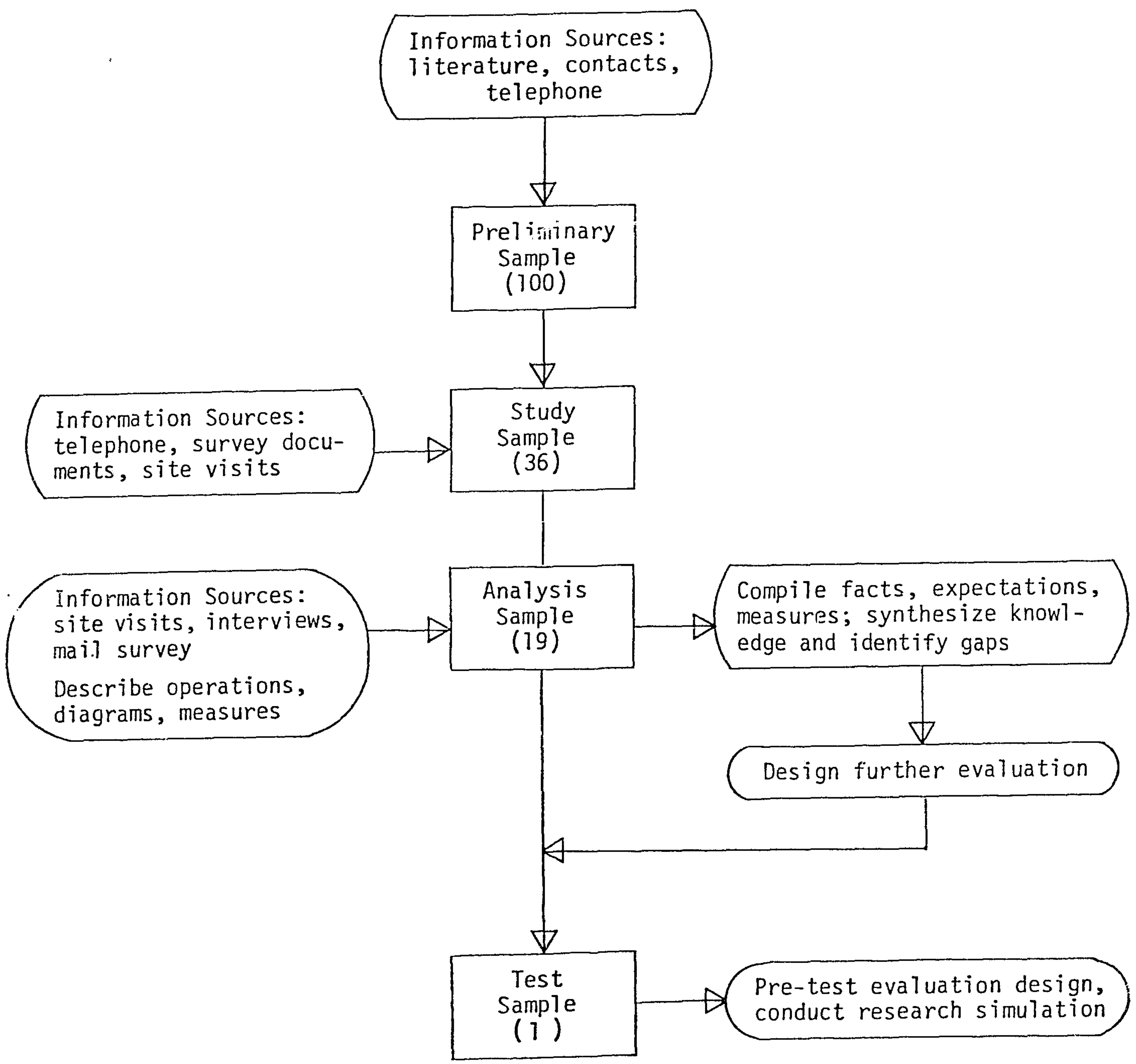

Exhibit 2.5

PCCC Preliminary Sample

Jurisdiction	Associated PCCC Technologies				
	911	CAD	MDC	AVM	RCS
Alameda County, CA	x				x
Albany, NY		x	x		
Anoka County, MN					x
Atlanta, GA		x	(x)[2]		
Atlantic City, NJ	x	x	x		
Aurora, CO	x	x	(x)		
Baltimore County, MD	x	(x)			
Birmingham, AL	x	x			
Boston, MA	x	x			
Broward County, FL	x	x			x
Camden, NJ	x	x			
Champaign, IL	x	x			
Charlotte, NC	x	x			
Chesapeake, VA		x			
Chicago, IL	x		x		
Cleveland, OH			x		
Colorado Springs, CO	x	(x)			
Columbus, OH		(x)			
Cranston, RI		x			
Dade County, FL	x	x			x
Dallas, TX		x	x	x	
De Kalb County, GA	x	x	x		
Denver, CO	x	(x)			
Detroit, MI	x	x	x		
Fort Worth, TX		x			
Fresno City, CA		x	x		
Fresno County, CA		x			
Garden Grove, CA		x			
Garland, TX		x			
Glendale, CA		x	x		
Greensboro, NC		(x)	(x)		
Hamilton County, OH		x			x
Hampton, VA		x	[x][3]		
Hennepin County, MN			x		x
Hillsborough County, FL		x	x		x
Huntington Beach, CA		x	x	x	
Indianapolis, IN	x	x			
Jackson, MS	x	x			
Jacksonville, FL		x			
Johnstown, PA		[x]			
Kansas City, MO			[x]		
Kenosha, WI		x			
Lake County, IN		x			
Lansing, MI	x	(x)			
Las Vegas, NV		x	x		
Long Beach, CA		x	(x)		
Los Angeles, CA		(x)	x		
Los Angeles County, CA		x			
Madison, WI		x			x
Memphis, TN		(x)			
Miami, FL	x	x	(x)		

Jurisdiction	Associated PCCC Technologies				
	911	CAD	MDC	AVM	RCS
Milwaukee, WI			x		
Minneapolis, MN		x	x		
Moline, IL	x		[x]		
Montclair, CA				[x]	
Multnomah County, OR		x			x
Muskegon County, MI	x				x
Nashville, TN	x				
Newark, NJ	x	x	x		
New Castle County, DE		(x)			
New Orleans, LA		x	[x]		
New York City, NY	x	x	x		
Norfolk, VA		(x)			
North Las Vegas, NV		x			
Northbrook, IL		(x)			
Oakland, CA	x	x	x		
Oak Park, River Forest, Forest Park, IL	x	x			x
Oklahoma City, OK		(x)			
Palm Beach County, FL		(x)	x		
Peoria, IL	x	x			
Phoenix, AZ		x	x		
Philadelphia, PA	x	x			
Pinellas County, FL	x	x	x		x
Portland, OR		x			x
Prince Georges Cnty., MD	x	x			
Quad Cities (IA, IL)					(x)
Reading, PA		(x)			
Rock Island, IL			[x]		
Sacramento County, CA		x	x		
St. Louis, MO			x	x	
St. Petersburg, FL	x	x			
Salt Lake City, UT	x	x			
San Antonio, TX	x	x			
San Diego, CA		x	[x]		
San Francisco, CA			[x]		
San Joaquin County, CA			x		
San Jose, CA		x	x		x
San Mateo, CA	x	(x)	(x)		
Santa Ana, CA		x			
Santa Clara County, CA		x			x
Seattle, WA	x	x			
Shreveport, LA		x	x		
South Bay Area, CA		x	x		x
Sunnyvale, CA	x	x	x		
Tacoma, WA		x			
Tampa, FL			x		
Tucson, AZ	x	x			
Tulsa, OK		x			
Virginia Beach, VA		x	x		
Washington, DC	x	x	[x]		
Winston-Salem, NC	x				

[1]Data in this table came from a variety of sources, including: letters, phone calls, and site visits to police departments and suppliers of PCCC technology; a review of the documents available from PSE, NCJRS, and other research firms; and discussions with informed persons.

[2](x) indicates that the city is in the process of implementing the technology.

[3][x] indicates that the technology is being (or has been) phased out.

was on CAD, MDC, and AVM, the preliminary sample included all cities which were identified as having any of these technologies. This sample also included several manual dispatch systems, as well as some jurisdictions with advanced 911 systems and some with Regional Communication Systems.

A second sample level, the *study sample,* was drawn from the preliminary sample. Thirty-six cities were selected, and these cities are listed in Exhibit 2.6. The study sample was selected in order to yield jurisdiction type, geographic location, combination of PCCC technologies, CAD system age, and CAD system success. The breakdown of the sample by these six factors is also shown in Exhibit 2.6. Data from the cities in the study sample were collected by two different methods: telephone interviews and follow-up mail surveys.*

The *analysis sample,* shown in Exhibit 2.7, consisted of the 19 cities which were selected for site visits. They were drawn from the study sample based on the six criteria listed above. Since our focus was on CAD, the majority of our site visits were made to police departments with CAD systems. We also visited cities with a wide range of combinations of PCCC technologies (e.g., 911 and CAD; CAD and MDC; MDC and AVM, etc.). We chose a mix among the size of cities, although our focus was on medium-sized cities (those in the 250,000 - 1 million range). Further, we selected cities which were a representative geographic sample, with varying jurisdiction type and with different system ages and success.

The final sample level was the *test sample.* The test sample consisted of the police department in one city-- Huntington Beach California--where we performed a field assessment of the single project evaluation design. Huntington Beach was selected as the test sample primarily because of its mix of PCCC technologies and the data available from a number of years of experience with system implementation.

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*Phone contacts were made with all 36 cities, and interviews were generally 30-45 minutes long. In most cases discussions were with the communications supervisor, and, although a precise interview questionnaire was not strictly followed, a common set of questions was raised with everyone. This general interview guide covered six major areas: CAD, 911, MDC, AVM, general communications, and communications personnel. The mail surveys were sent as a follow-up to the telephone interviews. Two of the jurisdictions (San Francisco and the Quad-Cities) were not sent mail interviews as they were found not to have any of the PCCC technologies. No one single interview questionnaire was used for all of the cities: rather, each jurisdiction received a follow-up survey which was closely tailored to the city's actual PCCC applications (based on data gathered from the telephone survey). Of the 34 cities which received mail questionnaires, 30 responded in some fashion for an overall response rate of 88 percent.

Exhibit 2.6

PCCC Study Sample

City or County Name	Size	Location	Jurisdiction Type	CAD System Age	PCCC Technologies
Albany	2	NE	City	Med	CAD, MDC
Aurora	1	W	City	New	CAD, 911
Boston	4	NE	City	Med	CAD, 911
Charlotte	3	SE	City	Old	CAD, 911
Chicago	5	MW	City	---	911, MDC
Cranston	1	NE	City	Med	CAD
Dade County	5	SE	City/County	Med	CAD, RCS, 911
Dallas	4	SW	City	Old	CAD, MDC, AVM
Denver	4	W	City	N.O.	(CAD)[1], 911
Detroit	5	MW	City	Old	CAD, MDC, 911
Fresno City	2	CA	City	Med	CAD, MDC
Fresno County	3	CA	County	Med	CAD
Hampton	2	SE	City	Old	CAD, [MDC][2]
Huntington Beach	2	CA	City	Old	CAD, MDC, AVM
Indianapolis	4	MW	City	New	CAD, 911
Las Vegas	3	W	City	Old	CAD, MDC
Los Angeles	5	CA	County	Old	CAD
Miami	3	SE	City	Med	CAD, 911
Minneapolis	3	MW	City	New	CAD, MDC
Nashville	3	SE	City/County	---	911
Newark	3	NE	City	Med	CAD, MDC, 911
New York City	5	NE	City	Old	CAD, MDC, 911
North Las Vegas	1	W	City	Old	CAD
Oakland	3	CA	City	Med	CAD, MDC, 911
Philadelphia	5	NE	City	New	CAD, 911
Quad-Cities	3	MW	County	---	(RCS)[3], [MDC]
St. Louis	4	MW	City	---	MDC, AVM
Salt Lake City	2	W	City	New	CAD, 911
San Antonio	4	SW	City	Med	CAD, 911
San Diego	4	CA	City	Old	CAD, [MDC]
San Francisco	4	CA	City	---	[MDC]
San Jose	4	CA	City/County	Old	CAD, MDC, RCS
Seattle	4	W	City	Old	CAD, 911
Sunnyvale	2	CA	City	Med	CAD, MDC, 911
Tulsa	3	SW	City	New	CAD
Virginia Beach	3	SE	City	Med	CAD, MDC

(Code)	Jurisdiction Size	Number of Jurisdictions
5	Over 1 Million	6
4	500,000 - 1 Million	10
3	250,000 - 500,000	11
2	100,000 - 250,000	6
1	50,000 - 100,000	3
	Total	36

(Code)	Jurisdiction Location	Number of Jurisdictions
NE	Northeast	6
SE	Southeast	6
MW	Midwest	6
SW	Southwest	3
CA	California	9
W	Other West Coast	6
	Total	36

(Code)	Jurisdiction Type	Number of Jurisdictions
City	City-wide	30
County	County-wide	3
City/County	Combination	3
	Total	36

(Code)	CAD System Age	Number of Jurisdictions
Old	Older than 5 years	12
Med	2-5 years	12
New	Less than 2 years	6
N.O.	Not yet operational	1
---	No CAD	5
	Total	36

CAD System Status	Number of Jurisdictions
System Operational	30
Not Operational	1
No CAD	5
Total	36

(Code)	PCCC Technologies	Number of Jurisdictions
911	911	18
CAD	Computer-Aided Dispatching	31
MDC	Mobile Digital Communications	17
AVM	Automatic Vehicle Monitoring	3
RCS	Regional Communication System	3

---

[1]Parentheses indicate that the technology is in the process of being implemented.

[2]Brackets indicate that the technology has been (or is being) phased out.

[3]Quad Cities attempted to create a regional communication system but has so far been unsuccessful.

Exhibit 2.7

Site Visits and Site Selection Criteria

Jurisdiction	Technology	Jurisdiction Size	Location	Type	CAD System Age	CAD System Status
Aurora	911,CAD	1	W	City	New	✓
Charlotte	911,CAD	3	SE	City	Old	✓
Cranston	CAD	1	NE	City	Med	✓
Dade County	911,CAD	5	SE	City/County	Med	✓
Dallas	CAD,MDC,AVM	4	SW	City	Old	✓
Denver	911,(CAD)*	4	W	City	NO	X
Huntington Beach	CAD,MDC,AVM	2	CA	City	Old	✓
Indianapolis	911,CAD	4	MW	City	New	✓
Las Vegas	CAD,MDC	2	W	City	Old	✓
Miami	911,CAD	3	SE	City	Med	✓
Newark	911,CAD,MDC	3	NE	City	Med	✓
N. Las Vegas	CAD	1	W	City	Old	✓
Oakland	911,CAD,MDC	3	CA	City	Med	✓
Philadelphia	911,CAD	5	NE	City	New	✓
St. Louis	AVM	4	MW	City	---	---
Salt Lake City	911,CAD	2	W	City	New	✓
San Antonio	911,CAD	4	SW	City	Med	✓
San Diego	CAD,[MDC]**	4	CA	City	Old	✓
Sunnyvale	911,CAD,MDC	2	CA	City	Med	✓

Technologies

None	- 1
CAD	- 2
911,CAD	- 9
CAD,MDC	- 2
911,MDC	- 0
911,CAD,MDC	- 3
CAD,MDC,AVM	- 2

Jursidiction Size

5: Over 1 million	- 2
4: 500,000-1 million	- 6
3: 250,000-500,000	- 4
2: 100,000-250,000	- 4
1: Under 100,000	- 3

Jurisdiction Location

NE: Northeast	- 3
SE: Southeast	- 3
MW: Midwest	- 2
SW: Southwest	- 2
CA: California	- 4
W: Other West Coast	- 5

Jurisdiction Type

City	- 18
City/County	- 1

CAD System Age

Old: More than 5 years	- 6
Med: 2-5 years	- 7
New: 0-2 years	- 4
NO: Not yet operational	- 1
--- No CAD	- 1

CAD System Status

✓ : CAD operational	- 17
X : CAD not yet operational	- 1
--: No CAD	- 1

* Parentheses indicate that a technology is in the process of being implemented.

** Brackets indicate that a technology has been (or is being) phased out.

3 ASSESSMENT OF PCCC TECHNOLOGIES AND APPLICATIONS

This chapter provides a general assessment of each of the six PCCC technologies and applications based on a review of the available literature and information from PSE's surveys and site visits. It is important to note that the chapter does not provide detailed evaluations of particular PCCC systems, but instead consists of a general assessment of PCCC problems and issues. Furthermore, because of the lack of detailed evaluation data, the results presented here are to a certain extent subjective and based on PSE's opinions or impressions.

Because CAD has received special emphasis in this study it will be discussed first, followed by an assessment of MDC, AVM, 911, Formal Deployment Models, and Regional Communication Systems. Within each section will be a general discussion of the state of the art of the technology, its objectives and impacts, and general conclusions.

3.1 COMPUTER-AIDED DISPATCH (CAD)

3.1.1 STATE OF THE ART OF CAD

CAD systems are those systems which involve the computer in the process of handling service calls from the public, in making decisions as to which patrol units should be dispatched to an incident, and in making appropriate adjustments in the status of units as necessary. In general, CAD systems do not completely automate the normal handling of service calls from the public, but instead make use of the computer's unique capabilities to enhance the handling of calls for service.

CAD generally assists the complaint operator by verifying incident-related information to the extent possible (most commonly by verifying addresses) and checking to see if certain necessary information (such as incident address and incident type) has been entered. Most CAD systems also automatically determine the beat in which an incident is located (by checking a geocoded address file) and generally assign a case number and priority to each call. If the address has a "dangerous" history (which the computer would check by searching past incident files), the computer may also report this. The incident-related information is then routed automatically to the appropriate dispatcher.

Based on the status and anticipated locations of the patrol units (which the CAD system checks from a field unit status file and a personnel file), the computer typically recommends to the dispatcher several possible units to dispatch. Once a unit has been dispatched, the computer can automatically record the time it is dispatched, the time it arrives at the scene, and the time it becomes free. CAD also assists the dispatcher by keeping track of the status of all incidents, and provides the dispatcher with instant recall of dispatch data.

As outlined in Exhibit 3.1, CAD systems encompass a number of possible features. Although any single CAD system does not generally include all of the features identified in Exhibit 3.1, the listing outlines the range of options available with CAD.

CAD serves at the heart of the command and control process. It provides direct assistance in the dispatch process through the incident and dispatch-related information it provides, and allows police departments the potential for increased control over their command and control operations. Furthermore, because CAD automates much of the dispatch process, it provides a basic framework for bringing together many of the PCCC-related technological innovations. For these reasons, the trend has been for police departments to install CAD before Mobile Digital Communications (MDC) or Automatic Vehicle Monitoring (AVM), and CAD has been more widely implemented than either MDC or AVM.

A number of police departments are currently using CAD systems, although the actual rate of implementation has been somewhat slower than initially predicted. A survey conducted by Colton in 1971 indicated that 61 police departments were planning to install a CAD system within the next 3 years (Colton, 1972). However, when a second survey was conducted in 1974, only 15 departments had systems close to operational (Colton, 1974). The failure of some departments to establish operational systems is an indication of the difficulties involved in implementing such applications. Such failures also indicate that the use of CAD is still in an early phase.

In the past several years, however, the implementation rate of CAD seems to have increased. A mid-1975 study by the Jet Propulsion Laboratory found that only 10 percent of the 135 police departments and jurisdictions with more than 100,000 population had a CAD system, and many of these were essentially new (Sohn et al, 1975(a)). Based on PSE's analysis to date, it now appears that about 30 percent of the cities with a population above 100,000 have operational CAD systems, and another 10 percent are either in the planning or implementation process for CAD.

Data collected by PSE indicate that there are 65 police CAD systems currently in operation in the United States, and another 15 currently being implemented. These are listed in Appendix B where a breakdown of CAD by city size is also shown. As illustrated, CAD systems are most prevalent in cities with a population greater than 250,000; of these, 50 percent have CAD systems. There seems to be little significant difference in implementation rates between very large cities (those with a population greater than 500,000) and large cities (population 250,000 - 500,000). Medium-sized cities (population 100,000 - 250,000) have approximately half as many CAD applications as larger cities, with a 17 percent application rate. It appears that only a very small fraction (1%) of cities with a population less than 100,000 have CAD systems.

Exhibit 3.1

CAD: Possible System Features

PCCC Function	CAD-Related Features[1]
• Needs Identification	• Complaint clerk enters incident-related information into the computer • CAD adds routine data (incident number, date, time, etc.) • Computer checks data validity (address verification, etc.) • Computer assigns a call priority • Computer assigns a beat number • Computer checks for previous incidents at this address or other related data (e.g., hazardous information) • Computer estimates length of time until a unit can respond to the call • Backup operator handles lengthy calls
• Status Monitoring	• CAD provides real-time monitoring of vehicle status (and vehicle location, if tied to AVM) • CAD maintains a continuously updated incident file (assigned, unassigned, cases cleared, etc.) • Supervisor can monitor unit and incident status by calling up complaint clerk and dispatcher displays
• Response/Adjustment	• Operator has computerized files of frequently used telephone numbers (ambulance, tow, etc.) • CAD routes incident information to appropriate dispatcher • Computer provides a summary list of incidents in the system • Computer recommends which unit(s) to select (based on estimated unit location) • Computer automatically times calls and raises a "flag" if a call takes longer than a specified time • Computer provides telephone, radio, digital activity statistics • Unit status can be updated automatically (with MDC), or through an operator (using CAD or a separate system) • Patrolmen can automatically sign in as "available" at shift change using remote terminals • Data base queries can be handled automatically (via MDC), or through an operator (using CAD or a separate system)

[1]This exhibit draws from, among other sources, "Table 3:CAD System Functions" [Sohn et al, 1975(a), p. 13]. The reader should note that some of these features relate directly to the computer technology. Other features are essentially manual and involve a human element which could be part of any dispatch system, whether or not it is automated.

Exhibit 3.1

(Page 2 of 2)

PCCC Function	CAD-Related Features
	• Dispatcher can have one, two, or more CRT screens
	• Computer maintains temporary situation files (e.g., traffic and street repairs)
	• CAD supports coordination of multiple unit (and/or agency) assignments to one incident
	• CAD provides a basis for officers' daily incident reports
	• Computer handles routine log-off operations (e.g., adds time, date, and stores in closed incident file)
• Resource Management	• Computer periodically generates crime statistics reports for state and federal use
	• Computer reports can be generated off-line
	• Computer provides statistics by any desired set of categories (type of crime, area, time of day, etc.)
	• Computer generates management reports from CAD for departmental use (e.g., incident logs, officer activity logs)
	• Computer can automatically flag deviations or trends
	• One-time, special reports (e.g., particular crime activity patterns) can be generated
	• Computer can automatically generate required data for resource allocation models
	• On-line information is available via remote terminals for patrolmen, sergeants, etc.

We have also identified 14 county-wide CAD systems. In some cases (such as Santa Clara County) city and county agencies have pooled resources to create a joint CAD system; in other cases (e.g., Fresno County) the county-wide system is independent of a city-wide system within that county. (Section 3.6 of this report provides a more detailed discussion of current applications of regional communication systems.)

Since CAD is the primary focus of our project, 31 of the 36 jurisdictions in our study sample have an operational or partially operational CAD system. A number of basic statistics related to these systems (collected from telephone and mail surveys and site visits) are shown in Exhibit 3.2.

CAD system characteristics vary greatly from city to city. While there are some basic functions carried out by all the systems, there are also a number of different functions carried out in different departments. The CAD systems in our study sample range from the very simple to the very complex. In Detroit, for example, the CAD system includes graphic computer terminals (called CRTS) only for complaint operators; the dispatchers use a manual system. In other cities, such as Las Vegas and San Diego, both dispatchers and complaint clerks have CRTs, while the officers in the cars have mobile digital terminals which can be used to receive dispatch messages as well as to inquire directly into law enforcement data files.

SYSTEM DESIGN/PHILOSOPHY

Much of the actual design of CAD systems is based on the philosophy of each department regarding CAD. Departments also differ depending on whether they have a shared or dedicated computer facility and whether the police CAD system is shared with other emergency services such as fire or emergency medical services.

There are at least three *different approaches/philosophies* among the jurisdictions we surveyed regarding the actual function of CAD. First, in some jurisdictions, such as Philadelphia, Dade County, or Salt Lake City, CAD is looked upon mainly as a tactical tool for dispatch. These systems serve as efficient tools to aid the dispatch process, but they produce few, if any, management reports. A second group of cities, such as Huntington Beach, look upon CAD as a source of management data. In Huntington Beach, with a population of only 150,000, and an area of only 35 square miles, the need for CAD as a dispatch tool is much less. Instead, CAD is viewed primarily as a means of collecting incident-related information to assist the patrol and investigation divisions in making management decisions, and as a part of an entire process to automate and tie together their record-keeping and reporting systems. A third attitude toward CAD is found in San Antonio, Dallas, and Cranston. In these cities, CAD is seen primarily as one component of an entire computerized, "on-line" police information system. CAD is thought of not only as a dispatch tool or as a management information system unto itself, but also as an important first step which feeds into other components of an automated police information system (including reporting, property, and investigation subsystems). Finally, in some cities some combination of the above philosophies is found. It is also important to note that a city's attitude toward CAD can change over time so that, for example, CAD may at first be thought of primarily as a dispatch tool but later may be the foundation for an on-line police information system. Failure of a police department to formulate its philosophy (which may even be some combination of the three above) will generally leave the department at the mercy of the vendor or designer to choose their own special focus.

Of the 31 cities in our study sample with operational or partially operational CAD systems, 27 have a computer *dedicated* to the CAD system. Most cities appear to believe it is important to have a computer dedicated to the CAD system in order to assure adequate computer response time. In San Antonio, however, where the computer is *shared* with the city government, the police department decided not to get a dedicated computer for their CAD system because they felt that sharing a computer with other agencies would enable them to have access to a larger, more up-to-date computer. This, they believe, will give their CAD system a longer lifespan. Also, while computer response time is slow in San Antonio during the day (when the other city agencies are open), it is not slow during the evenings and weekends when the department believes that quick response time is most important. Thus, San Antonio has made a tradeoff between quick computer response time during the day and the use of a larger and more powerful computer. This example illustrates that there are typically tradeoffs involved in system design decisions and the same solutions may not always be the best for all departments.

While we discovered relatively little *sharing of computer facilities* between police CAD and local city (or county) computer operations, we did find some sharing of CAD systems with local fire or emergency medical service (EMS) agencies. For example, the Boston CAD system is shared with the Boston EMS agency; and Dallas, Sunnyvale, Salt Lake City, Aurora, and Indianapolis share their CAD systems with the local fire departments. However, this sharing seems to be the exception rather than the rule, and in general there seems to be little CAD sharing between public safety agencies. This may be due to political problems, to tradition (if the agencies have traditionally not worked together in the past), to differing command and control needs, or to some combination of these factors.

IMPLEMENTATION PROCESS

In most jurisdictions we surveyed, CAD serves as a "base technology." CAD is the first PCCC technology implemented. Once the system becomes operational, and as the department obtains additional funding, other PCCC technologies such as MDC and AVM may be added. Hungtington Beach, for example, has had five PCCC-related implementation phases. In 1973, CAD and mobile digital status terminals were installed as a first step. Then in 1975 and 1976 the CAD system was upgraded and expanded; in 1977 AVL was added. The last two phases, which are currently underway, involve the addition of an automated report writing system and new MDTs in the patrol cars with teleprinters and data base access. Of the 33 cities in our study sample with CAD, MDC, or AVM, 24 cities implemented CAD as a first technology, 4 implemented CAD at the same time as MDC, and only 5 installed either MDC or AVM first.

In most cases the implementation of CAD is an iterative, ongoing process. After initial CAD installation--which, based on our study sample, can take half a year to several years--systems typically undergo upgrading every few years. After initial implementation, cities discover new uses for CAD. As they become more familiar with the capabilities of their system, they begin to adjust their system to fill further needs. PCCC system use is a dynamic process; after implementing a system such as CAD, departments should expect that the system will need to continually evolve and mature to satisfy changing needs.

COSTS

Consistent and reliable data concerning PCCC costs are difficult to obtain. Costs seem to vary from city to city, and jurisdictions--even during site visits--seem to have only an imprecise idea as to costs and only aggregate data seems to be readily available. Still, it is worthwhile to review the cost data we obtained from our surveys and site visits, primarily as a means of highlighting the problems with the data. In Appendix A we discuss some of the methodological and analytical considerations in estimating CAD system costs.

CAD installation costs varied widely among the cities we surveyed, as shown in Exhibit 3.2. The lowest CAD system was $154,000 in Cranston, and the highest was $16.8 million in New York City. It could be expected that much of this variation would be accounted for by city size and communications center workload. However, there was also a wide range of system costs per capita, ranging from a low of 35¢ per person in Dade County to a high of $33 per person in Aurora. In cost per thousand dispatches, the low was $1 in Boston and the high was $21 in Los Angeles County. We did not find any apparent economies (or diseconomies) of scale when comparing cost per thousand dispatches, although we did find that in cities with a population greater than 250,000, the average cost per thousand dispatches was approximately $7.50, while in cities with a population less than 250,000, the average cost per thousand dispatches was approximately $11.30. Difficulties associated with comparison of CAD costs among cities are discussed in more detail in Appendix A.

Exhibit 3.2

CAD-Related Statistics

Jurisdiction	CAD[1]	Population served (1000's)	# Dispatches/year (1000's)	Vendor	When Installed	Total CAD Cost (1000's)	Fraction of $ from LEAA	Fraction of $ from State and Local Sources	Cost/Population Served ($)	Cost/Dispatch ($)	Yearly Maintenance Cost (1000's)	Installation time (months)
New York City	X	7,605	3,650	IBM	10/70	16,800	0%	100%	2.21	4.60		
Chicago												
L. A. County	X	2,750	670	SDC	6/74	14,120	0%	100%	5.13	21.07	31.8	48
Dade County	X	2,000	495	In-House	9/77	690	90%	10%	.35	1.39	5.0	12
Philadelphia	X	1,820	3,240	ADL Systems	9/78	1,100	90%	10%	.60	.34		14
Detroit	X	1,300	778	Boeing	10/73		(some)					
Dallas	X	859	526	In-house	6/70		0%	100%				12
San Antonio	X	850		In-house	12/77	601	100%	0%	.71		15.0	36
Indianapolis	X	741	401	Gen.Electric	11/78		0%	100%	2.82	5.21	4.0	26
San Francisco												
San Diego	X	697	409	Motorola	1/75	650	0%	Other[2]	.93	1.59	5.0	
San Jose	X	570	198	Kustom	6/74	1,600	45%	55%	2.81	8.08	20.0	24
Boston	X	550	650	ADL Systems	4/75	650	75%	25%	1.18	1.00	6.0	24
St. Louis												
Denver	(X)	515	248	Mauchly-Wood/ City D.P.	N.Y.O.[3]	3,000	65%	35%	5.83	12.12	N.Y.O.	48+
Seattle	X	505	226	Kustom	6/71	500	50%	50%	.99	2.21	2.6	24
Fresno County	X	485		PRC-PMS	6/76	1,000	60%	40%	2.05			6
Nashville												
Minneapolis	Y	435	217	ADL Systems	4/80	1,200	90%	10%	2.76	5.53		
Miami	X	354	260	E-Systems	11/76		(some)					
Newark	X	352	250	Boeing	1/77	960	(some)		2.73	3.84		
Oakland	X	350	300	Boeing	6/77	493	90%	10%	1.41	1.64	4.2	24
Tulsa	X	343	260	In-house	11/78		0%	100%				
Las Vegas	X	322	168	Kustom	6/75		100%	0%				24
Quad Cities												
Charlotte	X	310	190	SDC	6/74	641	36%	64%	2.07	3.37	9.3	15
Virginia Beach	X	255	113	Motorola	6/76	1,000	0%	100%	3.92	8.85	4.1	12
Fresno City	X	186		Kustom	6/76		(some)					24
Salt Lake City	X	169	100	Motorola	1/78	2,400	0%	100%	14.20	24.00		36
Huntington Beach	X	160	73	Motorola	10/74	825	40%	60%	5.16	11.30		18
Hampton	X	150	35	Motorola	6/75		(some)					
Albany	X	114		In-house	11/75		0%	100%				12
Sunnyvale	X	106	60	Motorola	11/76	816	50%	50%	7.70	13.60	9.9	
Cranston	X	77	19	J.Larimore	5/77	154	90%	10%	2.00	8.11	1.1	7
Aurora	X	75		ADL Systems	10/79	2,500	0%	100%	33.30			
North Las Vegas	X	50	12	J.Larimore	6/74	50	100%	0%	1.19	4.17		12

[1] Y = yes; (X) = not yet fully operational
[2] Federal Revenue Sharing funds
[3] N.Y.O. = not yet fully operational

3.1.2 OBJECTIVES AND IMPACTS

STATED OBJECTIVES

A CAD system is often at the center of police activities related to command, control, and communications. Many of the activities of actual CAD systems are routine (i.e., the computer is simply carrying out a structured activity which had been performed manually before CAD). However, CAD also has non-routine applications as a resource management tool, both on-line (through call prioritization, estimation of the time until a unit can respond to a call, etc.) and off-line (by generating management reports, data for resource allocation models, etc.) The stated objectives of CAD, as presented in the literature, reflect the range of functions encompassed in a CAD system and reflect the actual use of CAD mainly for routine purposes. Most of these objectives, which are summarized in Exhibit 3.3 relate to CAD as an on-line operational tool that directly assists the dispatcher in processing calls. These include objectives which focus primarily on the *status monitoring* and *response/adjustment* functions of PCCC. Objectives related to *resource management* do not receive as much emphasis.

IMPACTS

The level of success of different CAD applications varies significantly although many systems are working around the country and the number of systems continues to increase. For example, the systems in San Diego (Colton, 1978; Hoobler and Fortier, 1975), and New York City (Colton, 1978) seem to be quite successful, while those in Boston (Hebert, 1978) and Denver (Moya, 1978) have met with major difficulties. Based on our surveys and site visits, most departments are pleased with CAD and their systems seem to be well accepted. Many departments did note initial resistance to CAD among cummunications personnel, patrol officers, and supervisors, but they reported that once their system began to operate smoothly, it became well accepted. The question in many police departments now is no longer *will* there be computer-aided dispatching, but *when* will it be installed and with what impact?

Unfortunately, very few formal evaluations of CAD have been conducted, and those that do exist focus on input and process measures. Practically no data are abailable concerning outcome and systemic impacts. Exhibit 3.4 summarizes actual and potential impacts for each of the stated objectives. Objectives are grouped as to whether they relate primarily to input, process, outcome, or systemic impacts.

INPUT OBJECTIVES

Based on literature reviews, surveys and site visits, it appears that most of the input-related objectives have been met. CAD has undoubtedly provided more and better data to police personnel to aid in the dispatch process. In our site visits, numerous cases were cited of easy access to information which was not readily available prior to CAD. Further, CAD has generally been designed so as to facilitate police officer access to local, state, and federal data files, although CAD is not essential for officers to access such remote files.

Exhibit 3.3

CAD: Stated Objectives

- To monitor and better display PCCC data -- including outstanding calls, ongoing incidents, and patrol unit status and activities.
- To provide better information to PCCC personnel -- including complaint clerks, dispatchers, and supervisors.
- To help decide which patrol unit(s) to assign to a call for service -- based on estimated unit locations.
- To reduce response time -- through reductions in call answering, call processing, unit assignment, and travel times.
- To improve officer safety -- by more effectively monitoring unit status and responding more rapidly in case of emergency.
- To facilitate access to remote data files -- including outstanding warrants, stolen property, and state and national inquiry systems.
- To improve the quality of data maintained from the dispatch process -- through address verification, automatic assignment of case numbers, dates, and times, elimination of duplicate entries, etc.
- To better manage police resources -- through the use of better data and a better understanding of the command and control process.
- To improve service to the public -- through quicker response time, better dispatch data, and improved management of police resources.

Exhibit 3.4

CAD Impacts

INPUT OBJECTIVES	ACTUAL IMPACT	POTENTIAL IMPACT
Better monitor and display PCCC data	CAD systems have achieved this objective through automatic call monitoring, formatted screens, etc.	
Provide better on-line information to PCCC Personnel	CAD systems have achieved this objective through formatted screens, unit status lists, multiple screens, etc.	
Make available better data from the PCCC process	In systems in which CAD stores dispatch and related data, data is saved more quickly, cheaply, and accurately than under a manual dispatch system.	
Facilitate access to remote data bases	When tied into CAD, automatic data base access is greatly facilitated. However CAD is not necessary for automated data base access.	
PROCESS OBJECTIVES		
Help decide which unit(s) to dispatch to a call for service	This objective is automatically achieved in CAD systems which recommend which unit(s) to dispatch, although recommendations are not always followed.	
Reduce emergency response times	Of 26 cities surveyed by PSE, 10 felt that CAD had reduced response time, 9 said it was the same, and only 1 said it was longer. (The other 6 did not know.) However, no cities had any solid data.	While CAD will probably have little impact on *average* response time, through improved call prioritization procedures, CAD may reduce response time to *high priority* incidents.
Improve coordination of emergency services	This objective has been met in some cities where, for example, CAD is shared with local police, fire, or EMS agencies. In other cities, political problems have precluded coordination.	CAD systems have much potential, not yet realized, to improve coordination of emergency service.
Improve management of police demand	Current CAD systems carry out little management of police demand which did not occur before CAD.	CAD has strong potential in this area. Management of demand can be improved by such features as pre-emptive dispatching, estimation of the time until an officer can respond, etc.
OUTCOME OBJECTIVES		
Improve management of police resources	Most CAD systems have had little impact in this area, although there are a few exceptions.	CAD has strong potential to improve management of police resources, through better on-line information, management reports, and management of demand functions.
Improve service to the public	There is no evidence to indicate that CAD has either improved or degraded service to the public.	CAD may have the potential to improve service to the public (through reduced response time, for example), but actual benefits will be hard to attribute specifically to CAD.
Allow for a transferable PCCC	Little CAD transfer has taken place, except through vendors. Some sharing of experiences has occurred, but most police departments have, in effect, "reinvented the wheel" in creating and implementing their CAD system.	Most of the potential for CAD transfers lies with the vendors. Such vendor-initiated transfers can be expected to grow in the future, as vendors gain experience in modulized hardware and "packaged" software.

While most of the input objectives have been met, many CAD systems still appear to have certain fundamental flaws in system design. Many of the police CAD systems we have seen lack flexibility in the dispatcher and complaint clerk operations. Generally, CAD systems tend strictly to format and linearize operations which had been relatively unformatted and often multiplexed (i.e., carried out simultaneously) in the past. Thus, dispatchers using a CAD system can carry out only one operation at a time (such as changing unit status, assigning units to an incident, deleting an incident, etc.), when under a manual system they could carry out several tasks at once. CAD systems also often require that information be entered only according to a specific format, sometimes in a specific order. More careful attention should be devoted in system design to the complexity of the tasks involved and to the human aspects of PCCC operations. Input from future system users can be critical to successful system design.

PROCESS OBJECTIVES

Concerning process objectives, the impact is less clear. CAD has clearly provided useful information to dispatchers concerning the availability of units and the selection of unit(s) for a call for service. Also, although CAD has not, in general, influenced the coordination of emergency services, there have been a few cases where police departments and fire departments have better coordinated their activities through a common or related CAD system, and the potential certainly exists for better coordination in the future.

One of the areas of service performance which has received attention in the past is the impact of CAD on response time. In a few cities some benefits have been documented. In Phoenix, police officials reported that CAD has achieved response time benefits, although they did not specify how much (Farmer, 1977); and Huntington Beach, California claims an average response time reduction of 45 seconds per call as a result of CAD (Robitaille, 1974). A survey conducted in San Diego prior to CAD indicated that the emergency telephone sometimes rang as many as 80 or 90 times before it was answered. With CAD and a new call distributor system, 90 percent of the calls are answered within 2.5 seconds, and operator talk time has been reduced to 60 seconds (Hoobler and Fortier, 1975); the report did not specify, however, how much the *average* response time was reduced or how much of the reductions were due to CAD and how much to the call distributor system.

In all of these reports it is extremely difficult to ascertain the quality of the response time analysis. In many cases, reliable data are absent; and estimates, based on only a few weeks worth of data, appear to be somewhat subjective. Of 26 cities in our study sample with operational CAD systems, 10 felt that CAD has reduced response time, 9 said that it was the same, and only 1 (Denver) said that it was longer. (The other 6 did not know or did not answer the question.)

In considering response time, we should mention that it is unclear what effect any CAD-related reductions in response time will have on the arrest rate, and ultimately, on the actual crime rate. Recent research has shown that decreasing response time by, say, one minute may result

in very little real impact since citizens often wait a significantly longer time before even reporting an incident to the police (Kansas City, 1977; Tien et al, 1977). In a study done for the Crime Commission in the late 1960's, Isaacs found that a delay in the communications center and field travel time resulted in fewer arrests (Presidents Commission on Law Enforcement and the Administration of Justice, 1967). He indicated, however, that faster response time does not necessarily lead to more arrests. A later study by Poe and Calvin found that there was essentially no relationship between response time and arrests (reported in Edmonson, 1977). On the other hand, research carried out by the Seattle Police Department analyzing 1975 and 1976 data on emergency crime-in-progress calls in Seattle found that higher arrest rates were associated with lower travel times and lower total response times (Clawson and Chang, 1977; Tarr, 1978). In the literature related to CAD, only in Phoenix did officials claim any link between their CAD system and a reduction in crime-related activity such as arrests or crime rate. In Phoenix, officials pointed to a two percent reduction in the crime rate, but the drop in the crime rate may have also been the result of other factors (Farmer, 1977).

OUTCOME OBJECTIVES

Concerning the impact of CAD on the management of police demand as well as the outcome objectives noted in Exhibit 3.4, the impacts to date have been small. While most cities we spoke to on the phone said that their CAD system produced management reports and most cities mentioned management information as a major benefit of CAD, based on information from our site visits it appears that the decisions which are being made are short-term operational or tactical decisions, rather than long-term, strategic decisions. In most cities we have seen, the management information being used appears to be lists of calls for service, lists of calls handled by each particular patrol unit, and the like. Few of the cities we visited were actually using CAD data for more complex studies, such as an investigation of response time or an examination of revised district/beat configurations. Even in cities such as Huntington Beach, which has a fairly extensive management reporting system, CAD seems to be mainly used to dispatch, to check on the workload handled by particular officers, to research complaints, and to provide a base of information for incident reports. In other cities, such as Newark and Philadelphia, the CAD management reports are not even used.

In fact, it appears that many computer-based CAD applications have to a large extent simply replaced previous manual operations. An overriding feature of most CAD systems we have seen is that the potential of the computer has not been fully utilized; in fact, many CAD systems are little more than expensive and fast "electronic conveyor belts." For example, the CAD system automatically assigns an incident number and a beat number to each call and atuomatically transfers calls from the complaint clerk to the dispatcher--all operations carried out under manual dispatch systems. However, the computer also has a range of other capabilities that have not yet been fully explored in such PCCC systems.

Use of the computer in such non-routine applications to date has been disappointing. Only one city we have visited has attempted to use an "intelligent" CAD system.* This city, Newark, included such features in its system as an estimation of the time until a unit will respond to a call; a real-time display on the CAD screen of the number of incoming 911 calls; a "flag" to alert the dispatcher if a call takes longer than a specified period of time; and direct computer input to the Hypercube and PCAM deployment models. However, due to inadequate numbers of communications personnel and technical problems, many of the advanced system features are not being used. Attitudes toward the system have deteriorated, and the consensus among the communications personnel now is that the system is "too sophisticated."

In general, designers of PCCC systems often approach the complaint processing and dispatch functions as a set procedure that has been followed for many years. Whether dealing with an automated or manual PCCC system, there is a need for greater attention to the overall management of police demand. This includes such items as giving priority to calls for service, informing citizens as to how long it might be before an officer arrives at the scene, "stacking" calls with low priority, learning to deal more effectively with citizens' perceptions, etc. The potential for such management of demand activities as they relate to PCCC is discussed in greater depth in Chapter 4.

SYSTEMIC OBJECTIVES

Finally, when it comes to systemic impacts, little information is available. It appears, though, that little transfer of experience occurs between police departments in the CAD area. In our surveys and site visits we found that the majority of cities with CAD did not carry out any extensive or systematic studies assessing the feasibility and cost-effectiveness of CAD prior to CAD implementation. While most cities appear to have made some type of in-house feasibility study prior to CAD, only a few (e.g., Huntington Beach, Miami, Boston, and Charlotte) had a formal pre-CAD study made. In our sample, representatives from most of the cities did visit nearby cities with CAD systems to get ideas before implementing their own CAD system.

Although a number of cities in our sample have had relatively few problems in implementing CAD, it appears that many cities have basically "reinvented the wheel" in creating their CAD systems. In other words, they have created systems independently of other cities and have often made mistakes which might have been avoided if they knew of the experiences of other cities in designing and implementing CAD. For example, Detroit installed a Boeing CAD system in late 1973, but because of poor system design, dispatchers had more work than they could handle, and the system had to be taken out. The department now uses a skeleton version of the original CAD system. It is possible that such problems could have been avoided had they studied other operational CAD systems in more depth before designing their own system. There is a strong need for more sharing of ideas and experiences among cities implementing CAD and other automated PCCC systems.

There has also been very little direct CAD system transfer among police departments. Most cities mentioned that they used some features they liked from other systems, but they did not want to transfer an entire CAD system because they felt that they needed a system specifically tailored to their needs. The one department in our sample that has transferred its CAD system is Charlotte, North Carolina. The Charlotte system, developed as part of the federally-assisted USAC* project to aid in establishing integrated municipal information systems has been transferred to a handful of cities, including Minneapolis, Minnesota; Tampa, Florida; Clearwater, Florida; Madison, Wisconsin; and Prince William County, Virginia. However, from information we have gathered, it is still unclear if any of these transfers were successful. Minneapolis transferred the Charlotte system and then attempted to change the system to make it compatible with their own dispatch procedures. However, they discovered that despite the changes they made, the Charlotte CAD system was too slow for their needs, so the project was abandoned after a year. (In fact, in a site visit to the Charlotte Police Department, we found that computer response time in the Charlotte CAD system is indeed quite slow.) Minneapolis has since installed a CAD system developed specifically for its own needs by an ouside vendor.

Although few police agencies are directly transferring CAD systems from other police departments, it does appear that a fair amount of transfer is taking place through vendors who modify a system they have installed in one jurisdiction for use in another. In doing this the vendors, in general, use the same basic system from place to place, but modify the hardware configuration, screen formats, and optional features to suit each particular department. This has been borne out in our communications with CAD vendors. For example, G.E. reported that they were installing a system in Baltimore County which is very similar to the system they established in Indianapolis. Joseph Larimore and Associates reportedly installed the same system in Cranston, Rhode Island; North Las Vegas, Nevada; and Kenosha, Wisconsin; and they are now installing similar systems in several other jurisdictions. Motorola established one of their earliest CAD systems in Huntington Beach, California (in 1974), and later established successively modified versions of this system in San Diego (1975), Virginia Beach (early 1976), Sunnyvale (late 1975), and Salt Lake City (1979).

As time goes on, vendor initiated transfer will most likely continue and even grow. Whether it will benefit law enforcement agencies, though, will depend on the quality of the vendor-user interactions and the specification of adequate performance measures.

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* Many cities, however, use one or two of the more advanced CAD system features.

*Urban Information Systems Inter-Agency Committee

The nature of the relationship between police departments and computer vendors seems to have a strong bearing on the success (or lack of success) of any PCCC system. As discussed in the literature, and as we found in our site visits, departments with clearly defined, carefully specified vendor performance specifications (e.g., San Diego, Huntington Beach) generally have more successful PCCC systems than those departments with uncertain or ill-defined vendor performance specifications (e.g., Denver, Boston).

The City of Denver has so far spent four years and almost $3 million in trying to create a CAD system, but they do not yet have one that is operational. Although all dimensions of the implementation problems are not clear, the problem appears to be linked, at least in part, to poor relationships on the part of the police department with the vendor. The vendor who had been awarded a contract for the system in late 1975 left the project in February 1977. The system did not work at that point, so the Denver City Data Services took over. More than two years later, the CAD sysem still does not work. Independent auditors who investigated the difficulties in Denver were especially critical of the system planning and vendor-user interaction.

On the other hand, San Diego outlined precise specifications regarding work schedule, functional specifications, deliverable hardware and software packages, installation and test plans, training, maintenance requirements, payments and warranty. Because such detailed specifications existed, the department was able to require satisfactory vendor performance. Further, because the contract called for 90 consecutive days of satisfactory system operation*, the vendor had to wait an extra six months from the time the system was in operation until final payment was made.

In stressing performance guidelines it is also important to emphasize long-range planning. If a department does not conduct careful long-range planning, it may get "locked-in" to a system which cannot adapt to changing conditions. In fact, if long-range planning is overlooked, strict performance standards may even have negative consequences since they may make it difficult to maintain flexibility for the future.

CONCLUDING REMARKS

The implementation of CAD systems, while slower than initially expected, has increased rapidly in recent years, and it appears that this growth will continue. It is therefore important to develop a nationwide comparative data base regarding the use and impact of CAD systems. At present such a base of information is not available, and to the extent that information does exist, it generally focuses on input and process measures, but ignores outcome and systemic impacts.

At this point, several conclusions seem appropriate regarding the implementation and evaluation of CAD systems. First, the potential exists for better management--both tactical and strategic--of police field resources and dispatch personnel through the use of the information generated from the elements of a PCCC system. The ultimate impact, though, will depend on the ability of law enforcement administrators to analyze and use this information effectively. It appears that police chiefs often have not considered themselves managers; rather, their responsibilities have been to balance political pressures and to promote the need for law enforcement and police resources. Consequently, it is still uncertain whether police will be able to channel the potential technological talent of the computer to do more than simply perform routine operations.

Second, experience to date has forcefully demonstrated the importance of performance guidelines in the further development of CAD technology. The relationship between the user and the vendor must be clearly defined.

Third, the implementation of CAD technology requires more than technical expertise. The consideration of behavioral and institutional factors is also important. Where systems are working, there also appears to be a sensitivity to human and behavioral considerations.

*Satisfactory was defined as system performance according to agreed-on specifications for 95 percent of the time.

3.2 MOBILE DIGITAL COMMUNICATIONS (MDC)

3.2.1 STATE OF THE ART OF MDC

Mobile digital communications provides a non-verbal means of transmitting messages (both dispatch and status) between the police communications center and the patrol units, and an automated method of accessing law enforcement data files. The basic element of an MDC system is a *mobile digital terminal*, which, depending on the sophistication of the particular system, could be a simple set of lights and status keys or a general alphanumeric keyboard with a hard copy printer and/or cathode ray tube (CRT) display. Messages are converted into and out of binary code by means of an *encoder* and a *decoder*. Message switching and display of messages is controlled by some type of *minicomputer*.

There is a large variety of possible MDC systems, ranging in complexity from quite simple to quite sophisticated, as outlined in Exhibit 3.5. The level of MDC sophistication can be stated in terms of the following options:

- *message capability*

  --status-only
  --full-text
  --full-text plus automatic data base query

- *terminal display*

  --light-emitting diode (LED)
  --cathode ray tube (CRT)
  --hard copy printer

- *transmission flexibility*

  --mobile unit only
  --mobile unit plus out-of-car digital transmission capability

- *radio channel assignment*

  --separate MDC channel
  --combined channel (MDC plus voice)

- *communication mode*

  --simplex (if any patrol unit or base station is transmitting, no one else can transmit)
  --half duplex (frequency band is divided into two--base station can transmit and receive simultaneously, but patrol units operate in simplex mode)
  --full duplex (two frequencies are used--base station and patrol units can transmit and receive simultaneously)

The simplest type of MDC is a status-only system. In such a system the mobile digital terminals (MDTs) in the patrol cars have function buttons which send "canned" status messages to the dispatcher. Status-only systems can be either one-way (allowing communications only from the patrol car to the dispatcher) or two-way. Such simple MDC systems do not require a minicomputer. A more sophisticated type of MDC allows for full text transmission between the patrol car and the dispatcher; in such a system the MDTs have function buttons (like those of the status-only system) plus full alphanumeric keyboards, which allow transmission of any message which could be typed on an ordinary typewriter. The next level of digitization allows for direct data base queries from patrol cars; officers can search law enforcement data bases without relay through the dispatcher or an information operator by typing information requests directly into their MDTs.

Exhibit 3.5

MDC: Possible System Features

Level of Digitization	Description	Comments
Status Only		
One-way	Mobile unit can report status by pressing a single key on mobile unit console. Dispatcher's console maintains indication of last status transmission. All messages from base station are by voice.	Minimum hardware in mobile unit and minimum expense; useful in reducing channel congestion where there are many cars per channel, since status reports constitute a significant portion of traffic.
Two-way	As above, plus comparable capability for base station to transmit status or other "canned" messages (primarily acknowledgments) to mobile units by a single console key. Mobile unit displays messages as lights (no text) or numbers.	Advantages as above, plus saves significant amounts of dispatcher time used to acknowledge status messages. Lack of an acknowledgment capability by either mobile or base unit is generally not acceptable.
Full Text Plus Status	As in two-way status above, plus a full alphanumeric keyboard and display (luminous and/or printer) in mobile unit plus function keys for status and other "canned" messages.	Requires a telecommunications controller at the base station. Reduces dispatcher workload significantly and further reduces channel congestion over status-only capability.
Direct Data Base Query Capability	Mobile unit can make data base queries directly of local, state, and national data bases without relay through dispatcher.	Requires additional hardware (modems to interface with remote data base lines) and additional switching software for minicomputer. Dispatcher control and/or monitoring can be provided.
Computer-Aided Dispatching	Computer performs computations to help dispatcher locate nearest available unit or units to assign to a given incident. Verifies jurisdictional boundaries, valid address, prior complaints, and possible dangerous condition.	Can be added to any system with a computer, requiring primarily additional software. Can be provided with any level of dispatcher control. May require larger computer and more peripherals.
Automated Data Collection and Report Generation	Computer logs all messages or selected types and automatically generates reports of traffic by message type, car, time of day, or other breakdowns. Officer reports can be entered through mobile terminals, and used as part of Field Officer Daily Report although this can increase traffic significantly.	Requires additional software. Useful capability to monitor system performance and usage, trends in message traffic, etc.. May require larger computer and more peripherals.

Source: [Sohn et al, 1975 (b), p. 5]

Despite the fact that military applications of MDC have been ongoing for many years, its introduction into police departments dates only to the early 1970's. We have identified 30 cities currently using MDC, and another 5 cities which are implementing this technology. (Details are in Appendix B.) Fifteen of the 36 jurisdictions in our study sample have operational MDC systems, 2 others are implementing MDC, and 4 jurisdictions have tested MDC and abandoned it. Basic statistics relating to these systems are shown in Exhibit 3.6.

The cost of mobile digital terminals appears to range from $3,200 to approximately $5,000 per unit, with the average approximately $4,500 per unit. Because the cost of an MDC system is unit-based, total MDC system cost for any jurisdiction naturally depends on the size of the jurisdiction and on the fraction of the patrol vehicles equipped with MDC. Some cities have reported that MDC maintenance costs are fairly large compared to the initial installation cost. For example, Oakland purchased its 32-unit MDC system for $149,980 with an associated yearly maintenance cost of $49,815 or about one-third of the initial purchase price. This is indeed a very high maintenance cost; it should hopefully decrease as MDC technology is further tested and developed. Despite the relatively high cost of purchase and maintenance, however, Oakland felt that it was cost-effective to have an MDC system.

As in the case of CAD, MDC applications vary significantly among cities; some cities, such as St. Louis and Dallas, use 10-code status-only terminals as a part of a larger AVM system; other cities, such as Albany, use MDTs with teleprinters as a one-way dispatching system; Chicago and Detroit, for example, use MDC exclusively for data base inquiries; and still other cities, such as Las Vegas, have full-text terminals with teleprinters, direct data base query capability, and digitized dispatch capability. The types of systems in use in the various jurisdictions in our study sample are also noted in Exhibit 3.6.

From our surveys it seems that variation in the use of MDC depends primarily on the needs of a particular department, the PCCC system capabilities, and the overall philosophy of the department towards MDC (and PCCC-related technology). For example, status reporting and dispatching capabilities may not be used in cities which do not have CAD or AVM. Likewise, highly automated systems may not be used in cities which are somewhat resistant to new technologies. The use of MDC in any city also relates closely to the perceived benefits and problems of MDC in that city (which will be discussed below).

As mentioned earlier, the trend has been for police departments to install CAD before MDC or AVM; currently, there are only 30 operational MDC systems and 65 operational CAD systems. Furthermore, three-fourths of the MDC applications are in cities which have CAD systems.

3.2.2 OBJECTIVES AND IMPACTS

It appears from the PCCC-related literature that few evaluations of MDC have been performed. However, there have been several studies

Exhibit 3.6

MDC-Related Statistics

Jurisdiction	Population Served (1000's)	MDC[1]	Keyboard Type[2]	Display Type[3]	Data Base Access[4]	Dispatching[5]	Status[6]	Vendor	Fraction of Patrol Force with MDC	Implementation[7]	Installation Date
New York City	7,605	X	A	C	X	X	*	Motorola	small	S	
Chicago	3,115	X	A	L	*	X	X	Motorola	.14	S	5/77
L.A. County	2,750										
Dade County	2,000										
Philadelphia	1,820										
Detroit	1,300	X	A	C	*	X	X	Motorola	.60	S	6/78
Dallas	859	X	10	L	X	X	*	Supplied by Hazeltine	.20	S	--/77
San Antonio	850										
Indianapolis	741										
San Francisco	716	[X]	A	C	*	X		[Kustom]	.10	0	1/70
San Diego	697	[X]	A	T	*	X	*	[Motorola]		0	--/77
San Jose	570	X	A	C	*	*	*	Kustom	.25	S	12/76
Boston	550										
St. Louis	538	X	10	L	X	X	*	Motorola	1.00	S	6/74
Denver	515										
Seattle	505										
Fresno Coun	485										
Nashville	470										
Minneapolis	435	X	A	C	*	X	X	Kustom	.90	S	6/74
Miami	354	(X)						(E-Systems)			
Newark	352	X	A	C	X	X	*	Motorola	1.00	0	6/77
Oakland	350	X	A	C	*	X	X	E-Systems	.60	0	6/71
Tulsa	343										
Las Vegas	322	X	A	C	*	*	*	Kustom	1.00	0	12/75
Quad Cities	320	[X]	A	T				[Xerox]			
Charlotte	310										
Virginia Beach	255	X	A	C	*	X	*	Motorola	1.00		6/76
Fresno City	186	X	A	C	*	*	X	Kustom	1.00		
Salt Lake City	169										
Huntington Beach	160	X	A	T	X	*	*	Motorola	1.00	0	6/74
Hampton	150	[X]	A	C				[IBM]			6/75
Albany	114	X	A	T	X	*	X		1.00	0	3/75
Sunnyvale	106	X	A	C	*	*	*	Motorola	1.00	0	6/76
Cranston	77										
Aurora	75	(X)						(Motorola)			
North Las Vegas	50										

[1] X = with MDC; blank = no MDC; [X] = MDC tested and abandoned; (X) = MDC planned.
[2] A = alphanumeric; 10 = ten-code.
[3] L = light-emitting diode; C = cathode ray tube; T = teleprinter.
[4] * = with data base access; X = no data base access.
[5] * = used for dispatching; X = not used for dispatching.
[6] * = used for status reporting; X = not used for status reporting.
[7] S = implemented in stages; 0 = implemented all at once.

assessing the *potential* of MDC in law enforcement (Telcom, 1969; Urban Sciences, 1973; Sohn et al, 1975 [b]), as well as somewhat formal evaluation studies of three test systems (Oakland Police Department, 1975; Hennepin County Sheriff's Department, 1975; Minneapolis Police Department, 1975). The findings of these studies, along with information from our surveys and site visits, are reviewed in the following subsections.

STATED OBJECTIVES

Congestion of police radio frequencies has been a primary reason for the adoption of MDC in police operations. In fact, the National Advisory Commission on Criminal Justice Standards and Goals (1973, p. 566) predicted that MDC could reduce frequency congestion by 40 to 50 percent. A second major reason for the interest in digital communications is that many law enforcement data bases are now computerized, and a patrol unit equipped with digital communication can *automatically* access these data bases if a suitable switching device (i.e., a minicomputer) is provided at the base station. Furthermore, easier data base access would in turn contribute to enhanced officer safety as well as increased "hit" rates.

A complete list of MDC objectives as identified in the literature is contained in Exhibit 3.7. A review of the objectives shows that MDC supports both the *status monitoring* and *response/adjustment* functions of PCCC. However, in actual practice, all implemented MDC systems have status monitoring potential, while only a few are capable of effecting the more general response/adjustment function, including for example, the direct dispatch of patrol units using only digitally transmitted instructions.

MDC IMPACTS

Overall, the response to MDC in different cities has been mixed. As mentioned earlier, a number of jurisdictions have tested MDC and abandoned it. Furthermore, in some cities with operational MDC systems, the terminals are used only by some of the patrol officers and in some cases all of the system capabilities are not being used.

Primary MDC uses include data base access, status reporting, and dispatching--and MDC success for each of these purposes differs. MDC seems to be best accepted when used for *automated data base access*, since it significantly decreases the amount of time needed to query a remote data base, and in tests in some cities has led to substantial increases in arrest rates. However, while MDC may increase officer effectiveness, it may also decrease officer efficiency since officers spend more of their time making data checks. MDC has met with mixed success when used for *status reporting*: in a number of cities we have visited (such as Newark, Oakland, and St. Louis) the status reporting capabilities, though operational, are not used or are only partially

Exhibit 3.7

MDC: Stated Objectives

- To reduce voice congestion and expand the communications capability of existing radio channels -- using digital signals which have a higher transmission rate than voice signals.
- To increase officer effectiveness -- through easier access to remote data files, which could potentially result in more "hits" (i.e., apprehensions and recoveries).
- To increase dispatcher effectiveness -- by relieving the dispatcher of routine data inquiries, patrol status updates, message repetitions, and/or dispatches of some (non-critical) calls for service.
- To increase officer safety -- through easier data base access, increased communications capability, and an "Emergency" button on MDT units.
- To improve message security -- using digital signals which are more difficult to decipher than voice messages.
- To improve accuracy and decrease message repetition -- using mobile digital terminals which can provide hard copies.
- To allow selective routing of messages -- using terminals which can be addressed either collectively or individually, on an "as need to know" basis.
- To allow unattended message reception -- using terminals which can record messages while the officer is out of his vehicle.

used. For *dispatching*, MDC systems have also met with mixed success: some cities, such as Albany, use CAD for a large fraction of the total dispatches; others, such as Oakland, have experimented with MDC for dispatching and abandoned it. In many cities, patrol officers object to MDC for dispatching because they want to hear what other officers on the street are doing. Most of the problems with using MDC for status reporting and dispatching appear to be personnel-related. These problems highlight the importance--as also found with the other PCCC technologies--of behavioral and institutional factors in successful PCCC applications.

Exhibit 3.8 summarizes the results of the available MDC evaluations, and Exhibit 3.9 reviews the actual and potential impact of MDC for each of the stated objectives. As with CAD, it seems from our literature search, site visits, and surveys that the *input* objectives for MDC have generally been met. In the 30 jurisdictions with operational MDC systems, the systems are working from a technical perspective, although only a limited amount of evaluation data is available.

When *process* and *outcome* objectives are considered, the results are more mixed. A major objective of many police departments in MDC implementation has been reduced voice-band congestion. However, although digital transmission may be faster than voice transmission, it seems from the available literature and from our surveys and site visits that MDC has not reduced radio air congestion per se. The three available evaluation studies found that (1) quicker and easier access to remote data bases significantly increased the level of data inquiries, and (2) the channel time made available by the digitization of some voice messages was taken over by voice messages which previously could not be transmitted due to excessive channel congestion. In many cities, it appears that what has actually occurred is not a reduction in voice congestion, but instead an increase in the total level of communication and in the *quality* of the voice communication. This was the case, for example, in Huntington Beach and St. Louis. In St. Louis, there is still a fair amount of voice congestion, but the actual amount of total communication (voice and digital) has increased greatly and the information which is being handled by voice is more important dispatch information (rather than status information). In Huntington Beach, administrative messages and routine dispatch information are transmitted through MDC, thus removing the pressure for these kinds of messages from the voice channel. While there is still approximately the same amount of traffic on the voice channels as before, the content of the information being transmitted is more important. Thus, while reduced air congestion may not be a realistic objective for MDC systems, increased air communications can be a valid MDC objective.

Another interesting finding in Exhibit 3.9 concerns officer effectiveness. Oakland (1975) found that their MDC-equipped patrol units

Exhibit 3.8

MDC: Reported Findings

Stated Objectives	Reported Findings
• Reduced Radio Air Time	• Ratio of a message's voice to digital air time[1]: --Sohn et al. [1975(b)] estimated the ratio to be between 5 and 10. --Minneapolis [1975] found that it took an average of 175 seconds to make a voice inquiry to a remote data base (via dispatcher) and 17 seconds using MDC, yielding a ratio of 10.4. --Hennepin County [1975] calculated an average air time for voice and digital messages of 107.4 and 23.2 seconds, respectively, yielding a ratio of 4.6. --Oakland [1975] found the ratio to range from 3 (for a stolen vehicle check) to 6 (for a registered owner check).
	• Ratio of number of remote data base inquiries made under MDC to that prior to MDC[2]: --Minneapolis [1975] found the ratio to be 15.5. --Hennepin County [1975] found the ratio to be 1.8. --Oakland [1975] did not identify such a ratio, but instead found a ratio of 5.7 when comparing the average number of inquiries made by MDC-equipped patrol units to those without MDC equipment.
	• No evaluation study measured radio channel utilization, but all 3 studies indicated that *no* air time was saved because: i) the number of remote data base inquiries increased significantly; and ii) the extra channel time created by conversion to digital communications was immediately replaced by those voice messages which could not be transmitted before because of frequency congestion.
• Increased Officer Effectiveness	• Oakland [1975] found that MDC-equipped patrol units averaged 14.5 times as much "possible hit" information as non MDC-equipped units, which resulted in 2.8 times as many actual warrant arrests and vehicle recoveries.
	• All 3 sites (Hennepin County, Minneapolis, and Oakland) conducted questionnaire surveys of officers and dispatchers and found strong support for their MDC systems.
• Increased Dispatcher Effectiveness	• No evaluation study measured impact of MDC on dispatcher workload.
	• Oakland [1975] found that *potentially* 45% of all calls for service could be digitally dispatched -- however, during a 2-week special effort test, only 16% of all calls were digitally dispatched.
	• No evaluation study measured the impact of canned digital messages on attracting the dispatcher's attention on an immediate or pre-emptive basis, although St. Louis, Missouri, has reported verbally that this has had an important impact.

[1]This ratio is a function of: a) the type of message being transmitted; and b) the digital transmission rate, which can range from 50 to 700 characters per second, with an average of 150 characters per second.

[2]In comparing these ratios, it should be kept in mind that both Minneapolis and Oakland had fully automated access to remote data bases, while Hennepin County's access was only partly automated (inquiries were sent through the dispatcher and only responses were sent through MDC).

Exhibit 3.8

(Page 2 of 2)

Stated Objectives	Reported Findings
• Increased Officer Safety	• No study measured the degree of increased officer safety, but all 3 studies stated that the *availability* of a digital link to summon help contributed to the officers' sense of safety.
• Improved Message Security	• None of the studies measured the impact of improved message security. Hennepin County [1975], however, suggested that MDC could help prevent media representatives and members of the public from showing up at the scene of in-progress crimes.
• Improved Message Accuracy	• No evaluation study measured the degree to which message accuracy had improved, if at all.[3] Hennepin County [1975] noted that there was less need for message repetition.
• Selective Routing of Messages	• None of the studies measured the degree and/or impact of selective routing.
• Unattended Message Reception	• No evaluation study measured the degree and/or impact of unattended message reception. Minneapolis [1975] indicated that this feature was liked by the patrol officers.

[3]It should be noted that all 3 sites (Hennepin County, Minneapolis, and Oakland) were using CRT terminals in their tests -- no hard copy terminals were tested.

Exhibit 3.9

MDC Impacts

	Actual Impact	Potential Impact
INPUT OBJECTIVES		
•Allow selective routing of messages	•This objective will automatically be achieved if the MDC system has selective routing capabilities.	
•Allow unattended message reception	•This objective will automatically be achieved if the terminals include teleprinters.	
•Improve message security	•No formal evaluation has measured the impact of MDC on message security, but it seems that MDC by its very nature will improve message security.	
•Facilitate access to remote data files	•MDC systems which include terminals with remote data base access greatly facilitate data base access.	•MDC may achieve improved arrest rates for outstanding warrants, although it may also have an impact on the nature of police work (e.g., amount of time spent on file checks).
PROCESS OBJECTIVES		
•Reduce voice-band congestion	•The three available MDC evaluations indicate that no air time was saved because: i) the number of remote data base inquiries increased greatly; and ii) the extra air time was taken up by messages which could not be transmitted previously.	•Rather than reduced voice-band congestion, it appears that a more realistic MDC objective is increased communications.
•Increase dispatcher effectiveness	•Little evaluative information is available.	•MDC has potential for improving dispatcher effectiveness. Features such as automatic status updating and automatic data base access may relieve the dispatcher for other tasks.
•Improve accuracy and decrease message repetition	•Little evaluative information is available.	•MDC has potential for improving accuracy and decreasing message repetition, especially if the system includes teleprinters.
OUTCOME OBJECTIVES		
•Increase officer effectiveness	•Oakland found that officers in MDC-equipped units averaged 2.8 times as many arrests as officers without MDC, but those officers were found to be less efficient. Little other data is available.	•MDC has potential to increase officer effectiveness, but it is important to realize that putting a terminal in the patrol car may eventually result in a significant change in police work.
•Improve officer safety	•No formal evaluation results are available, but the three available MDC studies all stated that MDC contributed to the officers' *sense* of safety.	•MDC has potential to improve officer safety if the terminals include an "Emergency" status button.
SYSTEMIC OBJECTIVES		
•Avoid encroaching upon citizen privacy	•Little evaluative information is available.	•MDC provides easier access to law enforcement and related data files. Important questions remain concerning the impact of the increased information on citizen privacy.

accessed an average of 14.5 times more "possible hit" information than their non-MDC-equipped units, but made only 2.8 times as many warrant-related arrests and vehicle recoveries. Consequently, although the total number of "hits" and arrests on a per request basis was higher, the MDC-equipped units were *less* efficient than their counterparts, since they have a lower ratio of "hits" to requests.*

There are also a number of potential problems associated with MDC use. Cities mentioned maintenance cost, improper use by officers, and "bulk" in the patrol vehicle as disadvantages of MDC. Maintenance cost and terminal size relate directly to the newness of the technology; as the technology becomes better established, these problems should improve. Improper use of the MDC, on the other hand, is a training and behavioral problem which is directly parallel to problems we have found in other PCCC application areas.

Finally, important questions remain concerning the impact of increased access to information on citizen privacy. MDC may eventually change police patrol operations significantly. As one observer noted about the "MDC approach which encourages mass data checks rather than the selective use of data base inquiries" in conducting field work:

> "I'm a bit old fashioned, perhaps, but I fail to see the cost-effectiveness of police field units running inquiries en masse on everyone they contact, license plates in parking lots, etc. It rubs against my grain in terms of *privacy* and intelligent use of field patrol time. An examination of this issue may indicate a lack of planning in MDC systems and acquiescence of police administrators who don't realize the change in philosophy they are embarking upon when they stick a computer terminal in the front seat of a patrol car."

CONCLUDING REMARKS

In conclusion, several points can be made regarding the use and impact of MDC. First, although digital transmission may be much faster than voice transmission, it appears that MDC does not reduce radio air time, but does allow for increased air communications. Therefore, although reduced channel congestion is not a realistic objective for MDC systems, increased *air communications* can be a valid MDC objective.

Finally, as with other PCCC technologies, very few evaluations of MDC systems have been performed; those that have been identified and

* The MDC equipped units had 14.5 times as many requests, but only 2.8 times as many hits, so they were 2.8/14.5 or approximately one-fifth as efficient as the non-MDC-equipped units.

reviewed in this section are lacking in many respects. All three studies leave a number of unanswered questions regarding many of the stated MDC objectives, including the impact of MDC on dispatcher efficiency, officer safety, message security, and message accuracy. Furthermore, all three studies base their conclusions on small samples of data--sometimes less than a week's worth of data. To a certain extent they also lack objectivity; all three studies were conducted by police department personnel who were closely associated with the implementation of their respective MDC system. Final conclusions are not available as to whether MDC will actually reduce voice congestion, whether officers are more or less productive with MDC, or whether MDC serves to increase officer safety. MDC systems around the country will undoubtedly expand over time; hopefully such issues concerning the outcome and systemic impacts will also be addressed as the use of the technology grows.

3.3 AUTOMATIC VEHICLE MONITORING (AVM)

3.3.1 STATE OF THE ART OF AVM

An AVM system provides a police dispatcher with real time location estimates of each vehicle in a fleet and provides additional vehicle status information (e.g., "in pursuit," "enroute to scene," "driver door opened," etc.). However, an automatic vehicle location (AVL) system provides only location estimates without additional status information. Although a distinction can be made between AVM and AVL, our study deals primarily with AVM systems. An AVM system is usually linked to a CAD system as a part of an overall computerized dispatch operation.

Different methods have been developed for locating vehicles as a part of an AVM system, and a number of references compare and contrast these methods, reviewing the advantages and disadvantages of each; [G. Larson, 1976; G. Larson and Simon, 1978; Hansen and Leflang, 1976; Doering, 1974; Mitre, 1973; Aerospace Corporation, 1976]. Four methods are generally discussed.

- *Navigation (hyperbolic) systems.* The principal navigation type AVM application is Loran C, which has been used for nearly twenty years in the navigation of ships at sea. Utilizing radio location techniques, shifts in location with the Loran C system are identified by the arrival time of patterns of pulses emitted from various transmitters. The intersection of two hyperbolas defines the vehicle location.

- *Trilateration systems.* Such systems also utilize radio location techniques. Three or more fixed sites are used to determine the vehicle distance from each of the sites by measuring the radio signal travel time. Fixed receivers relay the signals to a headquarters location where the computer locates the vehicle.

- *Signpost/proximity systems.* With this technique, electronic signposts are positioned in fixed locations throughout an area, and a vehicle is located when it comes within the proximity of a signpost. Signposts can be either receivers or, in most cases, transmitters. A number of different types of transmitters have been developed, including radio signposts, magnetic signposts, and microwave signposts.

- *Dead-reckoning systems.* With computer-aided dead-reckoning, the vehicle starting position is established, then instruments are used to track the vehicle's location using data on speed and direction. The computer then translates the vehicle's position to a specific location on the "city map" utilizing an advanced geocoding system.

AVM for urban applications is a relatively new technology. The development of commercial AVM systems was not begun until the late 1960s, and only 5 cities have installed police AVM systems since then. Furthermore, only three of these systems are still operational; these three (St. Louis, Dallas, and Huntington Beach) were included in our study sample. Each of the five police AVM applications is discussed below.

The first system established was in Montclair, California, a city with a population of approximately 30,000 people. Montclair utilized a signpost transmitter system where the transmitter radiated the signpost identification to the vehicle and the vehicle in turn transmitted the identification to headquarters. The Montclair project began in the early 1970s and an evaluation was completed in 1974 [Montclair Police Department, 1974]. However, the system is no longer in operation, due in large part to operational problems.

In 1975-76 Huntington Beach, California, a city with a population of about 150,000 people, installed a proximity signpost AVM system along with CAD. This system is not currently operating because of problems with the interface between the CAD and AVM systems, but should become operational again in 1981.

The first full-scale implementation of an AVM system in a major urban police department occurred in the St. Louis Police Department in

the mid-1970s. Utilizing a computer-aided dead-reckoning system, the St. Louis AVM system was established on an experimental basis in one police district in 1976 (Phase I), and then was implemented citywide (Phase II) in 1977. Evaluations were conducted of both the Phase I and Phase II efforts [R. Larson et al, 1976; G. Larson and Simon, 1978].

Dallas has AVM in one of its five police districts. The system is a Hazeltine pulse trilateration system which was implemented in 1977 with potential for expansion to the rest of the city. While the system implementation was initially very smooth, the system developed a number of technical problems (for example, the equipment in the patrol cars overheats in the summer). The Dallas Police Department is still uncertain as to when or if they will expand AVM to the rest of the city.

AVM has also been discussed and tried in a few other cities. Stamford, Connecticut, established a signpost system where the signpost served as a receiver to pick up the identification of the vehicle and relay this identification to headquarters. However, the Stamford system has experienced a number of difficulties and is no longer in operation. Orlando, Florida, also considered establishing an AVM system [Doering, 1974].

3.3.2 OBJECTIVES AND IMPACTS

When the potential police uses of AVM systems were first highlighted by the President's Commission on Law Enforcement and Administration of Justice [1976], studies at that time suggested that such systems might achieve cost-effective reductions in police response time. Others hypothesized that AVM would improve apprehension rates and would thus serve as a deterrent to crime. The following sections will consider these stated objectives and the reported results of such AVM systems.

STATED OBJECTIVES

The primary objectives of AVM, as outlined in the literature and summarized in Exhibit 3.10, relate mainly to the *status monitoring* function of PCCC. For example, the primary focus of much of the early AVM-related literature is on response time reduction, both in terms of reduced dispatch time (because the AVM system would continually monitor vehicle status and location, thereby allowing the dispatcher to make more rapid dispatch decisions) and reduced travel time (because the closest car would be assigned to the incident) [Hansen and Lefland, 1976; Aerospace Corporation, 1976]. Other studies further hypothesize that reduced response time could increase apprehension rates [Riter, 1972]. A third anticipated benefit is that of improved officer safety, since an officer in an emergency situation could simply push a button and the precise location of his vehicle would be known to the communications center.

Exhibit 3.10

AVM: Stated Objectives

- To reduce response time -- through reductions in dispatch and travel times.
- To increase apprehension rates -- through reduced response time.
- To improve officer safety -- by continually monitoring the status and location of police vehicles.
- To improve dispatch efficiency and coordination -- by providing the dispatcher with precise data on unit status and location.
- To improve tactical command and control -- through on-line direction of such special tactical events as high speed chases, bank robberies, emergency deployment, and support for covert operations.
- To improve patrol efficiency and effectiveness -- through the availability of *direct* information regarding the location and allocation of the patrol force, and through the *indirect* realization of patrol officers that they are being monitored.
- To improve supervision of the patrol force -- through better on-line supervision of officers in the field and through the use of the management information generated from the AVM system.
- To reduce voice-band congestion -- when linked with some type of mobile digital communications (MDC).

Several AVM objectives also relate to the *response/adjustment* function of PCCC. These include hoped-for improvements in dispatch efficiency and coordination, and improved tactical command and control. The basic expectation regarding these objectives is that better data concerning status and location will allow for improvements in determining the appropriate response to an incident and in coordinating the activities of the police force [R. Larson et al, 1976; McLean, 1974]. For example, with an AVM system, the dispatcher and/or communications supervisor would be able to directly supervise the movements in a high speed chase or a bank robbery using real-time location information.

AVM objectives also may relate to *resource management* through potential improvements in patrol efficiency and effectiveness, and through improved supervision of the patrol force. However, many of the benefits related to these objectives are subjective and thus are difficult to measure.

The final AVM objective relates to reducing voice-band congestion and improving police communications. This objective may be possible when AVM is linked with some type of mobile digital communication (MDC) system. Although AVM-related, such an objective is not limited to AVM systems, but also relates to other PCCC applications.

AVM IMPACTS

It appears that most of the potential benefits of AVM have yet to be realized. This is illustrated by a review of Exhibit 3.11 which outlines AVM impacts for each of the AVM objectives. Even the input objectives of AVM have met with only mixed success because of technical and behavioral problems; and when it comes to process and outcome objectives, the results are very uncertain.

The first objective, that of *monitoring patrol officer locations* with a predetermined level of accuracy, has met with mixed results because of system performance and reliability difficulties in the implemented AVM systems. In Montclair, overall reliability was estimated in the 80 percent range, with the mobile unit transceiver presenting the lowest level of reliability. Such operational problems no doubt influenced officer attitudes towards AVM, and the system in Montclair is no longer in operation. In St. Louis the greatest difficulty has been "lost cars." During a Phase I test period, cars had to be relocated or "reinitialized" at a rate of 11 cars per day (i.e., an average of 2.2 hours between losses).

Regarding improvements in *voiceband congestion*, positive results were reported in St. Louis. However, the primary benefits appear to come not from a reduction in voiceband congestion per se, but from the fact that digital communication offers the officer instant access to the communications center. In Montclair, a digital transmission was not seen as a particular advantage to the field officer since the communi-

Exhibit 3.11

AVM Impacts

	Actual Impact	Potential Impact
INPUT OBJECTIVES		
•Monitor patrol officer locations with predetermined accuracy	•Results to date have been mixed due to technical problems.	•If technical problems can be resolved, AVM has strong potential to achieve this objective.
PROCESS OBJECTIVES		
•Reduce voice-band congestion	•A study in St. Louis showed that no air time was saved because the extra air time was taken up by messages which could not be transmitted before because of congestion.	•Rather than reduced congestion, it appears that a more realistic objective is increased communications.
•Reduce emergency response times	•Data from the St. Louis and Huntington Beach AVM systems indicate no significant improvements in response time. Montclair noted some response time benefits, but this was based on a relatively small data sample.	•Reductions in *average* response time do not appear to be a primary benefit of AVM, but it may be possible to significantly reduce response time to *high priority* incidents through prioritization.
•Improve dispatch efficiency and coordination	•Little evaluative information is available.	•AVM has the greatest potential for improving dispatch efficiency and coordination when linked with a CAD system.
•Improve supervision of the patrol force	•When AVM is working properly, both communications personnel and police supervisors have greater supervision of the patrol force.	•In terms of patrol force supervision, AVM has strong potential for both good and abuse; actual impact will depend on the ability of the department to use the information wisely.
•Improve tactical command and control	•Little evaluative information is available, but there are a few cases of success in high speed chases, etc.	•AVM has strong potential in this area.
OUTCOME OBJECTIVES		
•Increase apprehension rates	•Little evaluative information is available.	•If AVM reduces response time, especially to high priority incidents, it is possible that apprehension rates would increase, but the link between response time and apprehension rates is still uncertain.
•Improve officer safety	•Little evaluative information is available, but in St. Louis many officers lacked confidence in the officer safety aspects of the AVM system due to poor accuracy.	•AVM has potential for improving officer safety, assuming it is working properly, since officers' locations are automatically known to the communications center.
•Improve patrol efficiency and effectiveness	•Little evaluative information is available.	•While AVM seems to have potential to improve patrol efficiency and effectiveness, such benefits must still be demonstrated and will be difficult to pinpoint.
SYSTEMIC OBJECTIVES		
None.		

cation environment prior to AVM was relatively uncongested because of the small size of the department.

Of all the PCCC-related technologies, AVM initially placed the greatest emphasis on *response time* reduction as a potential benefit. However, it appears that very few improvements have been achieved. In St. Louis a careful evaluation of before-and-after response time was carried out, but in both Phases I and II no significant improvements in travel time due to AVM occurred. There were modest travel time improvements during Phase I; but at the end of the Phase II citywide implementation, it appears that response time on the whole was somewhat longer. (There were many factors other than AVM, such as less experienced dispatchers, which probably accounted for most of the increase in response time.) In any case, contrary to earlier expectations, response time reductions do not appear to be a primary benefit of AVM.

Similar conclusions regarding response time were also reached in Huntington Beach. A sampling of response time data before and after the installation of the AVM system was made for both "dispatcher processing time" and "travel time." Data were taken for operations over two one-month periods, one year apart, in order to minimize the effect of seasonal variations in patrol activity. Based on the study, "no significant change was found in response time before and after the installation of the AVM systems" [Reichardt, 1977].* In Montclair, some response time benefits were noted in 1974. However, the evaluation was based on a relatively small sample. Also, in a city the size of Montclair, response time does not appear to be a significant difficulty, and, according to McLean [1974], the benefits of improved response time seem minimal when compared to the cost.

As mentioned during our CAD analysis, recent studies have also raised questions as to what effect, if any, reductions in response time will have on *apprehension rates,* since citizen reporting delays are often quite long.

Results concerning *officer safety* have also been disappointing so far. Poor accuracy was the major contributor to the loss of confidence in St. Louis, and in times of emergency officers now prefer to use the voice radio in combination with an AVM-related emergency button. Officer safety is still a potential benefit of AVM, but in St. Louis the impressions of the past several years must be modified if attitudes are to change.

Perhaps the greatest potential benefits of AVM relate to possible improvements in *police supervisory capabilities* and improvements in *police productivity*. In the area of patrol force supervision, AVM can be a powerful tool, but it has strong potential for both beneficial

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* It is important to keep in mind that potential response time reductions may be limited by a requirement that patrol cars stay in or close to their assigned beats.

effects and abuse. Related to this capability are a number of attitudinal problems, as reported in the available evaluations and confirmed in our site visits; the officers on the street feel that AVM may be used as a "Big Brother." (There was one instance in Huntington Beach where an officer received disciplinary action when his sergeant, using their AVL system, discovered him at an unauthorized location.) Although a number of officers still think AVM is a good idea, many are fearful that the system will be used primarily as a disciplinary tool.

Regarding police productivity, little evaluative information is available, although the St. Louis study concluded that "reasonable levels" of productivity improvement could bring a very attractive return on investment. [G. Larson and Simon, 1978] However, the key is to establish a link between AVM and such returns.

CONCLUDING REMARKS

Relatively few AVM systems have been established throughout the country, and evaluations have been conducted in only two cities. These studies have focused primarily on input and process measures, and broader evaluations concerning the outcome and systemic impacts remain to be done. Still, it is possible to make a number of conclusions based on the evaluation efforts to date and based on PSE's survey and site visits.

First, there is a close tie between the technical performance of a system such as AVM and the overall results and attitudes concerning the system. St. Louis, Huntington Beach, and Dallas have all experienced a number of technical and operational difficulties, and these difficulties have led to a decline in officer attitudes toward the system. Such a tie highlights the necessity of outlining clear performance specifications prior to implementing such technological innovations.

Second, the expected benefits regarding response time have not been achieved. If AVM systems are to be justified, other benefits must be forthcoming. The most promising possibilities appear to be improvements in tactical command and control and police productivity, and related improvements in management and supervision of the patrol force. The potential exists in each of these areas, but further evaluation and experimentation are essential.

Third, there is an important link between AVM and other PCCC applications. For example, the implementation of AVM may be more effective when tied to a CAD system. In St. Louis, AVM was established independently, and as such certain activities required intervention, such as manually placing a cursor to identify the location of an incident. With a CAD system, this could be done automatically.

AVM is a relatively new, untested technology for police applications. Two systems were tested and abandoned, and the three systems which are currently operational have a number of technical and/or behavioral difficulties. As AVM technology becomes more advanced, and if more departments meet with success using AVM, increased use of the technology may occur. AVM may also receive more applications if it can be linked with a wide range of users, including taxis, buses, delivery systems, etc. At this point, however, most of the departments we surveyed feel that although AVM systems have potential, the major question at present is whether the benefits of AVM justify the costs.

3.4 NINE-ONE-ONE (911)

As mentioned earlier, 911 has been a limited part of this study; a nationwide evaluation of 911 has been carried out by SRI International.* The following sections will review the state of the art of 911 and then briefly summarize the objectives and impacts of 911.

3.4.1 STATE OF THE ART OF 911

In response to growing public and law enforcement demand, the American Telephone and Telegraph Company (AT&T) announced January 12, 1968, that "911" was being reserved as the all-purpose emergency telephone number in the U.S. However, contrary to the telephone industry's established practice of forwarding those emergency calls placed by dialing "0" for operator assistance, AT&T viewed the answering of 911 calls outside the scope of telephone company business. Nine-One-One calls were to be directly switched to public safety answering points (PSAPs), which were to be handled by personnel of one or more local public safety agencies.

A *basic* 911 system provides a central answering point to which all 911 calls are routed. There are, in addition, a number of *advanced* features which can be incorporated into a 911 system. These include:

- Automatic Number Identification (ANI), which allows automatic display of the number of the telephone from which the 911 call is initiated;

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* SRI International, "Dial 911 Transfer and Assessment Study" (LEAA grant number JOLEAA-010-8), 1980.

- Automatic Location Identification (ALI), which allows automatic display of the address of the telephone from which the 911 call is initiated, using ANI information in conjunction with an inverse telephone directory;

- Jurisdictional Selective Routing (JSR), which allows routing of the 911 call to the appropriate jurisdictional PSAP, using ANI and/or ALI information;

- Supplementary Dispatch Support Date (SDSD), which is an ALI-initiated data base that includes the police beat designation, the fire box area, and the ambulance zone of the location where the 911 call is initiated;

- Internal Selective Routing (ISR), which allows routing of the 911 call to the appropriate answering operator within a large PSAP, using ALI information in conjunction with SDSD; and

- Automatic Registered Name Identification (ARNI), which allows automatic display of the registered name of the telephone from which the 911 call is initiated, using ANI information in conjunction with an inverse telephone directory.

Although the AT&T announcement of 911 occurred over a decade ago and was met with much enthusiasm, widespread adoption of 911 has not occurred. While there are now some 800 such systems in operation throughout the United States, only one out of every four persons can access 911. Most 911 implementations have been in smaller cities; two-thirds of the implemented 911 systems are in cities with populations less then 25,000 (Reinke, 1978). In the larger U.S. cities (those with populations above 500,000) 911 has been implemented in only 11 out of 26 cities, as shown below. Eighteen of the 35 jurisdictions in our study sample have 911; basic statistics relating to these systems are shown in Exhibit 3.12.

	No.		Population	
911 Cities:	11	42%	18,421,000	59%
Cities with other Numbers:	15	58%	12,630,000	41%
	26	(100%)	31,051,000	(100%)

Adapted, based on PSE data, from: [Reinke, 1978, p. 30]

We were able to obtain 911 costs for 6 or 18 cities in our study sample. For the systems where we did obtain 911 costs there was a wide variation in the figures reported by the police department, ranging from lows of $2,000 in Sunnyvale and $4,000 in Boston to a high of $125,000 in Dade County. The costs reported to us in our surveys are those incurred by the departments themselves, and in different jurisdictions the telephone company may have absorbed different fractions of the actual 911 system costs. Further research is required in order to make any generalizations about 911 systems costs.

Most of the existing 911 systems are basic systems. However, a handful or jurisdictions--such as Chicago, Dade County, and Alameda County--have also implemented some of the advanced features, including automatic number identification (ANI), internal selective routing (ISR), and jurisdictional selective routing (JSR). To date, these features have been installed only in major population areas.

IMPLEMENTATION

There are three major factors which have constrained the implementation of 911. Probably the most significant problem is a technical one and stems from the fact that, in most urban and suburban areas in the U.S., the telephone company's central office exchange boundaries do not coincide with the politically defined jurisdictional boundaries. There are several possible solutions to this problem, as suggested in the literature (Maricopa Association of Governments, 1979). First, the boundary mismatch problem can be solved technically through the use of selective routing, as in Alameda County, California, (Hovey, 1974). Selective routing can be carried out automatically, if the telephone company has electronic switching equipment, or with a central computer. However, if the telephone company does not have electronic switching equipment, selective routing may be very expensive to install. Electronic switching equipment has not been installed nationwide, and even in some large urban areas, telephone companies do not have such equipment. A second solution involves creation of multiple PSAPs (as if there were no boundary mismatch problem), and transfer of calls which are incorrectly routed. This solution was chosen in San Antonio, Texas, where the San Antonio Police Department receives 911 calls for 22 surrounding

Exhibit 3.12

911-Related Statistics

Jurisdiction	911[1]	Advanced Features[2]	When Installed	Number of Phone Companies	911 Cost (1000's)	Short-term % Increase in Calls	Long-term % Increase in Calls
New York City	X	ISR	7/68	1		Large	Large
Chicago	X	ISR, ANI, ALI	9/76	1		Large	Large
Los Angeles County							
Dade County	X	JSR, (ANI)	2/79	1	690	35	NA[3]
Philadelphia	X		3/74			15	0
Detroit	X		9/73			Large	Large
Dallas							
San Antonio	X		10/78	1	7	30	NA
Indianapolis	X	"lock-in"	10/76	1	89	25	25
San Francisco							
San Diego							
San Jose							
Boston	X		11/72	1	4		40
St. Louis							
Denver	X		5/71	1			
Seattle	X		4/71	1		13.6	35.7
Fresno County							
Nashville	X		4/72				
Minneapolis							
Miami	X	ANI,JSR,(ALI)	2/79	1	690[4]	46	34
Newark	X		5/77			"No great	increase"
Oakland	X	"lock-in", ANI, JSR, (ALI)	7/78		60	"Small	increase"
Tulsa							
Las Vegas							
Quad Cities							
Charlotte	X		7/79	3	50	NA	NA
Virginia Beach							
Fresno City							
Salt Lake	X		7/75	1			
Huntington Beach							
Hampton							
Albany							
Sunnyvale	X		11/72	1	2	10	0
Cranston							
Aurora	X		7/75	1		0	25
North Las Vegas							

[1] X = yes, blank = no
[2] ISR = internal selective routing, JSR = jurisdictional selective routing, ANI = automatic number identification, ALI = automatic location identification
[3] NA = not applicable
[4] Total county-wide implementation cost.

jurisdictions and transfers them as necessary. Finally, a third solution involves regionalization of call answering and dispatching; this has occurred, for example, in Multnomah County, Oregon [Johnson and Valenzuela, 1977], and in Allentown, Pennsylvania [G. Praul Associates, 1974].

The second factor hindering 911 implementation is political. As identified by Roger Reinke [1971] of the Office of Telecommunications Policy, local government officials are now burdened with the task of implementing and operating an integrated system for processing the different requests for emergency assistance, including requests for police, fire, ambulance, and other emergency services (e.g., suicide prevention, poison prevention, gas leakage, etc.). The establishment of such public safety answering points (PSAPs) requires close cooperation among the various local agencies, and that often is not an insignificant political problem. Agencies must agree, for example, on the number of PSAPs, call answering methods, and methods of cost sharing. As pointed out by Felperin et al [1974], there has been little statewide coordination of 911. States have provided little policy guidance or technical assistance to local agencies, and have only recently begun to see 911 as part of their responsibilities. Funding especially seems to be a major question, particularly in areas where 911 has been state mandated. In California a telephone surcharge was imposed to obtain 911 funds, but an appropriate method of allocation was not worked out, so many areas in the state were uncertain how much, if any, 911 funding they would receive from the state. Funding disagreements were also a major problem in the Quad Cities region (Rock Island County, Illinois, and Scott County, Iowa). Quad Cities received an LEAA grant for a regional 911 system, but the project was halted when the jurisdictions involved could not agree on a method of cost sharing. Also, the jurisdictions in Rock Island County felt that 911 costs should be paid by the state, since 911 is state mandated in Illinois, while the state felt that the local agencies should absorb the costs.

Finally, a third difficulty, mentioned by several jurisdictions in our surveys, stems from the existence of multiple phone companies in single jurisdictions. In such areas cooperation among the various phone companies is required before 911 can be implemented, and the call routing required may be very complicated.

There are strong countervailing pressures which support, if not require, 911. Three states--California, Illinois, and Minnesota--have mandated 911, and a number of other states have passed legislation requiring 911 plans from local governments [Reinke, 1978]. However, because of the political and technical problems mentioned previously, actual implementation of 911 has been limited in some areas; those that have been made were independent implementations, where local agencies overcame the political and technical problems on their own [Felperin et al, 1974].

3.4.2 OBJECTIVES AND IMPACTS

Despite the existence of 911 systems for over a decade, the level of evaluation is still limited. The following sections will review the available information concerning the objectives and impacts of basic and advanced 911 systems.

STATED OBJECTIVES

A review of the 911 objectives, as summarized in Exhibit 3.13, shows that 911 is an application which exclusively supports the *needs identification* function of PCCC. The objectives are divided into two groups, according to whether the 911 system is basic or advanced.

911 IMPACTS

Actual and potential impacts of 911 for each of the stated objectives are shown in Exhibit 3.14. The first 911 system objective--that of providing an easy-to-remember number for emergency purposes--appears to have been successfully met by 911. A number of studies have shown that in areas without 911 service, few citizens actually know the correct police, fire, and ambulance emergency numbers. A study performed by Franklin Institute in a large urban area with a well-publicized 7-digit emergency number found that only 34% of the citizens surveyed know the correct police emergency number, 5% knew the fire number, and none knew the ambulance number [Office of Telecommunications Policy, 1973]. SRI has reported that, based on a number of surveys carried out by them, only 25% of all citizens know their correct 7-digit emergency numbers, and only 5-10% know their fire emergency numbers [Yung, 1979]. In areas with 911, citizen awareness of the correct emergency number seems to be substantially higher. A study in Springfield, Massachusetts found that after 911 implementation, 92% of the citizens surveyed were aware of 911 [Office of Telecommunications Policy, 1973]. Another study in Allentown, Pennsylvania found that after 911 implementation, 90% of the citizens surveyed were aware of 911 [G. Praul Associates, 1974].

Related to easier police department access, one apparent drawback of 911 systems is an increase in the total call-for-service workloads in some cities, especially in larger cities. However, based on information from our site visits, most cities with 911 seem to believe that 911 has not caused an increase in the number of emergency calls, but only in the number of non-emergency calls. In general it appears that the largest increase in the total number of calls occurs immediately after initial 911 installation, and then levels off in later months. In our study sample there was a wide variation in the reported call workload changes due to 911, as shown in Exhibit 3.12. While most cities did report some increase due to 911, some cities reported increases of only 5 or 10 percent, while other larger cities--such as New York City, Detroit and Chicago--reported substantially large increases in their call workload. For example, in the first 12 months after 911 implementation in New York City, the number of calls to the police department appears to have increased by 50-100%.* As evidenced by the data we obtained, the issue of call level changes caused by 911 still requires further research.

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* Based on conversations between Richard C. Larson and members of the New York City Police Department.

Exhibit 3.13

911: Stated Objectives

BASIC 911 SYSTEM

- To have an easy-to-remember number for emergency purposes.
- To reduce emergency response times.
- To increase apprehension rates and decrease the level of property damage.
- To promote citizen involvement in public safety.
- To improve coordination of emergency services.

ADVANCED 911 SYSTEM

- To overcome the disparity between jurisdictional boundaries and the telephone company's central office exchange boundaries -- using the automatic location identification (ALI) and jurisdictional selective routing (JSR) options.
- To reduce the number of false alarms, bomb threats, and other malicious calls -- using the ANI option.
- To allow for call-back and address identification in case a distressed caller gives inadequate information -- using the ANI and ALI options.
- To minimize the number of complaint clerk transcription errors -- using the ANI, ALI, and automatic registered name identification (ARNI) options.
- To enhance an emergency operator's area familiarity, awareness of resource availability, and identification of redundant calls -- using the ALI, supplementary dispatch support data (SDSD) and internal selective routing (ISR) options.

Exhibit 3.14

911 Impacts

	Actual Impact	Potential Impact
INPUT OBJECTIVES		
•Have an easy-to-remember number for reporting purposes	•In several studies, significantly more citizens knew the emergency number after 911 than before 911.	
•Promote citizen involvement in public safety	•Little evaluative information is available.	•It is possible that public incidents may be reported more often or more quickly when 911 is available.
•Overcome the disparity between jurisdictional and telephone company boundaries (using ALI and JSR)	•Assuming no technical problems, this objective will automatically be accomplished by the ALI and JSR options.	
•Allow for call-back and address identification (using ANI and ALI)	•Assuming no technical problems, this objective will automatically be accomplished by the ANI and ALI options.	•Related to the increased information are important citizen privacy issues.
PROCESS OBJECTIVES		
•Reduce emergency response times	•There is disagreement as to whether or not 911 will reduce police response time, and little evaluative information is available.	•While 911 may have potential to reduce response time, any reductions would occur in citizen reporting times.
•Improve coordination of emergency services	•In some cases 911 has improved coordination of emergency services since all calls are routed to a common answering point, but in other cases an extra step in the response process is merely added.	•Nine-One-One has further potential, not yet realized, for improved coordination of emergency services.
•Reduce the number of false alarms and other malicious calls (using ANI and ALI)	•While some police departments believe that ANI and/or ALI have reduced the number of malicious calls, little evaluative information is available.	•The ANI and ALI options seem to have strong potential for reducing the number of malicious calls.
•Minimize the number of complaint clerk transcription errors (using ALI, ANI, and ARNI)	•Assuming no technical problems, this objective will automatically be achieved by the ANI, ALI, and ARNI options.	
•Enhance an emergency operator's familiarity with the area, available resources, etc. (using ALI, SDSD, and ISR)	•Little evaluative information is available.	•The advanced 911 options (ALI, SDSD, and ISR) may have limited potential in this area.
OUTCOME OBJECTIVES		
•Increase apprehension rates and decrease the level of property damage	•Little evaluative information is available.	•If 911 reduces response time, it may have potential in this area. SRI has estimated that if 911 were implemented statewide in Florida, the savings in fire losses in one year would pay for the entire system installation.
SYSTEMIC OBJECTIVES		
•Avoid encroaching upon citizen privacy	•Little evaluative information is available.	•Important questions remain as to the impact of the advanced 911 options (such as ANI and ALI) on citizen privacy.

The second 911 objective--providing faster access to emergency services--has been discussed at length in the literature, although no formal evaluation study has been carried out to test the actual response time benefits of 911. Any response time benefits of 911 would come from reductions in citizen reporting time--that is, the time from when the incident is detected to the time the police department is notified. While there is some disagreement in the literature as to whether there are any reponse time reductions caused by 911, most of the available documents indicate that 911 does reduce response time. A study in Allentown, Pennsylvania concluded that, based on a sample of 200 incidents, overall response time was 10.4% lower after 911 implementation [G. Praul Associates, 1974]. Studies carried out by SRI in Santa Clara and Orange Counties, California, found that 911 could make a "dramatic improvement" in citizens' reporting times, and that reductions in individual reporting times of 1.5 to 4 minutes are possible [Felperin et al, 1974]. SRI also reported that in a survey of 911 users, 75% reported that 911 had provided "tangible" response time benefits [Dayhars, 1979]. Only one study reported that 911 would not reduce response time. A report by a California legislative analyst stated that 911 would have minimal, if any, impact on response times [Concklin et al, 1979]. This statement, however, was based on data from an SRI study, which SRI later reported had been misinterpreted in the legislative analyst report [Yung, 1979].

The third 911 objective is that of increasing apprehension rates and reducing the level of property loss--through reduced response time. As discussed earlier in Section 3.1 (CAD), there is some disagreement in the literature as to whether reduced response time will increase apprehension rates, and this remains an area of continuing debate. With respect to reduced property damage due to quicker response time, SRI estimated that if 911 were implemented statewide in Florida, the concomitant reductions in response time would reduce fire losses and the savings in one year would cover the cost of the entire 911 system installation [Felperin et al, 1974].

The fourth and fifth basic 911 system objectives--those of increased citizen involvement in public safety and improved coordination of emergency services--have been discussed in the literature as potential benefits, but no studies have examined the actual impact of 911 in these areas.

*Based on conversations between Richard C. Larson and members of the New York City Police Department.

With regard to the advanced 911 objectives, little evaluative information exists; the available information, though, is summarized in Exhibit 3.13. The only document to analyze these options in any detail was produced as part of the Alameda County 911 planning process [Hovey, 1974] and discusses only the *potential* usefulness of the advanced features. It is instructive to summarize the key findings of the Alameda County report in relation to the six advanced 911 options:

- Automatic Number Identification (ANI) is the critical element for all the advanced 911 options. The Aerospace Corporation [1974] found that (a) approximately 80% of all telephone subscribers presently terminate in central offices which are already equipped with ANI for accounting purposes; (b) central offices which do not now have ANI are in low population areas where ANI and selective routing are not pressing needs; and (c) ANI could be provided to PSAPs fairly easily and at relatively modest costs.

- In an attempt to assess the potential usefulness of Automatic Location Identification (ALI), 963 calls placed to seven Alameda County agencies were monitored, and it was found that only 52% of the police calls and 40% of the fire calls were from telephones located at the exact location of the incidents.

- Jurisdictional Selective Rounting (JSR) is necessary for any 911 system which contains more than one PSAP. Although it is easier to implement JSR in a central office with an electronic switching system, it can also be implemented in an electromechanical central office.

- Alameda County found that the telephone company was opposed to carrying Supplementary Dispatch Support Data (SDSD) on any computer that it owns or operates. Aside from the problem of updating information that has no value to telephone operations, there are legal regulations prohibiting the common carriers from such data processing services. However, the telephone company is willing to include some zonal information, as is the case in Chicago where data for 13 police and fire zones are maintained for each of Chicago's 1.6 million telephone numbers.

- Within large PSAPs, like New York City and Philadelphia, Internal Selective Routing (ISR) is being carried out on a Borough basis, or according to central office exchange boundaries. Alameda County found ISR unnecessary since only the Oakland PSAP would have been large enough to require it, and Oakland decided against it at that time.

- In order to assess the potential usefulness of Automatic Registered Name Identification (ARNI), a small sample of dispatch tickets of the Oakland Police Department was analyzed to determine the level of coincidence between the complainant's name and the telephone subscriber's name. It was found that 61% had identical surnames. Although police representatives were strongly in favor of the ARNI feature, the Alameda County 911 Steering Committee decided against it for reasons of privacy.

Alameda County also tried to gauge the public's reaction to an important privacy issue--that of governmental access to telephone subscriber records--by conducting a brief telephone survey* of 105 listed and 206 unlisted subscribers. Its findings were:

- 88% had a favorable reaction to an advanced 911 system that included both the ANI and ALI features;

- 81% approved of having subscriber records on a government computer for 911 purposes, and an additional 7% approved of 911 uses as long as the records remained in the custody of the telephone company;

- there were no significant differences in any of the responses between the listed and unlisted subcribers.

Overall, little evaluation has been done regarding the advanced 911 features. Further research is needed to determine which of these features are desired, needed, and cost-effective.

CONCLUDING REMARKS

In conclusion, several points should be made. First, although the concept of 911 is sound, it is obvious that its full-scale implementation is being hindered by both political and technical problems. In this regard, 911 is perhaps an excellent example of a technological concept which could and should have undergone an intensive technology assessment before the AT&T announcement of its availability and before several state legislatures mandated its widespread adoption. One result of such an assessment, for example, would have been the identification of appropriate background and training requirements for 911 operators. This still remains a critical need, and is illustrated by the fact that at one time the New York Police Commissioner transferred 121 civilian operators who were

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* S.W. Hovey, Study for Alameda County (CA) 911, Washington, D.C. LEAA, October 1974.

"unqualified or unsuited to cope with the demands of the stress-filled job" [Kalech, 1978, p. 1]. Furthermore, better statewide coordination of 911 is required. In order to assure continued implementation of 911 systems, states must provide policy guidance, technical assistance, and funding provisions for local agencies.

Second, the impact of the advanced 911 options on personal privacy and confidentiality has not yet been fully resolved. Although Alameda County attempted to address the issue by conducting a telephone survey of a sample of telephone subscribers, the final resolution may only come in the courts, if and when a pertinent case is filed. Meanwhile, a legal study could be funded by the federal government in this area.

Third, the fact that 911 serves not only the police but also fire, ambulance, and other emergency services should be recognized as a critical factor which may eventually lead to a *combined* command, control, and communications system for the public safety area. Therefore, current and future PCCC systems should be flexible in design so that they can interact with and/or accommodate the needs of other emergency services. Inasmuch as PCCC systems are in a more advanced state of development and implementation than those of other emergency services, it is possible that PCCC systems will be the cornerstones of future public safety command, control, and communications systems.

3.5 FORMAL DEPLOYMENT METHODS (FDMs)

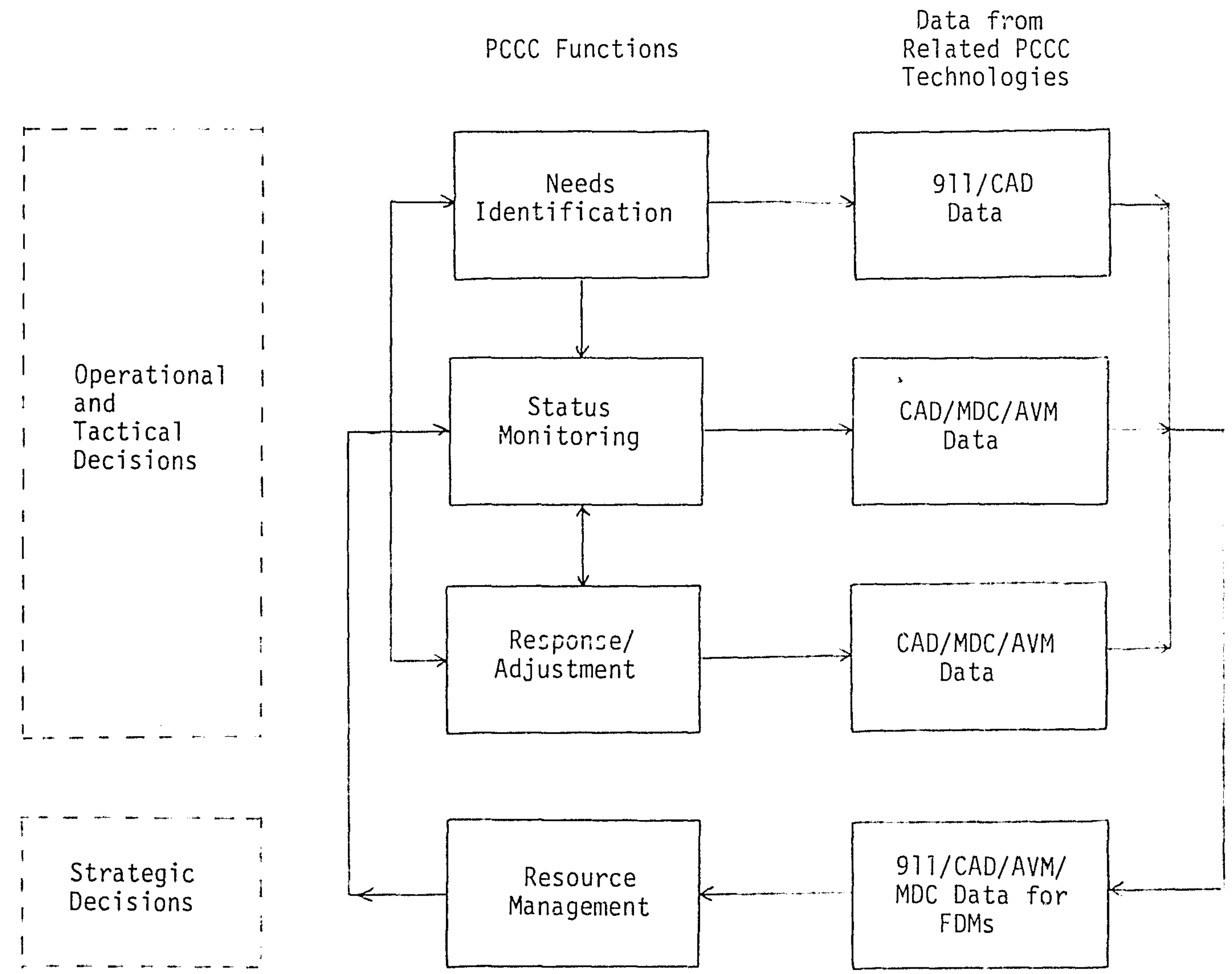
As stated earlier, the 911, CAD, AVM, and MDC applications primarily support the short-term *tactical* and *operational* PCCC functions of needs identification, status monitoring, and response/adjustment. Formal Deployment Methods (FDMs) use data from these applications to support the longer-term *strategic* PCCC function of resource management. As identified by Larson [1969], resource management includes such functions as: allocation of districts and beats; determination of the hourly demand for police services and personnel; assignment of personnel to shifts or tours; assignment of personnel to calls and the related spatial repositioning of units; and determination of needed police force strength for future planning. The relationship of FDMs and resource management to the other PCCC functions is shown diagrammatically in Exhibit 3.15. Our interest in this study is not with formal deployment methods unto themselves, but with FDMs as they relate to PCCC technologies, especially the computer-related technologies (i.e., CAD, MDC, and AVM).

3.5.1 A REVIEW OF FORMAL DEPLOYMENT MODELS

A number of police-related formal deployment models have been identified and reviewed by Sohn and Kennedy [1976]. There are, in addition, a number of internally-generated resource allocation tech-

Exhibit 3.15

Relationship of Resource Management and Formal Deployment Methods to PCCC Functions



niques in use by various police departments around the country. However, only three of the existing formal deployment models--the Law Enforcement Manpower Resource Allocation System (LEMRAS), the Patrol Car Allocation Model (PCAM), and the Hypercube Queueing Model--have been used to any great extent. These are described below.

LEMRAS was developed and marketed by IBM in the late 1960s [Sohn and Kennedy, 1976]. The model used exponential smoothing and queueing methods to predict the number of events needing police service by type and location, and the number of patrol units needed to service these events. In the fact of more realistic, probabilistically-based models (such as PCAM and Hypercube), however, IBM has since withdrawn LEMRAS from the market. PCAM was first developed by R. Larson [1972] and subsequently refined and computerized by Chaiken and Dormont [1975]. It is an analytic queueing model which has both descriptive and prescriptive output concerning the number of patrol units to be allocated to different commands and at various times of the day. Hypercube was likewise developed by R. Larson [1975], and like PCAM, it is an analytic queueing model. Hypercube is basically a descriptive model which can assist in the design and evaluation of beats, sectors, districts, or response areas for police patrol units.

3.5.2 FDM USAGE

As mentioned earlier in this report, the use of the computer by police for *non-routine* purposes such as resource allocation has so far been disappointing. While police departments have had success with routine applications in which the computer performs straightforward, repetitive tasks, in non-routine areas, where the computer becomes a tool for decision making and strategic planning, the results to date have been less successful.

The use of computer-based formal deployment models such as Hypercube, PCAM, and LEMRAS is relatively recent. The main barrier to implementation of such models in the past was the sizeable data requirements of such models; police departments with manual dispatch systems typically did not have readily available extensive information for such models. However, with the advent of computer-related PCCC technologies (especially CAD), police departments have large data bases which can be used to support such models, and the use of such models has increased. In the past few years a number of police departments with CAD have begun to make use of the data from their CAD system to support formal deployment models such as Hypercube or PCAM. In 1977 Chaiken [1977] identified some 40 law enforcement agencies which had received copies of the Hypercube and/or PCAM programs. Fully half of these cities also had CAD systems.

No police departments appear to have yet exploited the full potential of their computerized PCCC systems in the area of resource management. The existing resource allocation systems still require a certain amount of manual intervention; for example, the data generally must be drawn from a variety of sources and reformatted before it can be used in a model such as Hypercube or PCAM. However, computer-based PCCC systems provide the potential for automated support of the resource management function, since the computer can be programmed to *automatically* collect appropriate data for formal deployment models. Such a system was implemented in Newark, New Jersey where data for the Hypercube and PCAM programs were automatically generated by the computer; however, because of problems with the CAD system, the data has not yet been used. No other police departments appear to have created an integrated PCCC system of this kind.

In conclusion, there is a need for a resource management system where FDMs and the associated strategic PCCC designs are fully integrated with the operational and tactical PCCC functions of needs identification, status monitoring, and response/adjustment. The two sets of PCCC functions--strategic and tactical--could be designed to automatically provide feedback to one another. However, the resource management function is a complex, iterative process; the degree to which FDMs can be used effectively as a part of a computerized PCCC system must remain an area of continued research and evaluation.

3.6 REGIONAL COMMUNICATION SYSTEMS (RCSs)

3.6.1 STATE OF THE ART OF RCS

Regional communication systems (RCSs) are those systems which involve the cooperation among various law enforcement agencies in the creation of a common communication system. This could involve a minimum amount of regional cooperation (as in the allocation of a common radio frequency which allows different police departments to communicate with one another) or extensive cooperation among different agencies (as in the creation of a centralized dispatch center). Our interest in the RCS area is no[illegible] n reviewing each of the various PCCC applications in the context of [illegible] RCS, but rather in investigating the salient features and relative merits of regionalizing PCCC functions.

We have identified a number of different types of RCS applications, as outlined in Exhibit 3.16. Some areas, such as Santa Clara County, California; Hamilton County, Ohio; and Oak Park, River Forest, and Forest Park, Illinois, have developed centralized CAD systems. Others, such as Hennepin County, Minnesota; and Muskegon County, Michigan, have developed centralized manual dispatch systems. Dade County, Florida, and Alameda County, California have developed regional advanced 911 systems with multiple PSAPs. Other regions, such as Erie County, New York, and Madison, Wisconsin have cooperated to create region-wide record-keeping systems. Finally, some areas have implemented regional radio frequency allocation schemes: the BAPERN network in Boston provides a single communication frequency for 23 police agencies in the Boston metropolitan area to communicate with one another in emergency situations, and Orange County, California has developed a county-wide frequency allotment scheme.

Exhibit 3.16

RCS: Reported Applications

Population Served (1000's)	Status[1]	Jurisdiction	Source	Description
I. Regionalized Dispatching				
With CAD				
2,000	X	Dade County, Florida	Site visit	Dispatching for Sheriff, 22 municipal jurisdictions; does not include Miami and 3 other cities.
600	X	Portland/Multnomah County, Oregon	[Barker et al, 1975]	Includes Sheriff, Portland police, and 3 suburban police departments. RCS begun 1974.
570	X	San Jose/Santa Clara County, California	Telephone survey	CAD shared by Sheriff and San Jose police, but separate dispatchers. RCS begun 1976.
500	X	Hamilton County, Ohio	[Johnson and Valenzuela, 1977]	Dispatching for 91 police, fire, EMS agencies. Does not include Cincinnati. RCS more than 25 years old
250	X	South Bay Area, California	[JPL, 1978]	Dispatching for 7 communities in LA County. RCS begun 1975.
93	X	Oak Park, River Forest, Forest Park, Illinois	[Sohn et al, 1976]	CAD shared by 3 communities in Cook County. RCS begun 1975. Separate dispatch centers.
Without CAD				
692	X	Broward County, Florida	[Leberman, 1975]	4 Dispatch centers serve a total of 29 communities.
634	X	Hennepin County, Minnesota	[Johnson and Valenzuela, 1977]	Includes Sheriff and 22 suburban police departments. Does not include Minneapolis.
230	X	Onondaga County, New York	[Gabriel, 1975]	Includes Sheriff and 9 suburban police departments.
227	X	Saginaw Area, Wisconsin	LEAA grant description	Includes Sheriff and police departments of Saginaw and several other towns.
200	X	Snohomish County, Washington	[Johnson and Valenzuela, 1977]	Dispatching for Sheriff's office and a number of local police departments.
190	X	Anoka County, Minnesota	[Johnson and Valenzuela, 1977]	Includes Sheriff and 6 municipal police departments. RCS begun 1973.
150	X	Muskegon County, Michigan	[McDonnell, 1974]	Includes 8 of the 11 police agencies within the county. Begun in 1969 as an LEAA Exemplary Project.
II. Regionalized Advanced 911				
2,000	X	Dade County, Florida	Site visit	911 system with selective routing, ANI, 5 PSAPS. Established in 1979.
1,090	X	Alameda County, California	Site visit	911 system with selective routing, ANI, multiple PSAPs. Established in 1978.
320	(X)	Quad Cities Area (Iowa/Illinois)	Telephone survey	Advanced 911 system planned; currently stalled due to political problems.
III. Radio Frequency Allocation				
3,000	X	Boston Area Massachusetts	[Coogan, 1978]	Provision of one radio channel for inter-jurisdictional emergency communications.
1,700	X	Orange County, California	Site visit	Radio channel allocation scheme for law enforcement agencies in Orange County. Provision of status-only MDTs.
IV. Regionalized Law Enforcement Data Bases				
1,089	X	Erie County, New York	[Bolas et al, 1974]	Centralized record-keeping, identification, training facilities, etc. Begun 1972.
302	X	Madison Area, Wisconsin	Letter to PSE from police department	Area-wide automatic reporting system.

[1] X indicates that an RCS currently exists; (X) indicates an RCS is currently being planned.

CONTINUED

1 OF 2

3.6.2 OBJECTIVES AND IMPACTS

The literature in the RCS area contains very little evaluative information. Most of the available documents concentrate on input and process measures, containing material such as descriptions of actual regional communication systems and discussions of potential benefits of such systems. The objectives and impacts of RCSs are summarized below.

STATED OBJECTIVES

There are a number of reasons for establishing an RCS, and the form of the actual RCS implemented will reflect the particular benefits expected by the jurisdictions involved. Possible objectives for RCS include:

- To decrease operating costs, especially personnel-related costs.
- To decrease equipment and implementation costs.
- To overcome radio channel congestion problems.
- To provide a means of coordinating police actions during certain emergencies.
- To establish a joint entity which would more easily attract federal and state subsidies.

A major reason for adopting an RCS is cost savings: through consolidation, a regional communication system may decrease operating costs (especially personnel-related costs), and total equipment and installation costs. Furthermore, by creating an RCS, cities may be able to afford technologies--such as CAD--that they may not be able to afford on their own. For example, three Chicago suburbs, Oak Park, River Forest, and Forest Park, Illinois [Sohn et al, 1976] cooperated to create a joint CAD system shared by the three departments. Consolidation of dispatch operations was recommended in Contra Costa County, California where there were a number of cities too small to afford a 24-hour dispatching operation by themselves. Record-keeping costs led Erie County, New York to develop the Erie Municipal Police Information Retrieval Enhancement (EMPIRE) system [Bolas et al, 1974], and general cost considerations led to a recommendation for San Diego County, California to adopt a coordinated Records and Communication System [Public Systems, Inc., 1971].

A second reason for introducing regional communications is radio channel congestion and frequency interference. Muskegon County, Michigan decided on a central police dispatch center because eight dispatching centers in the county were competing for the use of a single radio frequency, often resulting in garbled communications. An interference

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A second reason for introducing regional communications is radio channel congestion and frequency interference. Muskegon County, Michigan decided on a central police dispatch center because eight dispatching centers in the county were competing for the use of a single radio frequency, often resulting in garbled communications. An interference problem also caused Orange County, California to adopt a computer-controlled regional radio and status-only MDC system [Wand, 1973]; the county communications authority worked out a scheme of radio frequency allocation where the same dispatch channel would be shared by jurisdictions in opposite ends of the county. In this case, dispatch centralization did not occur.

Regionalization may also occur because of a need for coordination of certain inter-jurisdictional emergency situations. The BAPERN network in Boston consists of a single communication frequency for use by 23 police agencies in the Boston area in inter-jurisdictional events. Coordination of dispatching was also a motivating factor in Broward County, Florida where 29 jurisdictions are centralized into 5 dispatch centers [Leberman, 1975].

Finally, a fourth reason for establishing an RCS is that a joint entity might more easily attract federal and state subsidies because of the increased magnitude of the population served.

Although the objectives of an RCS are straightforward, the process of creating the legal and administrative framework for procuring and operating the RCS may be extremely complicated. Agreement must be reached on a number of issues.

Insights concerning some of the major issues and how to resolve them are listed below; they are primarily found in Sohn et al [1976, pp. 14-15].

- A new legal entity, separate from any of the participating communities--but under their control--must be created. This is not only advisable for efficient administration, but essential because frequencies can be assigned only to a legal entity and federal grants can be made only to such a single body--not to a collection of independent communities.

- Procedures for creating, financing, and governing the new legal entity must be defined and agreed upon. Since the different communities will have different sizes, different terrains, different tax resources and different crime rates, it is not easy to reach agreement on what support is to be provided by each and what services each is to receive.

- Radio frequency allocations now held by individual communities must be assigned to the new agency. Which frequencies are to be assigned (police only, police and fire, other, all or part, etc.) is a subject requiring extensive discussion. Provisions must also be made for disposition of frequencies allocated to the combined agency if one of the cooperating communities chooses to withdraw.

- Centralized dispatching centers should use civilian dispatchers, both for reasons of economy and efficiency and because the new agency probably will not have the ability to exercise authority over sworn personnel. For small departments now using sworn personnel for dispatching, this change will require some accommodation.

- The change in dispatching personnel is part of the general problem of changing from a small, closely integrated dispatching operation to a larger, physically and organizationally more dispersed operation. Such a change is not always welcomed by all parties, and considerable discussion is likely to be required.

- Each community must retain command authority over its patrol force. Provisions need to be made in the design of the system for each community to monitor and redirect its forces if necessary.

- The legal structure and administrative procedures of the new agency must conform with applicable state and county requirements and regulations. State laws may govern the powers of such joint agencies.

- If allocations (or radio channels, personnel, financial support, etc.) are to be based on current rates of use, it is difficult to agree on the definitions concerning such rates. Different departments keep records in different ways that are not easily compared. Only after the combined system is in operation will it be possible to determine usage rates on a common basis.

RCS IMPACTS

The RCS-related literature focuses primarily on specific PCCC applications within the general context of an RCS and does not dwell on the salient features or characteristics of regional communications. Perhaps the only evaluation that addresses the RCS concept is the Muskegon County study [McDonnell, 1974], which reviews a *non*-computer-based RCS. The key finding of the study was that before consolidating their dispatch functions, the 8 member agencies had assigned 19 police officers to dispatching, while after consolidation 13 civilian personnel were able to meet the consolidated dispatching requirements. This represented a 32 percent savings in personnel time and a 42 percent savings in personnel costs, the latter reduction augmented through the use of lower-paid civilian personnel. Cost savings also seem to have been realized in the Dade County system (where we made a site visit). In Dade County the Department of Public Safety dispatches for the County Sheriff's office plus 22 of the 26 municipal jurisdictions in the county. (Each of the municipal areas has its own police force, however.) Many of the individual communities in the county do not generate enough work for a full-time dispatcher, so consolidation allows fewer total dispatchers. Further, the communities in the county enjoy the benefits of a CAD system, which individually they would not be able to afford.*

*CAD was not the reason regionalization occurred, however, since the dispatch operations had been centralized long before CAD.

Reduced channel congestion and improved coordination of police activities are also apparent in Dade County, where instead of having many dispatchers on the same frequency each frequency now has only one countywide dispatcher. Also, since one dispatcher supervises many jurisdictions, inter-jurisdictional dispatches are greatly facilitated. For example, if all the patrol units in one city are busy, the dispatcher can send a nearby county unit to answer any calls in that jurisdiction.

However, there may be possible drawbacks to such regionalization, as reported by Dade County. Because one dispatcher supervises many jurisdictions, he may not be as familiar with each area as would a local dispatcher. Also, because of the volume of calls handled, a centralized dispatch center often cannot provide the same kinds of services as many smaller dispatch centers. For example, Dade County reported that they will only dispatch units for police-related incidents, while the smaller cities could dispatch units to handle domestic complaints, turn off sprinklers, etc.

In general, RCSs appear to have anumber of potential benefits but have often been blocked by political problems. For example, the Quad Cities area (Rock Island County, Illinois, and Scott County, Iowa) attempted to install a regional 911/CAD system, but they have not yet been successful. Quad Cities received a $175,000 grant from LEAA in 1977 for 911 and CAD, and was to be a pilot site for a regional 911 system. The project was abandoned, however, when the jurisdictions involved could not agree on a method of sharing the system maintenance costs. At the same time, the various jurisdictions decided that they did not want to have one centralized CAD system, but rather a microcomputer-based CAD systems installed in each separate jurisdiction. The Quad Cities project has been stalled while the jurisdictions involved attempt to resolve these problems. Similar political problems barring regionalization are apparent in Charlotte, North Carolina where the city and county police dispatch are from the same dispatch center. The city uses a CAD system, and the county uses a manual dispatch system. The reason cited by the city communications supervisor for the lack of CAD sharing was that the city police are under control of the mayor, and the county police are under control of the county manager. Problems of this kind often appear to have blocked RCS implementation, although such combined systems may have substantial benefits for the departments involved.

CONCLUDING REMARKS

Although there are few supporting evaluations, the concept of a regional communications system seems sound. It is based on a well known principle that sharing of resources can result in certain benefits and/or economies of scale. However, actual practice has also shown that benefits and economies of scale can accrue up to a certain point, after which there are diseconomies of scale. In this regard, the question that remains to be answered is: What is the size--in terms of area, population, police services, etc.--of an *optimal* RCS? The answer to this question can only be forthcoming if careful, systematic evaluations of RCSs are undertaken.

4 EVALUATION CONCERNS AND IMPLEMENTATION CONSIDERATIONS

The previous chapters have provided a general assessment of the six PCCC technologies and application areas. In light of these findings the first part of this chapter will review some general evaluation concerns, and the second part will discuss along with the implementation process for PCCC technologies, future considerations in the use and linkage of such technologies. The third part of the chapter will outline specific research needs and recommendations.

4.1 EVALUATION CONCERNS

An overriding constraint in our national assessment of PCCC systems has been the lack of substantial PCCC evaluation data. Although there is an extensive body of PCCC literature, most of it is descriptive in nature, and there have been very few formal evaluations performed in the PCCC topic area. The studies which have been done concerning PCCC systems are often incomplete or unreliable, focusing primarily on measures of *input* and sometimes *process*, but almost never on *outcome* or *systemic* impacts.

Because of the lack of evaluation studies, PSE devoted a substantial amount of the project resources to direct information gathering, telephone and mail surveys, site visits, and one on-site field assessment. This research yielded a number of valuable insights, but we still found that the lack of concrete evaluation data was reflected in the field. Most cities seem to have little in the way of detailed cost data or other PCCC "impact" information which could be used for the evaluation of their systems. The state of the art of PCCC technology has not advanced to the stage where evaluations of second-order performance measures are considered necessary by police departments; at this point, police departments are generally satisfied if their systems simply operate smoothly.

The available data (both that contained in the literature and that gathered directly by PSE) nevertheless has allowed for a general assessment of the state of the art and the problems and issues of PCCC systems. Because of the lack of concrete evaluation research in some cases our findings have been somewhat subjective, based primarily on PSE's informed judgment. This points to the strong need for further PCCC evaluations and agreement on a common framework to use in the evaluation process, so the PCCC hypotheses can be tested and results can be compared from city to city. Still, it has been possible to reach a number of useful findings and conclusions regarding PCCC-related applications and research needs. Many of these findings have been listed already, others will be discussed in the remainder of this chapter.

4.2 IMPLEMENTATION ISSUES

One of the basic premises of this study was that the implementation of PCCC technology requires more than technical expertise--that the consideration of behavioral and institutional factors (both in system design and system implementation) is also essential. This premise was clearly confirmed by the study. In discussing communication problems, many cities emphasized problems relating to personnel and training. The emphasis on such problems highlights the fact that new technology alone is not enough to resolve communication problems. In fact, many problems are behavioral and can be resolved only by better management and greater sensitivity to personnel-related issues.

Involvement of department personnel is important not only during system implementation, but also during the earlier phases of system design. Systems where line personnel were involved in system design seem to have fewer problems than systems where the intent and capabilities of the new technology were not communicated adequately during the development stages of the system. Personnel often resent not having been involved in system design, since they sometimes have suggestions which would improve the system. As a consequence, such personnel may attempt to subvert system operation once the technology is implemented.

Also critical to the success (or lack of success) of any PCCC system is the relationship between the police department and the computer vendor. Departments with clearly defined, carefully specified vendor performance specifications in general have more successful PCCC systems than those departments with uncertain or ill-defined vendor performance specifications. Along with performance guidelines, it is also essential to develop a long-range plan and build in a certain amount of flexibility. In fact, performance guidelines may serve to hinder later flexibility if they are structured too tightly.

It is also important to realize that implementation and use of PCCC technologies is a dynamic process. No matter how much initial planning has gone into a system, a certain amount of time is always required for modification. Such modification occurs through usage, feedback, and monitoring from system users. After implementing a PCCC system (such as CAD), departments should expect that the system will need to continually evolve and mature to satisfy changing needs. For this reason, CAD and PCCC systems seem to have the smoothest implementation in cities with strong data processing capabilities. In cities without such data processing support, the systems may fall into disuse or disarray once the vendor leaves.

We have also found that there is a close tie between the technical performance of a system and the overall results and attitudes concerning the system. The problems of AVM noted earlier are probably the best illustration of this link. Before implementing any PCCC technology, there is a need for extensive testing and debugging to avoid such attitudinal problems.

Personnel training is also important to successful implementation and use of PCCC technologies. Police personnel (and particularly police communications supervisors) have recently begun to realize the importance of the command and control center in a police department. In the past, police communications centers have often served as assignments for officers with disabilities or discipline problems. In general, however, it seems that this trend is being reversed. Police departments

have started to realize the importance of well-qualified, well-trained personnel in the communication center. Skilled dispatchers and complaint operators are especially important in departments with computer-based PCCC technologies.

There also seems to be a strong trend toward civilianization of the police communications center, as a majority of the cities surveyed used some or all civilians in their communications center. (The main reasons cited by departments for moving to civilians are to reduce costs and to put more sworn officers on the street.) The use of civilians may present special training problems, and some resentment from officers in the field, but it may also allow for communications personnel with more specialized skills.

For departments interested in implementing PCCC systems, it appears that as a minimum a seven-step implementation approach is appropriate. These steps include:

(1) needs assessment;

(2) careful identification of PCCC philosophy and approach (e.g., management vs. operational perspective);

(3) preparation of a needs statement based on the needs assessment and overall philosophy, generally in the form of a request for proposal (RFP);

(4) responses from vendors to the RFP and selection based not only on cost, but also on quality concerns;

(5) specific commitment of vendors to a measurable level of performance;

(6) careful orientation, training, and involvement of operational personnel;

(7) evaluation and revision to assure that the system continues to meet the ongoing needs of users.

Naturally, these steps cannot always be followed precisely, and flexibility and adaptability are essential. Furthermore, such an approach by itself will not guarantee success. However, it is our judgment based upon our literature search, surveys, and site visits that using this kind of process as a checklist will make a major contribution towards successful PCCC system implementation.

4.3 FUTURE CONSIDERATIONS

Earlier in the report the concept of an "intelligent" PCCC system was raised. Will this ever be a reality in the future or is it only a myth of the "law enforcement space age"? If such a system is to be developed it must be *integrated, proactive,* and *flexible*. Each of these characteristics will be discussed below.

4.3.1 INTEGRATED PCCC SYSTEMS

PCCC applications have been individually reviewed in this study not only because they are relatively distinct in purpose and focus, but also because in practice they have been implemented on an individual basis and in an independent manner. No police agency has yet implemented an *integrated* PCCC system which links all the various PCCC applications or elements, although the parts of such a system have been established in a number of cities, and a few--most notably Dallas, Texas--seem to be moving in this direction. Exhibit 4.1 identifies an integrated PCCC system, assuming that the 911, CAD, AVM, and MDC applications are effective and pertinent to the PCCC functions, and that they generate meaningful management information system (MIS) data. Briefly, the system includes 911 information that is entered into the CAD computer, which also: 1) interacts digitally with the AVM and MDC systems; 2) serves, if necessary, as a switching machine for MDC inquiries to remote data bases; and 3) provides pertinent data to the MID element. Similarly, it may be cost effective for the MIS portion of the system to share the same CAD computer.

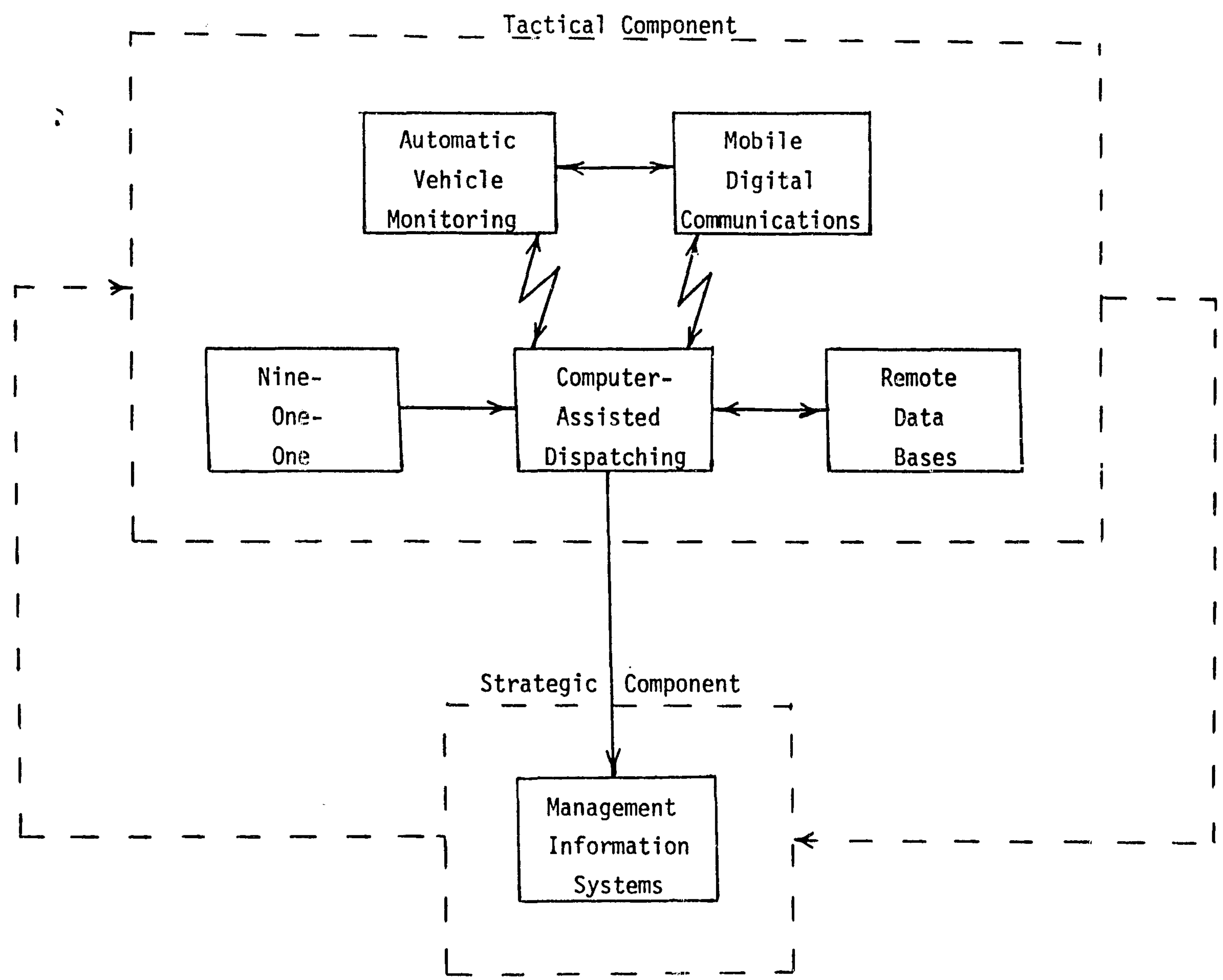
Aside from the physical links among the different PCCC elements, it is important to recognize that the PCCC system can be divided into two components. The first component--comprised of 911, CAD, AVM, MDC, and the remote data bases--primarily supports the *tactical* PCCC functions of needs identification, status monitoring, and response/adjustment. The second component--comprised solely of MIS--primarily supports the *strategic* PCCC function of resource management. As shown in Exhibit 4.1. the two components are *interactive;* the tactically generated data are fed into the management information system which, in turn, produces results that can strategically impact the tactical component. This integrated approach to PCCC may produce a synergistic result in which the integrated system is more effective than the sum of its parts.

It is obvious that because of budgetary constraints a police department cannot implement the total PCCC system at one point in time. Therefore it is necessary to the various PCCC elements from an implementation perspective. A quick glance at Exhibit 4.1 suggests that CAD is the heart of the integrated PCCC system; among other factors, the CAD computer can be the host computer for all the other PCCC elements or applications. Thus, CAD should be the first PCCC application to be implemented, followed by perhaps by 911, MDC, and AVM, if appropriate. Furthermore, Management Information System (MIS) capabilities should be built in each of the tactical PCCC technologies. Although any of the applications can stand alone, the proper sequencing and linking of their implementation would lead to greater effectiveness and overall compatability.

Our review of the range of PCCC nationwide applications noted earlier found that, except for basic 911, CAD applications are the most predominant. In theory, all police agencies which have taken the first step of installing a CAD system can expand it to an integrated PCCC system; in practice, the agencies will face severe compatibility problems. It is therefore recommended that a detailed system plan be developed before any PCCC element is purchased and implemented.

Exhibit 4.1

An Integrated PCCC System



A final comment concerning the integrated PCCC system depicted in Exhibit 4.1 is important. Although the depicted system is conceptually relevant for all police departments, it is obvious that not all agencies require a sophisticated system. Some departments may only require a microcomputer-based system; others may not need AVM or MDC. Some very small departments may want only an automated telephone answering system which allows officers to answer incoming telephone calls while in their patrol cars.

4.3.2 PROACTIVE PCCC SYSTEMS

As noted earlier in this report, computer-based PCCC applications have to a large extent simply replaced previous manual operations. Although recognized, the potential of the computer has not been fully realized. A CAD system can be used not only to assist in the traditionally reactive response/adjustment function, but also to provide the necessary information for a more proactive, decision-oriented dispatch operation.

A proactive or intelligent CAD would be effective in:

- checking the validity of calls for service;
- efficiently allocating patrol resources in a dynamic manner to account for fluctuating manpower levels;
- standardizing dispatch assignments among dispatchers and between dispatcher actions and departmental policies;
- improving police service by incorporating strategies which, for example, increase neighborhood identity or provide better response to emergency situations,
- incorporating complex mathematical models for purposes such as estimating patrol unit location and managing queues of calls for service; and
- collecting and processing statistics which are useful to police administrators.

According to preliminary design specifications, one city we visited had many of the elements of such an intelligent CAD system, but due to a wide variety of institutional and behavioral factors, the actual system was far below expectations.

A promising area for proactive decision making is in the management of police demand. Recognizing that some 86 percent of all calls for police service are non-critical in nature (i.e., do not require immediate response), and that citizen satisfaction is a function of expectation, Tien et. al. have proposed that the demand for police services can be managed and that alternative methods (i.e., other than the traditional

method of dispatching a costly patrol unit) can be used to respond to non-critical calls for service, provided the citizens are forewarned.* Proactive management of police demand can reduce or shift random demand peaks and may even lower the demand level, thus allowing more efficient and more effective allocation of limited police resources. In fact, a management program was recently developed and implemented in Wilmington, Delaware.** Calls were classified in response-oriented terms. It was found that citizens were willing to accept considerable delay in response as long as they were notified at the beginning of their call. While the program in Wilmington focused only on the reactive elements of management of police demand (i.e., creative reactions to citizens' calls for service), computer-based algorithms could be used on-line as a part of a proactive PCCC system to assist complaint operators and dispatchers in the performance of their PCCC functions.

4.3.3 FLEXIBLE PCCC SYSTEMS

The modern PCCC system is heavily dependent on the computer. Computer technology, meanwhile, is undergoing major changes, and technological advances are occurring on a daily basis. Any PCCC system must therefore remain flexible to take advantage of and be compatible with these advances. Changing computer technology will impact the PCCC functions in three areas.

First, the decreased cost of computers, together with increased computing capabilities, will make computer-based PCCC systems available to even the smaller police departments. Efficient memory media and device miniaturization are two primary reasons for this amazing development in computerization. Second, computer networking and distributed processing will allow PCCC functions to be decentralized yet coordinated. In a distributed system, data communication and data base management functions are performed by a number of small computers which are connected. Third, sophisticated terminals will facilitate interactions with the computer-based PCCC system. These terminals include intelligent interactive graphics terminals, magnetic card readers, optical character readers, and voice data entry terminals.

In conclusion, the reader should be cautioned that, although vendors will always speak highly of PCCC applications which make use of new technological advances, it is important that these applications are carefully tested and evaluated before their widespread adoption. The opportunity for technical advances undoubtedly exists and will continue in the future; however, technological innovation should not be implemented simply for the sake of change.

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*James M. Tien, James W. Simon and Richard C. Larson, An Alternative Approach in Police Patrol: The Wilmington Split Force Experiment, Washington, D.C.: National Institute of Law Enforcement and Criminal Justice, April 1978.

**M.F. Cahn and J.M. Tien, An Alternative Appraoch in Police Response: The Wilmington Management of Demand Program, Cambridge, Mass: Public Systems Evaluation, Inc., PPR-8104, March 1981.

4.4 FUTURE RESEARCH NEEDS AND RECOMMENDATIONS

This report has already pointed to a number of important issues requiring further study and to a number of potential impacts stemming from the use and implementation of PCCC technology. This section will not repeat these issues, but will instead focus on two areas which seem to be of special importance. First, additional evaluation research should be conducted to examine the use, benefits, and cost of PCCC technology; and second, a clearinghouse function should be established to facilitate the transfer of PCCC experience and technologies between police departments and state and local law enforcement agencies. Each of these items is discussed below.

4.4.1 FUTURE PCCC EVALUATIONS

As highlighted throughout this study, there have been very few evaluations of PCCC systems. Further, where studies have been done, they have generally been descriptive, with little effort to examine impacts in terms of outcome of systemic measures. Few cities have kept track of cost data for their systems, and almost none has gathered systematic before-after performance data. PCCC system success is usually determined by whether or not a system operates. To go beyond this, to calculate second-order performance measures often presents some difficulties--first, in choosing appropriate evaluation methodology, and, second, in obtaining the trust of those being evaluated. There is a strong need for further PCCC evaluations and for a common evaluation design which focuses not only on input and process measures, but also on outcome and systemic variables.

This project has developed one possible framework for a "single PCCC project evaluation design". Outlined in a separate volume*, the steps proposed in such an evaluation include:**

- identifying the general hypotheses or objectives to be evaluated;

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*Kent W. Colton and Bruce T. Dunn, A Single Project Evaluation Design for Police Command, Control, and Communications Systems, Cambridge, Mass.: Public Systems Evaluation, Inc., September 1980.

**Obviously, there are a number of ways to conduct a PCCC evaluation. The steps outlined here generally follow a traditional scientific approach to evaluation, building on the measures framework discussed elsewhere in the report with input, process, outcome and systemic measures. Further, one of the strengths of the evaluation plan is that it stresses multiple evaluation methods. Still, since there are so many approaches to evaluation, the need for flexibility in using the evaluation design is essential. We think the approach we outline could provide a consistent framework for evaluation and comparison, but it is certainly not the only framework possible. At a minimum, though, it should provide a place to start and an important checklist of factors to consider.

- identifying the relationships between the various PCCC technologies and these hypotheses;
- avoiding pitfalls which might threaten the validity of the evaluation;
- selecting a proper evaluation design to control for or avoid such pitfalls (threats to validity);
- outlining specific measures which can be used to evaluate each hypothesis;
- selecting methods to obtain these measures; and, finally,
- analyzing the data in order to confirm or reject each hypothesis or PCCC-related objective.

At the heart of such an evaluation is an effort to measure the impact of PCCC systems as they relate to input, process, outcome, and systemic variables.

The single project evaluation design identifies a number of hypotheses relating to the potential impacts of PCCC systems. These hypotheses include claims that PCCC systems will: improve communications capabilities; improve the availability, accuracy, and maintenance of information; reduce response time; improve the coordination of emergency services; improve the management of police demand; improve the management of police resources; improve service to the public; improve officer safety; and increase the flexibility and transferability of the communication system.

One of the primary aims of additional research and evaluation studies should be to test these hypotheses and then to consider whether or not the benefits of PCCC systems justify the costs expended. The results of this assessment have already shown that the answers to these questions will probably vary significantly from police department to police department, depending upon the philosophy involved in implementing the PCCC system, the nature of the department, and a number of other factors. While it is almost impossible to state absolutely that the benefits of a system justify the cost, it is possible to compare actual benefits to alternative uses of the same dollar amounts. Based on this type of information, law enforcement managers can then make a judgment as to which alternative use is best.*

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*An illustration of this is provided in Colton and Dunn (A Single Project Evaluation: Design for PCCC Systems) where the costs of the PCCC system in Huntington Beach, California are compared to the costs of additional dispatchers if the old manual system had remained, or to the annual costs of operating a certain number of one- or two-person patrol cars on a round-the-clock basis. Such an evaluation approach does not allow a manager to reach an absolute conclusion as to which use of the money is best, but it does allow a more informed judgment comparing two alternative choices.

The necessity for PCCC system evaluations is relevant not only to individual police departments, but to the law enforcement and public safety communities at large. We have learned a great deal about PCCC in this Phase I assessment, but a number of issues remain for further evaluation. For example:

- A number of input objectives/hypotheses for PCCC systems seem to have been met, but process, outcome, and systemic concerns are often unresolved. These second-order measures require additional examination.
- There appears to be some evidence that PCCC systems may lead to a greater coordination of public safety services (i.e., between police, fire, emergency medical services), although the influence to date in this direction has been slow. Evaluation is required in order to determine whether or not this is happening, and, more importantly, to determine what linkages are most important.
- Some PCCC efforts are moving toward regional communications systems. The success or failure of such efforts, though, is undocumented and requires further evaluation to understand what has happened and whether or not it deserves further promotion. What is the size--in terms of area, population, police services, etc.--of an optimal RCS?
- Although the preponderance of PCCC efforts to date have been in larger cities, an increasing number of smaller cities seem to be involved. Do the benefits of PCCC justify the costs for a city with a population less than 100,000 or less than 50,000?
- Appendix A outlines preliminary factors to assist cities in predicting the costs of implementing and maintaining a CAD system, but it is only a beginning. Further research is necessary both to help cities to realistically estimate future costs and to evaluate the benefits of alternative uses of their resources.
- Finally, although very few cities are taking advantage of the technology to establish an "intelligent" CAD or to creatively manage police demand, a number of cities have implemented parts of such systems. What is involved in moving to the next level of technology use? Research will undoubtedly be required if we are ever to develop a PCCC system which is integrated, proactive, and flexible. At the same time, how likely is it that the institutional, managerial, and behavioral difficulties can be overcome to establish such an "intelligent" PCCC system?

In conducting such further research (in essence, a Phase II evaluation), it will be especially important to obtain a cross-section of case studies or system evaluations in cities of different sizes and with PCCC systems of different ages. City size is important to more closely examine the

application of different technologies to jurisdictions with varying population and call-for-service demands. System age has importance both in testing the continuity and longer term utility of systems, and in terms of data availability. If a system has been established for a long period of time (e.g., Huntington Beach, Dallas, Cranston, North Las Vegas), the operation and maintenance can be reviewed over a long period of time, although systems established many years ago are also less likely to have up-to-date information to facilitate an in-depth before-after analysis. For systems still in the implementation process (e.g., Columbus, Oklahoma City, Los Angeles), it may be possible to collect information prior to implementation so that before-and-after comparisons can be made.

4.4.2 A CLEARINGHOUSE FUNCTION FOR PCCC

As noted earlier, the question in many police departments is not an automated PCCC system will be established, but when and with what impact. However, we have also discussed a number of issues, questions, and potential problems that can arise in such implementation and the report has noted the tendency thus far to "reinvent the wheel." With the exception of vendor-related transfers, direct efforts toward technology and the user through a facilitator role for some organization which is neutral to the systems being installed. At least three steps should be part of this role:

First, a planning document should be developed for law enforcement agencies which clearly describes the various PCCC technologies and presents specific steps to be followed in designing and establishing a PCCC system. The material in this report is a useful first step to such a document. However, it needs to be rewritten as a "users' manual" in order to provide police departments with specific information to determine whether they need to automate or modify their PCCC system, and then to help them carry out and evaluate their decisions.

The second step in the clearinghouse process is to keep current with respect to PCCC developments and to communicate this information to the law enforcement community. A regular newsletter might be established to monitor the status of PCCC applications and the developments in PCCC technology nationwide.

Finally, the last and most important role would be the facilitator/referral role. In the past, technical assistance has been tried as a means of helping police departments develop PCCC and other technologies. We are not advocating an extensive technical assistance role in this case; rather, we suggest a more formalized referral system--in essence, an effort to "institutionalize" what is already happening on an occasional, informal basis. A city interested in setting up a PCCC system could contact the clearinghouse to identify which cities have similar needs, interests, philosophy towards PCCC, etc. Utilizing this knowledge, as well as the "users' manual" and newsletter, departments with similar experiences could be introduced to help each other. A few regional workshops may also be appropriate to stimulate this exchange.

4.5 CONCLUDING THOUGHTS

As we look to the future, we should remember that the use of PCCC technology is still in its infancy. The first commercially sold computer, The Universal Automatic Computer, or Univac I, was built only 29 years ago in 1951. The third generation of computers has been commercially available only since the late 1960s. Perfection should not be expected in an area so young and rapidly changing. However, a certain mystique (as well as commercial force) surrounding the application of computers has led to high expectations and, in many cases, to oversell. This report has shown that the reality of the state of the art is often far less than the general impression portrayed in the literature--and thus there is a need for continued, ongoing evaluation.

Second, to the extent that evaluation efforts have been conducted, they have tended to demonstrate that actual performance has fallen below initial expectations--especially when one goes beyond the input objectives of such systems and begins to review process, outcome, and systemic results. For example, the hoped-for response time benefits of AVM and the objective of MDC to reduce radio air time have not been achieved. This does not mean that AVM or MDC should be discarded, but it does imply that if these applications are to prove cost effective, the initial objectives will need to be modified and reoriented in order to emphasize areas with greater potential. This discovery once again highlights the importance of effective and meaningful evaluations.

Third, one of the primary factors which seems to contribute to the dearth and ineffectiveness of past evaluations is the lack of a common study framework. If effective evaluation is to occur in the PCCC area, a common framework such as the one developed in this report should be established so that different police departments and outside evaluators can rely on a somewhat standard format when collecting data, conducting evaluations, and comparing results. With this in mind, we have tried to outline identified measures and reported results in each of the PCCC application areas. Although there are obvious gaps in terms of the evaluation efforts that have been conducted to date, the various measures and exhibits have been developed not only to describe the current state of knowledge but to assist others who may be conducting future evaluations of PCCC applications. They may serve as a checklist for such an evaluation, and, at a minimum, as a basis for discussion.

Finally, it should be clear that the implementation of new technology, such as that in the PCCC area, involves more than technical expertise. Too often it is assumed that the diffusion of technological innovation can be initiated from above; it is believed that the mere existence of the technology will prove its worth. Failure to recognize many of the complexities and motivations surrounding the implementation and use of technology can prove disastrous. In implementing and evaluating PCCC applications in the future, it should be clear that technological changes often result in behavioral and power shifts. This is especially true as PCCC use moves toward integrated, proactive, flexible systems and away from the computerized "conveyor belt" approach.

In conclusion, the greatest strengths of computer technologies seem to be closely related to their greatest weakness. Computers have the potential to aid in criminal justice activities through rapid communications, more accurate and complete information, and perhaps a more rational approach to decision making. The benefits of PCCC technology demonstrate the potential in these areas, but there are limits to this technology. If not properly controlled or planned, the benefits may result in misuse, unintended consequences, wasted results, and frustrations. Expanded computer use in PCCC systems by the police is at a crucial point, and now is the time to point to a new direction, one aimed towards careful implementation, detailed performance standards and interchange of ideas. Such a new direction requires careful consideration so that the strengths of technology can be judiciously marshalled and the weaknesses and potential risks prudently forestalled.

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APPENDIX A

CAD SYSTEM COSTS

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CAD SYSTEM COSTS

A.1 INTRODUCTION

Appendix A presents a preliminary analysis of CAD system costs and outlines a method for estimating related capital and operating costs over the lifetime of the system. The methodology is intended for budgeting and planning purposes. Although it is not intended to be predictive, it should provide a reasonable estimate of the range of costs that agencies can expect to pay for CAD system installations. The primary deficiency of the effort is the general lack of a broad data base of CAD system costs and the relative absence of current data. Still, even though the information contained in this chapter is based on a somewhat limited sample of 13 agencies, it is the first published effort to systematically review CAD costs, and as such it should provide valuable information to police and public safety agencies considering the installation or evaluation of a CAD system.

The costing methodology outlined here is applicable primarily to agencies serving populations ranging in size from around 50,000 to 700,000. Agencies serving populations outside this range have special needs and therefore deserve a separate cost analysis from the one presented here.

CAD system costs include any directly related costs for files such as geocoded or address files necessary to support the dispatch function, but they do not include costs for information files on wants, warrants, etc., even though the CAD system interfaces with such files. The software costs include costs for a limited number of basic management information reports, but it is assumed that extended analysis of data captured by the CAD system will be performed off-line, or by data processing departments within the agency.

This Appendix develops functional cost structures for CAD capital and operating costs, based on detailed cost data obtained from 13 agencies that installed CAD systems in the past six years.** These agencies serve populations from 45,000 to 650,000. In all but one case, cost values were taken from actual contract costs or from fixed price bids submitted by vendors in response to solicitations.

Most CAD systems represented in this data set were installed in 1974-1977. Extrapolation of total system costs to 1980 levels was made by adjusting the original costs according to the rise in the Consumer Price Index (CPI). However, basic changes in computer hardware and software costs over the past five years are more difficult to account for than simply working adjustments for inflation as reflected in the CPI. Costs for computers of a given capacity generally have declined, but the data available to

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*The principal author of this chapter was Robert L. Sohn, Jet Propulsion Laboratory, California Institute of Technology. He was assisted by Kent W. Colton. Research for the chapter was also conducted principally by Robert L. Sohn with the assistance of Kent W. Colton and Bruce T. Dunn.

**For the purpose of this report, most of the 13 agencies have requested that they remain anonymous.

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measure this trend indicate that agencies may tend to purchase equipment of larger capacity; hence, system costs may not reflect the generally lower hardware costs. Software costs have risen significantly in the past few years but, again, this trend may not have been experienced in CAD system applications because in many cases vendors developed basic software systems in earlier efforts and have therefore written off many of the earlier development costs.

In performing the analysis, costs have been correlated with population served rather than the number of incidents or the number of dispatches because of the wide variation in the number of incidents and dispatches per capita from one agency to another (due in part to the different interpretations given to the terms "incident" and "dispatch"). Nevertheless, the size and cost of CAD systems are more properly functions of the incident/dispatch loads on the systems. In the future, further analyses should be conducted to interpret the reported data on a more consistent basis related to the dispatch center workload.

In outlining CAD cost considerations, we will use a modular approach. Such a modular cost model has the advantage that CAD-related costs can be readily separated from non-CAD-related costs. Within the CAD system cost structure, several account codes have been defined based on vendor practice to give further visibility to system costs and to facilitate tradeoffs among system implementation options.

The reader should note that linear regression is used to identify relationships between PCCC costs and the populations of the respective jurisdictions. These relationships are derived from historical statistics and cannot be used to precisely predict the future. The linear regression analysis will show a correlation between the population of a jurisdiction and PCCC costs, but it does not indicate a cause-and-effect relationship. Still, such equations can provide agencies with a "ballpark" estimate as to the range of costs they might expect if they establish a CAD system, as well as a methodology for developing cost categories and cost estimates.

A.2 CAPITAL COST ANALYSIS

Capital costs include those expenses incurred by the agency in the design, development, procurement, installation and testing of the CAD system prior to the start of regular operations. Included are costs for complaint answering, dispatch stations, and supporting equipment, but not data base systems for nondispatch-related record keeping or detailed management analysis functions. Costs for communication system equipment, to which the complaint/dispatch system interfaces, are also not included.

Analysis of numerous CAD procurements indicates that a suitable cost structure can be developed using the following elements:

- Hardware (less consoles);
- Software; and
- Engineering Services (including integration and subsystem interface, documentation, acceptance testing, phaseover and initial operations support, and project management.)

Facility costs are not included in the model since they depend on whether, and to what extent, existing facilities are used; such costs should be addressed by agencies on the basis of their individual needs or plans. Communication console costs are also not included since the majority of the costs are usually attributed to communication equipment installed in the console for radio reception and transmission, channel selection, and telephone terminals and patch panels. However, examples of console costs have been extracted from a number of bid packages and are presented in the following section.

Bid solicitation response data, summarized in Exhibit A.1 were obtained from 13 agencies that had installed CAD systems in the past six years. Since in some cases more than one bid was obtained for the same system, a total of 21 data sets were acquired from these 13 agencies.

An attempt was made to correlate system costs to system loading, but because consistent system loading statistics were not available, system costs were instead correlated with population served. The results of the correlations for hardware, software, installation and services, and total costs, respectively, are summarized and plotted in Exhibit A.2. All data points used in computing the correlations and listed in Exhibit A.2 have been adjusted to the 1980 Consumer Price Index (CPI) level to account for the effects of inflation since the systems were installed. The ratios used to make these adjustments are given in the following table:

YEAR INSTALLED	CPI (ave.)	CPI/CPI_{80}
1974	1.477	1.676
75	1.613	1.535
76	1.724	1.436
77	1.818	1.362
78	1.967	1.259
79	2.166	1.143
80	2.476	1.000

(Source: Bureau of Labor Statistics)

Several cases in Exhibits A.1 and A.2 deserve additional explanation. Case 9 costs are noted to be considerably below the empirically predicted values. This can be attributed to two factors. First, the system utilized the municipal central data processing computer to support certain functions, thus reducing the loading on the CAD computers. Second, the procuring agency announced in advance that funding for the installation was limited. This strategy apparently forced software and installation service costs to the minimal levels shown.

Cases 5, 8, and 10 exhibit low hardware or total costs. Discussions with the vendors indicate that these are minimal systems (single CPU), and required few modifications of previous designs, i.e., the systems were essentially off-the-shelf installations. While these cases may not be indicative of trends toward standardization, they emphasize the significant cost savings achievable with off-the-shelf installations.

Exhibit A.1

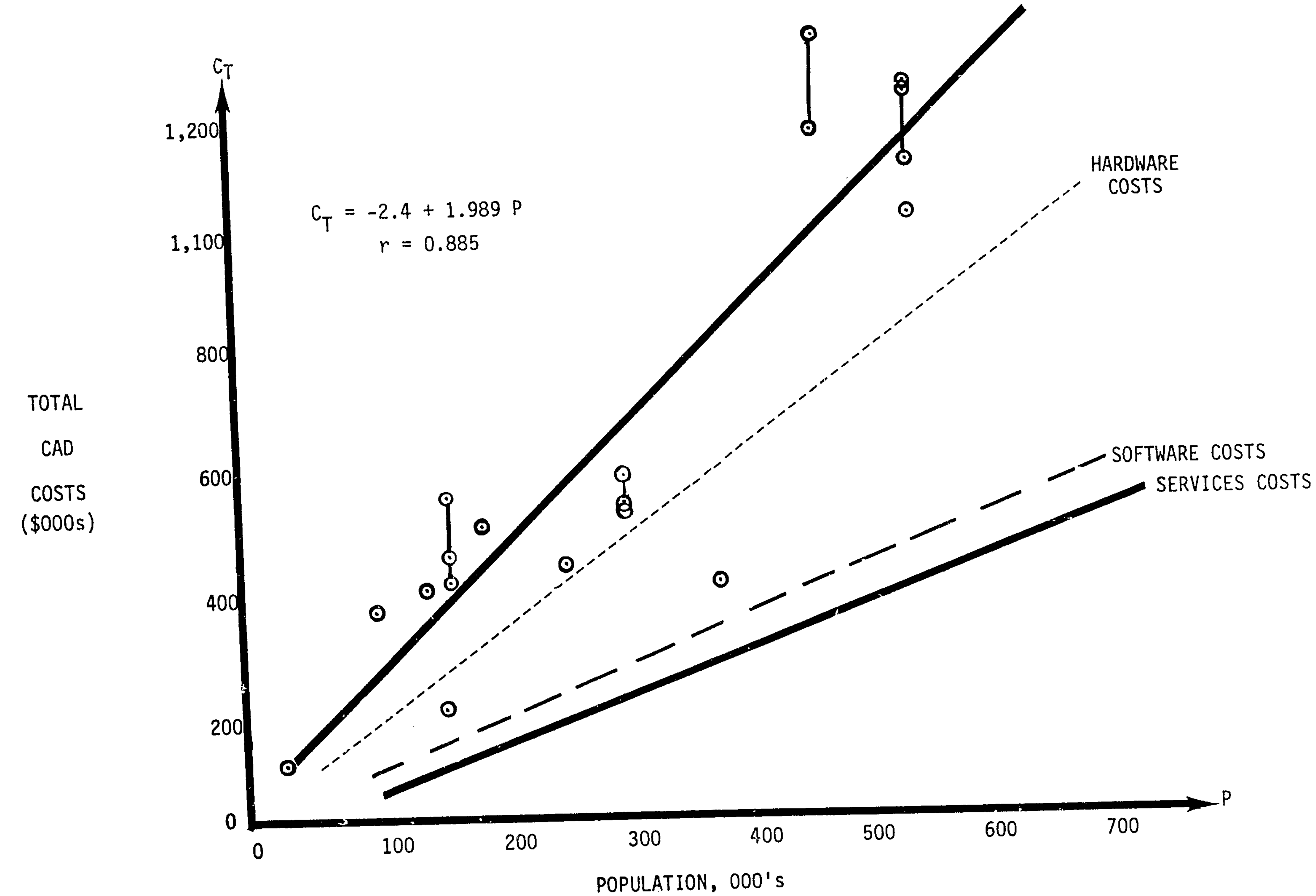
CAD System Costs

Case	Population (1000s)	Hardware	Software	Services(2)	Consoles(3)	Total	Year Installed	Number of Consoles: Complaint	Number of Consoles: Dispatch
		Costs ($1000s)							
1	45	36.0	18.0	9.0	--	63.0	1974	- 2 -	
2(4)	82	279.7	139.0	53.7	--	472.4	1980	3	2
3	108	198.6	- 159.7 -		--	358.3	1980	3	2
4	147	140.5	47.1	33.0	--	220.6	1974	2	2
5	155	73.4	- 64.2 -		--	137.6	1980	3	3
6 (a)(1)	176	180.6	40.0	52.1	--	272.7	1976	NA	
(b)		184.7	48.3	14.0	--	247.0			
(c)		307.9	10.0	35.9	--	373.8			
7	200	179.1	65.4	44.1	--	288.6	1975	6	6
8	275	229.5	- 165.7 -		--	395.2	1980	8	3
9 (a)	338	283.7	10.3	53.9	--	347.9	1975	10	3
(b)		213.1	71.5	36.2	--	320.8			
(c)		225.0	63.4	25.1	--	313.5			
10	380	--	--		--	326.0	1980	11	5
11 (a)	443	567.0	170.0	170.0	354.0	907.0	1978	9	7
(b)		659.0	197.0	188.0	320.0	1044.0			
12 (a)	554	395.3	231.7	147.7	212.9	774.7	1975	12	6
(b)		464.2	138.8	41.0	530.8	644.0			
(c)		503.0	63.8	197.0	377.0	763.8			
(d)		370.7	149.1	172.0	300.3	691.8			
13	650	650.0	- 300.0 -		350.0	950.0	1977	12	10

1. Cases (a), (b), etc., represent individual vendor bids for the same system.
2. Services include installation, testing, documentation, phaseover, and project management.
3. Although listed in the table, console costs are <u>not</u> included in the total costs.
4. Case (2) comprises a combined police, fire and records system; it is presented for interest, but is not included in the regression analysis.

Exhibit A.2

Total CAD System Costs (Less Consoles)



In summary, using the correlations of Exhibit A.2, the capital cost equations can be stated as:

Hardware cost (1980) = -24.0 + 1.250 P

Software cost (1980) = -13.3 + 0.495 P

Service cost (1980) = -46.4 + 0.895 P

where costs are in thousands of dollars, and P = population in thousands.

The best fit for total system costs as a function of population served is:

Total CAD system cost (1980) = -2.4 + 1.989 P

For system sizing purposes, it is of interest to relate the number of dispatches per year to the population served by the agency. Data from PSE's surveys and site visits were used for this purpose, and indicate that on the average around 525 dispatches per year were made per 1000 population. This value is independent of the population level for the data set given.

A.3 CAPITAL COST TRENDS

As noted in Section A.2, the data set used in the above correlations was adjusted by appropriate CPI ratios to the 1980 time frame. Thus in developing the CAD system cost correlations, it has been assumed that inflation was the only major factor influencing these costs over the time period of interest, and that other factors such as generally lower computer hardware costs and software standardization have not had a major impact. Is this assumption justified?

Turning first to computer hardware costs, these have in fact been reduced over the past five years. CPUs of a given capacity are considerably less espensive now than machines of the same capacity that were available in 1975. Peripheral costs, however, have not experienced equal reductions. We have noted that agencies do not always take advantage of these lower costs but opt for hardware of greater capacity to provide more margin in handling projected loads, to accommodate geo files, etc. A comparison of cases 11 (1978) and 12 (1975) indicates that although the population served by the former is considerably less, its system capacity in terms of the number of terminals handled, file sizes, CPU speed, number of communication ports, and geo file accommodation, is considerably greater. Potential cost reductions for case 11, therefore, were absorbed by the significant increases in capacity. Cases 5 and 8 (both 1980), are minimal installations (no geo file, single CPU), that have considerably below-average costs. Thus, lower costs are achievable but depend on agency needs. The cost of the average installation, however, has not been reduced over the years but has risen with inflation.

Although data on recent installations was limited, a brief analysis was made to verify the assumed cost trends. Correlations of cost versus population served were made assuming no inflation adjustment, 50 percent CPI adjustment, and full CPI allowance. The resulting correlation factors were 0.853, 0.880, and 0.899, respectively, which tends to confirm the recommended full CPI adjustment. The optimum is not sharply defined, however, and emphasizes the need to further parameterize the design variations represented in the data set. Thus, the indicated trend model is recommended for average installations, with the understanding that the requirements of the individual agency will influence costs significantly.

Software costs trends are more difficult to estimate. These costs, which are labor intensive, could normally be expected to increase directly with the CPI; however, most vendors now have off-the-shelf software packages for CAD installations that can be offered at reduced prices if the procuring agency does not require extensive modifications to the package and if the bid solicitation does not specify hardware with which the vendor has little or no experience. Most vendors tend to charge agencies for development or modification costs associated with individual installations, without attempting to recover all prior investments. Thus, it is reasonable to assume that development/modification costs have decreased as software packages reach an off-the-shelf maturity but that such decreases have been cancelled by the effects of inflation. Thus, in sum, numerous discussions with CAD software vendors indicate that CAD software costs can be expected to increase with the CPI (as a minimum).

As with hardware costs, correlations of software costs versus population served were made to verify the recommended cost trend relationship, assuming no inflation, 50 percent CPI, and full CPI adjustments. The resulting correlation factors were 0.878, 0.894 and 0.899, respectively, which tends to confirm the recommended full CPI adjustment, although the optimum is weakly defined. As with hardware costs, the needs of individual agencies can have a major influence on costs, and, if an agency can utilize a developed software package with few or no modifications, very appreciable savings can be made. Thus, the recommended software cost relationship applies to average installations only.

Similar analyses were made for service cost and total cost trends; in both cases full CPI adjustments produced near maximum correlation factors, although the optimums were not sharply defined.

Future analyses of CAD system cost correlations are necessary to improve our understanding of basic cost trends, and to enhance cost projections. However, as a way of summarizing the results to date, it is worthwhile to give an illustration of the use of this information. If an agency served a population of 150,000, utilizing the formulas listed above, they could expect a CAD system installation to cost approximately:

Hardware	$211,500	(59%)
Software	61,000	(17%)
Services	88,000	(24%)
Total	$360,500	

A.4 OPERATIONAL COSTS

Operating costs are considerably easier to estimate, since the preponderance of expenses are associated with staffing costs. Operating costs can be developed from the following cost account code:

- Personnel
- Maintenance
- Telephones
- Supplies

Facilities costs are not included in operating costs here since they generally are not segregated out for the dispatch function.

PERSONNEL COSTS

Personnel costs are directly related to the number of dispatchers, complaint operators, supervisors, and support persons, and to the overhead rate of labor burden. Staffing levels can be related to the system loading through the number of dispatch and complaint terminals. The data in Exhibit A.1 indicate that the total number of stations provided is roughly in the ratio of two complaint stations for each dispatch station. Thus, the number of stations is equal to:

Number of dispatch stations = 1/3 x total stations

Number of complaint stations = 2/3 x total stations

All stations are rarely fully staffed, but presumably staff levels are adequate to accommodate the busiest hour of the year. A number of analyses indicate that the busy shift staffing level should be about 70% of that required to handle the busiest hour of the year.* Thus, busy staffing levels can be estimated as:

Dispatchers = 0.70 x 1/3 x total stations

Complaint Operators = 0.70 x 2/3 x total stations

Supervisor = 1 (busy shift only)

Each position, assuming a full eight-hour shift, seven days per week, requires 1.62 persons, based on the following:

1. Maximum possible days per year worked by one person on a 40-hour week = 260
2. Vacation, holiday, and sick days per year = 34.5
3. Average number of days worked per year = 260 - 34.5 = 225.5
4. Number of persons required to continuously staff one shift = $\frac{365.0}{225.5} = 1.62$

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*See, for example, South Bay Regional Public Safety Communication/Dispatch System, Systems Development Corporation, 1974.

Assume three eight-hour shifts. The second and third shifts (midday and evening) are usually equally busy, and require the same number of complaint operators and dispatchers.* The first shift is assumed to require one-half the staffing level required for the other shifts. Thus, a given station would require the following staff:

	Dispatch and Complaint Operators	Supervisor
First shift	0.81	0
Second shift	1.62	1.62
Third shift	1.62	0
	4.05	1.62

The staffing levels are:

Dispatchers = 4.05 x 0.70 x 1/3 x total stations

= 0.95 x total stations

Complaint operators = 4.05 x 0.70 x 2/3 x total stations

= 1.89 x total stations

Supervisor = 1.62

Values obtained, rounded up to the nearest integer, are multiplied by the appropriate salary level for each staff category to obtain direct salary expenses. Overhead must be added to the direct labor costs to account for costs associated with support staff such as vacations, sick leave, holidays, social security and other fringe benefits. A figure of 60 percent can be used for total overhead expenses.**

Utilizing the relationship derived above, then, an agency serving a population of 250,000 would thus have the following personnel expenses:

(1) Total Stations	10 (Estimate based on Exhibit A.1 and authors' judgment)
- Dispatch Stations	3 (1/3 of total stations)
- Complaint Stations	6 (2/3 of total stations)
- Supervisor Stations	1
(2) Personnel	
- Dispatchers	9 (.95 x total stations and rounded down)
- Complaint Operators	18 (1.89 x total stations and rounded down)
- Supervisors	2
(3) Salaries	
- Dispatchers (@ $14,000/yr)	$201,600 ($14,000 x 1.6 x 9 dispatchers)
- Complaint Operators (@$10,000/yr)	288,000 ($10,000 x 1.6 x 18 complaint operators)

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*This is an approximation, since the second shift usually handles more complaints, but the busy hour can occur in either shift.

**South Bay Regional Safety Communication/Dispatch System, Systems Development Corporation; adjusted for CPI.

- Supervisors (@$24,000/yr) 76,800 ($24,000 x 1.6 x 2 supervisors)

TOTAL PERSONNEL EXPENSES $566,400 per year

Maintenance Costs

Maintenance costs are generally a function of the hardware capital cost, and are usually estimated as a percentage of hardware cost. The bid solicitation response data summarized in Exhibit A.1 contained several quotes for maintenance costs. These were analyzed and converted to a percentage of the hardware costs as follows:*

Case	Maintenance Cost Per Year (Percent of Hardware Cost)
4	5.89
9 (a)	11.10
(b)	12.70
(c)	8.69
11 (b)	7.30
Other**	10.00
AVERAGE	9.26%

From Section 4.2, 1980 CAD system hardware costs for an agency serving a population of 250,000 would be approximately $336,500. Yearly maintenance costs, then, would be 9.6 percent of this, or approximately $32,300.

Telephone Expenses

These expenses will vary considerably from agency to agency, due to differences in numbers of lines and in rates. An agency serving a population of 250,000 might have the following monthly telephone expenses:

Service	Monthly Charge
Private voice lines (10)	$600
Private data lines (5)	300
Long distance charges	300
Equipment rental	800
TOTAL	$2,000

Supplies

Supplies for the above agency can be estimated to cost about $10,500 per year.

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*Maintenance quotes as listed here apply only to maintenance of CAD. They do not include maintenance of consoles, facilities, or communications/radio equipment.

**Baltimore County, 1979.

For the agency serving a population of 250,000, annual operating costs associated with the CAD system can be summarized as:

Personnel (including overhead)	$566,400
Maintenance	32,300
Telephone	24,000
Supplies	10,500
TOTAL	$633,200

A.5 LIFE CYCLE COSTS

The foregoing models have dealt with initial capital costs and recurring annual operating costs. These can be combined, using the following methods, to give life cycle costs (LCC) -- the present value of all system related costs as of the start of operations. The present-value technique greatly facilitates comparisons of alternative system installations that have dissimilar capital costs and future espense streams.

As an example, the simplest case is that involving an initial capital expenditure followed by recurring annual operating costs at a constant level over the lifetime of the system. The present value sum of the operating expenses is given by:

$$PV(OC) = OC \times \frac{1}{i} \quad 1 - (1 + i)^{-n}$$

where: OC = annual operating costs

i = discount rate

n = system lifetime in years

The life cycle cost for the system is then equal to the initial capital expenditure plus the present value of the operating cost stream:

LCC = Capital Cost + PV(OC)

For the example given above for an agency serving a population of 250,000, the costs are:

CAD system cost (1980) = $494,900

Operating costs per year = $633,200

For a 10-year system life and a discount rate of 10 percent, the present value of the operating expense stream is:

PV (OC) = OC x 6.15 = $3,894,200

and the total life cycle cost is:

LCC = $494,900 + $3,894,200 = $4,389,100

A planner frequently must compare implementation alternatives involving systems of differing initial costs and operating expenses. For example, an alternative to the above system may have the following costs:

CAD system cost = $750,000

Operating costs per year = $450,000

The life cycle cost for this alternative is:

LCC = 750,000 + 6.15 x 450,000 = $3,517,500

which is considerably less expensive than the first alternative.

The above examples indicate that for the CAD system installations with lifetimes of 10 years and over, life cycle costs tend to be dominated by operational and maintenance costs rather than initial capital costs. In the first example, operating costs are 89 percent of the total LCC over a ten-year period. In turn, operating costs are made up largely of personnel costs (89 percent). Thus, the capital costs for CAD systems may be recovered easily if actual reduction in operating personnel requirements can be made with the installation of a CAD system.

A.6 IMPLICATIONS AND CONCLUSIONS

Appendix A has presented an analysis of CAD system costs, and outlines a method for estimating capital and operating costs over the lifetime of the system. The information is only preliminary and is the first published effort to document CAD system costs.

A formula which allows an agency to consider system costs as a function of population has been developed. For example, a CAD installation serving a population of 100,000 might cost approximately $196,500, while a system for a population of 250,000 might cost approximately $494,900. Annual operation costs for the latter installation would be approximately $633,200, of which nearly 90 percent are related to personnel expenses. As mentioned earlier, the cost formula developed here is based on linear regression and cannot be used to precisely predict the future or to derive a cause-effect relationship. However, such numbers can give a police department a rough estimate of the costs to establish a new CAD system. They can also be compared to actual vendor bids to evaluate whether the bids are low or high based on the experience of the other agencies.

A methodology for developing basic cost categories and for estimating CAD life cycle costs (LCC), also has been presented. Although these basic cost categories and LCC techniques are not used widely now, we would strongly recommend their use in the future since they greatly facilitate the comparison of alternative CAD system installations that have dissimilar capital costs and future expense streams. The LCC methodology also helps to illustrate the important point that CAD system cost with lifetimes of 10 years or more tend to be dominated by operational costs, which in turn are made up primarily of personnel and maintenance expenses.

The data trends also indicate that CAD system costs are lower proportionately for agencies serving small populations. A city of 45,000 reported a total cost of $63,000 for a CAD system (1974), including a software cost of only $18,000. This cost is reasonably affordable to cities this size and smaller; also smaller agencies may be able to more readily adapt to off-the-shelf CAD systems. If these cost numbers are representative, it seems that the cost barrier to the small agency market -- agencies serving populations less than 50,000 -- may have been reduced. This is significant since many of the large cities have already installed CAD systems and smaller cities now comprise an important part of the future market for this technology.

Finally, the analysis and supporting data reported in this Appendix should be useful to managers and planners of public safety agencies; however, the research is only preliminary and should be continued in order to substantiate or repudiate the initial findings. It is also recommended that additional research be initiated on multi-community and multi-agency CAD system costs to study the effects of consolidation on costs for public safety dispatch functions.

APPENDIX B

REPORTED APPLICATIONS FOR PCCC SYSTEMS

CAD: Reported Applications

Breakdown of CAD by City and County Size

MDC: Reported Applications

Breakdown of MDC Applications by City and County Size

911: Reported Applications in Larger Cities

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Exhibit B.1

CAD: Reported Applications

Cities	Operational CAD	Manufacturer/Installer	Source	Comments
Over 1 Million				
Chicago, Illinois	no		Telephone survey	
Detroit, Michigan	x	Burroughs/Boeing	Letter to PSE from police department	
Houston, Texas	no		Letter to PSE from police department	CAD in planning stages
Los Angeles, California	(x)[2]	Digital/SDC	Letter to PSE from police department	CAD to be operational by 9/81
New York City, New York	x	IBM/IBM	Preliminary site visit	
Philadelphia, Pennsylvania	x	IBM/ADL Systems	Site visit	
500,000 - 1 Million				
Baltimore, Maryland	no		Letter to PSE from police department	
Boston, Massachusetts	x	Data General/ADL Systems	Preliminary site visit	
Cleveland, Ohio	no		Letter to PSE from police department	
Columbus, Ohio	(x)	Digital/General Electric	Letter to PSE from police department	CAD to be operational by 1/81
Dallas, Texas	x	I-TEL/In-House	Site visit	
Denver, Colorado	(x)	---/Mauchly-Wood, City Data Services	Site visit	Uncertain when CAD will be fully operational
Honolulu, Hawaii	no		Letter to PSE from police department	
Indianapolis, Indiana	x	Interdata/General Electric	Site visit	
Jacksonville, Florida	x	Burroughs/In-House	Letter to PSE from police department	
Kansas City, Missouri	no		Letter to PSE from police department	
Memphis, Tennessee	(x)	---/---	Letter to PSE from police department	
Milwaukee, Wisconsin				
New Orleans, Louisiana	x	Digital/PRC-PMS	Phone call to police department	
Phoenix, Arizona	x	Interdata/In-House	Phone call to police department	
Portland, Oregon	x	Varian/Boeing	Letter to PSE from police department	Joint with Multnomah County
St. Louis, Missouri	no		Site visit	
San Antonio, Texas	x	IBM/In-House	Site visit	
San Diego, California	x	Digital/Motorola	Site visit	
San Francisco, California	no		Telephone survey	
San Jose, California	x	Digital/Kustom	Telephone survey	Run by Santa Clara County
Seattle, Washington	x	Digital/Kustom	Telephone survey	
Washington, D.C.	x	IBM/Modular Computer Systems	Letter to PSE from police department	
250,000 - 500,000				
Akron, Ohio	no		Letter to PSE from police department	
Albuquerque, New Mexico	no		Letter to PSE from police department	
Atlanta, Georgia	x	---/---	Letter to PSE from police department	CAD planned for Spring, 1982
Austin, Texas	no		Letter to PSE from police department	

[1]This table includes all cities with population greater than 250,000, whether or not they are reported to have CAD systems.
[2](x) indicates that CAD is in the process of being implemented.

Exhibit B.1

(Page 2 of 3)

Cities	Operational CAD	Manufacturer/Installer	Source	Comments
Baton Rouge, Louisiana	no		Letter to PSE from police department	
Birmingham, Alabama	x	IBM/In-House	Letter to PSE from police department	
Buffalo, New York	no		Letter to PSE from police department	
Charlotte, North Carolina	x	Burroughs/SDC	Site visit	
Cincinnati, Ohio	no		Letter to PSE from police department	CAD in planning stages
Dayton, Ohio	no		Letter to PSE from police department	
El Paso, Texas	no		Letter to PSE from police department	
Fort Worth, Texas	x	IBM/Apogee Systems	Letter to PSE from police department	
Jersey City, New Jersey	no		Letter to PSE from police department	CAD in planning stages
Las Vegas, Nevada	x	Digital/Kustom	Site visit	
Long Beach, California	x	Digital/PRC-PMS	Letter to PSE from police department	
Louisville, Kentucky	no		Letter to PSE from police department	
Madison, Wisconsin	x	Burroughs/In-House	Letter to PSE from police department	
Miami, Florida	x	Digital/E-Systems	Site visit	Separate from Dade County CAD system
Minneapolis, Minnesota	x	Data General/ADL Systems	Telephone survey	
Nashville, Tennessee	no		Telephone survey	
Newark, New Jersey	x	Data General/Urban Sciences, Boeing	Site visit	
Norfolk, Virginia	(x)	IBM/---	Letter to PSE from police department	
Oakland, California	x	Data General/Boeing	Site visit	
Oklahoma City, Oklahoma	(x)	Digital/General Electric	Letter to PSE from police department	CAD to be fully operational by 11/81
Omaha, Nebraska	no		Letter to PSE from police department	
Peoria, Illinois	x	Varian/Automated Systems	Letter to PSE from police department	
Pittsburgh, Pennsylvania	no		Letter to PSE from police department	CAD planned for 1982
Rochester, New York	no		Letter to PSE from police department	
Sacramento, California	no		Letter to PSE from police department	CAD in planning stages
St. Paul, Minnesota	no		Letter to PSE from police department	
Tacoma, Washington	x	Digital/PRC-PMS	Letter to PSE from police department	
Tampa, Florida	no		Letter to PSE from police department	
Toledo, Ohio	no		Letter to PSE from police department	
Tucson, Arizona	x	Digital/PRC-PMS	Letter to PSE from police department	
Tulsa, Oklahoma	x	Data General/In-House	Telephone survey	
Virginia Beach, Virginia	x	Digital/Motorola	Telephone survey	
Wichita, Kansas	no		Letter to PSE from police department	
100,000 - 250,000				
Albany, New York	x	Xerox/In-house	Telephone survey	
Camden, New Jersey	x	Xerox/Xerox	Letter to PSE from police department	
Colorado Springs, Colorado	(x)	---/---	Letter to PSE from police department	
Fort Lauderdale, Florida	no		Letter to PSE from police department	CAD in planning stages
Fresno, California	x	Digital/Kustom	Telephone survey	
Garden Grove, California	x	Kustom/Community Technology	Letter to PSE from police department	
Garland, Texas	x	IBM/IBM	Letter to PSE from police department	
Glendale, California	x	Digital/Kustom	Letter to PSE from police department	
Greensboro, North Carolina	(x)	---/Theorem, ADL Systems	Letter to PSE from police department	CAD to be fully operational by late 1980
Hampton, Virginia	x	IBM/Motorola	Telephone survey	
Huntington Beach, California	x	Digital/Motorola	Site visit	
Jackson, Mississippi	x	Digital/Motorola	Letter to PSE from police department	

Exhibit B.1

(Page 3 of 3)

Cities	Operational CAD	Manufacturer/Installer	Source	Comments
Lansing, Michigan	(x)	Digital/Motorola	Letter to PSE from police department	
Oak Park, River Forest, Forest Park, Illinois	x	---/Community Technology	LEAA grant description	
St. Petersburg, Florida	x	IBM/Booz Allen & Hamilton	Letter to PSE from police department	
Salt Lake City, Utah	x	Digital/Motorola	Site visit	Consolidated police/fire system
Santa Ana, California	x	Digital/---	Letter to PSE from police department	
Shreveport, Louisiana	x	Interdata/General Electric	[JPL, 1978]	
Sunnyvale, California	x	Digital/Motorola	Site visit	
Winston-Salem, North Carolina	no		Letter to PSE from police department	CAD in planning stages
Less than 100,000				
Atlantic City, New Jersey	x	Digital/Motorola	[JPL, 1978]	
Aurora, Colorado	x	Data General/ADL Systems	Site visit	
Champaign, Illinois	x	---/Community Technology	Letter to PSE from police department	
Chesapeake, Virginia	x	Digital/JRB Associates	Letter to PSE from police department	
Cranston, Rhode Island	x	Wang/J.W. Larimore	Site visit	
Johnstown, Pennsylvania	[x][3]	Wang/J.W. Larimore	Letter to PSE from police department	CAD destroyed in flood
Kenosha, Wisconsin	x	Wang/J.W. Larimore	Letter to PSE from police department	
Northbrook, Illinois	(x)	TI, E-Systems/In-House	Letter to PSE from police department	
North Las Vegas, Nevada	x	Wang/J.W. Larimore	Site visit	
Reading, Pennsylvania	(x)	Sperry Univac/Univac	Letter to PSE from police department	CAD to be fully operational by 11/80
Reno, Nevada	no		Letter to PSE from police department	CAD in planning stages
San Mateo, California	(x)	Digital/Motorola	Letter to PSE from police department	CAD to be fully operational by late 1980
Counties				
Baltimore County, Maryland	(x)	Digital/General Electric	Letter to PSE from police department	
Broward County, Florida	x	Digital/Motorola	Letter to PSE from police department	
Dade County, Florida	x	Digital/In-House	Site visit	Does not include Miami
DeKalb County, Georgia	x	Digital/[Kustom], Motorola	Letter to PSE from police department	
Fresno County, California	x	Digital/PRC-PMS	Telephone survey	Does not include City of Fresno
Hamilton County, Ohio	x	Digital/Motorola	[JPL, 1978]	Does not include Cincinnati
Hillsborough County, Florida	x	Digital/Kustom	Letter to PSE from police department	
Lake County, Indiana	x	Digital/Motorola	Letter to PSE from police department	
Los Angeles County, California	x	Digital/SDC	Telephone survey	Los Angeles Sheriff's Office
Multnomah County, Oregon	x	Varian/Boeing	Letter to PSE from police department	Includes Portland
New Castle County, Delaware	(x)	---/---	Verbal report	
Palm Beach County, Florida	(x)	Digital/In-House	Letter to PSE from police department	CAD to be fully operational by 9/80
Pinellas County, Florida	x	Digital/PRC-PMS	Letter to PSE from police department	
Prince Georges County, Maryland	x	Digital/PRC-PMS	Information from PRC-PMS	
Sacramento County, California	x	Digital/Kustom	[JPL, 1978]	Sacramento Sheriff's Office
Santa Clara County, California	x	Digital/Kustom	[JPL, 1978]	Includes San Jose
South Bay Area, California	x	Digital/PRC-PMS, E-Systems	Letter to PSE from police department	

[3] [x] indicates that CAD is no longer in use

Exhibit B.2

Breakdown of CAD by City and County Size

City-Wide Systems

City Size	Number of cities of this size[1]	Number of operational CAD systems	Fraction of cities this size with operational CAD systems	Additional cities currently implementing CAD systems	Total fraction of cities this size with operational CAD or implementing CAD systems
Over 1 million	6	3	50%	1	67%
500,000 - 1 million	22	12	55%	3	68%
250,000 - 500,000	37	16	43%	2	49%
100,000 - 250,000	90	15	17%	3	20%
50,000 - 100,000	257	6	2%	3	4%
25,000 - 50,000	539	1	.2%	0	.2%

County-Wide Systems

County Size	Number of operational CAD systems	Additional number of counties currently implementing CAD
Over 1 million	2	0
500,000 - 1 million	7	2
250,000 - 500,000	2	1
100,000 - 250,000	3	0

[1]Based on the most recent population estimates from the International City Management Association, and updated to reflect populations reported by police departments.

Exhibit B.3

MDC: Reported Applications

Cities	MDC	Equipment Manufacturer	Source	Comments
Over 1 Million				
Chicago, Illinois	x	Motorola	Telephone survey	MDC in 140 patrol cars
Detroit, Michigan	x	Motorola	Telephone survey	MDC in 200 patrol cars
Houston, Texas	no		Letter to PSE from police department	
Los Angeles, California	x	E-Systems	Letter to PSE from police department	MDC in 850 patrol cars (100% of units)
New York City, New York	x	Motorola	Preliminary site visit	MDC in 200 patrol cars
Philadephia, Pennsylvania	no		Site visit	
500,000 - 1 Million				
Baltimore, Maryland	no		Letter to PSE from police department	
Boston, Massachusetts	no		Preliminary site visit	MDC planned for 1980
Cleveland, Ohio	[x][2]	---	[Sohn et al, 1975 (b)]	MDC tested in 40 patrol cars
Columbus, Ohio	(x)[3]	---	Letter to PSE from police department	MDC to be operational by mid-1981
Dallas, Texas	x	---	Site visit	Status-only MDTs in AVM district
Denver, Colorado	no		Site visit	
Honolulu, Hawaii	no		Letter to PSE from police department	
Indianapolis, Indiana	no		Site visit	
Jacksonville, Florida	no		Letter to PSE from police department	
Kansas City, Missouri	[x]	Kustom	[Sohn et al, 1975 (b)]	MDC tested in 14 cars
Memphis, Tennessee	no		Letter to PSE from police department	
Milwaukee, Wisconsin	[x]	---	[Telcom, Inc., 1969]	Mobile teleprinters tested
New Orleans, Louisiana	[x]	---	Verbal report	MDC tested and abandoned
Phoenix, Arizona	x	Motorola	Letter to PSE from police department	MDC in 27 patrol units (5% of units)
Portland, Oregon	no		Letter to PSE from police department	
St. Louis, Missouri	x	Motorola	Site visit	Status-only MDTs in all patrol vehicles
San Antonio, Texas	no		Site visit	
San Diego, California	[x]	Motorola	Site visit	MDC tested in 20 cars
San Francisco, California	[x]	Kustom	Telephone survey	MDC tested in 25 cars
San Jose, California	x	Kustom	Telephone survey	MDC implemented in 2 districts out of 8
Seattle, Washington	no		Telephone survey	
Washington, D.C.	[x]	---	[King, 1976]; Letter to PSE from police department	
250,000 - 500,000				
Akron, Ohio	no		Letter to PSE from police department	
Albuquerque, New Mexico	no		Letter to PSE from police department	
Atlanta, Georgia	(x)	---	Letter to PSE from police department	
Austin, Texas	no		Letter to PSE from police department	MDC planned for 1982
Baton Rouge, Louisiana	no		Letter to PSE from police department	
Birmingham, Alabama	no		Letter to PSE from police department	
Buffalo, New York	no		Letter to PSE from police department	

[1]This table includes all cities with population greater than 250,000, whether or not they are reported to have MDC systems.
[2][x] indicates that MDC is no longer in use.
[3](x) indicates that MDC is in the process of being implemented.

Exhibit B.3

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Cities	MDC	Equipment Manufacturer	Source	Comments
Charlotte, North Carolina	no		Site visit	
Cincinnati, Ohio	no		Letter to PSE from police department	
Dayton, Ohio	no		Letter to PSE from police department	
El Paso, Texas	no		Letter to PSE from police department	
Fort Worth, Texas	no		Letter to PSE from police department	
Jersey City, New Jersey	no		Letter to PSE from police department	
Las Vegas, Nevada	x	Kustom	Site visit	MDC in all patrol units
Long Beach, California	(x)	---	Letter to PSE from police department	Test program of 13 MDC units
Louisville, Kentucky	[x]	---	Letter to PSE from police department	
Madison, Wisconsin	no		Letter to PSE from police department	
Miami, Florida	(x)	E-Systems	Site visit	MDC to be oerational by mid-1980
Minneapolis, Minnesota	x	Kustom	Telephone survey	MDC in 90 patrol units
Nashville, Tennessee	no		Telephone survey	
Newark, New Jersey	x	Motorola	Site visit	MDC in 100 patrol units
Norfolk, Virginia	no		Letter to PSE from police department	
Oakland, California	x	E-Systems	Site visit	MDC in 95 patrol units
Oklahoma City, Oklahoma	no		Letter to PSE from police department	
Omaha, Nebraska	no		Letter to PSE from police department	
Peoria, Illinois	no		Letter to PSE from police department	
Pittsburgh, Pennsylvania	no		Letter to PSE from police department	
Rochester, New York	no		Letter to PSE from police department	
Sacramento, California	no		Letter to PSE from police department	
St. Paul, Minnesota	no		Letter to PSE from police department	
Tacoma, Washington	no		Letter to PSE from police department	
Tampa, Florida	x	Kustom	Letter to PSE from police department	Shared with Hillsborough County
Toledo, Ohio	no		Letter to PSE from police department	
Tucson, Arizona	no		Letter to PSE from police department	
Tulsa, Oklahoma	no		Telephone survey	
Virginia Beach, Virginia	x	Motorola	Telephone survey	MDC in all patrol units
100,000 - 250,000				
Albany, New York	x	---	Telephone survey	MDC in all patrol units
Aurora, Colorado	(x)	---	Site visit	
Fresno, California	x	Kustom	Telephone survey	MDC in all patrol units
Glendale, California	x	Kustom	Letter to PSE from police department	
Greensboro, North Carolina	(x)	---	Letter to PSE from police department	
Hampton, Virginia	[x]	IBM	Telephone survey	
Huntington Beach, California	x	Motorola	Site visit	MDC in all patrol units
Shreveport, Louisiana	x	Xerox	Information from General Electric	
Sunnyvale, California	x	Motorola	Site visit	MDC in all patrol units

Exhibit B.3

(Page 3 of 3)

Cities	MDC	Equipment Manufacturer	Source	Comments
Less than 100,000				
Atlantic City, New Jersey	x	Motorola	[Johnson and Valenzuela, 1977]	MDC in 30 cars
Moline, Illinois	[x]	Xerox	Telephone survey	
Rock Island, Illinois	[x]	Xerox	Telephone survey	
Counties				
De Kalb County, Georgia	x	[Kustom], Motorola	Letter to PSE from police department	
Hennepin County, Minnesota	x	Xerox	Letter to PSE from police department	MDC in 85% of patrol units
Hillsborough County, Florida	x	Kustom	Letter to PSE from police department	
Lake County, Indiana	no		Letter to PSE from police department	MDC in planning stages
Palm Beach County, Florida	x	[Kustom], Applied Research	Letter to PSE from police department	MDC in 65% of patrol units
Pinellas County, Florida	x	Kustom	Letter to PSE from police department	
Sacramento County, California	x	Kustom	[Search Group, Inc., 1978]	
San Joaquin County, California	x	Kustom	Letter to PSE from police department	Test system
South Bay Area, California	x	E-Systems	Letter to PSE from police department	MDC in 60% of patrol units
States				
New York	[x]	---	[LEAA, 1976]	MDC tested by state police
Virginia	x	Kustom	[Kellam, 1974]	MDC in 20 patrol units

Exhibit B.4

Breakdown of MDC Applications by City and County Size

City-Wide Systems

City Size	Number of cities of this size[1]	Number of operational MDC systems	Fraction of cities this size with operational MDC systems	Additional cities currently implementing MDC systems	Total fraction of cities this size with operational MDC or implementing MDC systems
Over 1 million	6	4	67%	0	67%
500,000 - 1 million	22	4	18%	1	23%
250,000 - 500,000	37	6	19%	2	24%
100,000 - 250,000	90	7	8%	2	10%
50,000 - 100,000	257	1	.4%	0	.4%
25,000 - 50,000	539	0	0%	0	0%

County-Wide Systems

County Size	Number of operational MDC systems	Additional number of counties currently implementing MDC
Over 1 million	0	0
500,000 - 1 million	5	0
250,000 - 500,000	3	0
100,000 - 250,000	0	0

[1] Based on the most recent population estimates from the International City Management Association, and updated to reflect populations reported by police departments.

Exhibit B.5

911: Reported Applications in Larger Cities

City	Police		Fire	(1,000's) Estimated Population[1]	Year Installed
New York	----	911	----	7,605	1968
Chicago	----	911	----	3,115	1976
Los Angeles	625-3311		384-3131	2,750	
Philadelphia	----	911	----	1,820	1974
Houston	222-3131		227-2323	1,320	
Detroit	----	911	----	1,300	1973
Baltimore	222-3333		685-1313	878	
Dallas	742-2431		741-6543	859	
San Antonio	----	911	----	850	1979
Indianapolis	----	911	----	741	1976
Washington, DC	----	911	----	734	1972
San Francisco	553-0123		861-8020	716	
San Diego	236-5911		238-1212	697	
Milwaukee	765-2323		347-2323	691	
Honolulu	----	911	----	686	1975
Cleveland	623-5000		621-1212	679	
Memphis	528-2222		458-3311	659	
Phoenix	262-6151		253-1191	637	
New Orleans	822-4161		581-3473	573	
Boston	----	911	----	550	1972
San Jose	297-3565		294-4664	570	
Columbus	462-4545		221-2345	541	
St. Louis	231-1212		534-2244	538	
Jacksonville	633-4111		633-2211	522	
Denver	----	911	----	515	1971
Seattle	----	911	----	505	1971

[1] Based on the most recent population estimates from the International City Management Association and updated to reflect populations reported by police departments.

END